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

**Part 11:  
Laboratory measurements of the  
reduction of transmitted impact sound by  
floor coverings on lightweight reference  
floors**

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

*Partie 11: Mesurage en laboratoire de la réduction de la transmission  
des bruits de choc par les revêtements de sol sur les planchers de  
référence légers*



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## 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 140-11 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 2, *Building acoustics*.

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 for laboratory test facilities with suppressed flanking transmission*
- *Part 2: Determination, verification and application of precision data*
- *Part 3: Laboratory measurements 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 measurements 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*
- *Part 11: Laboratory measurements of the reduction of transmitted impact sound by floor coverings on lightweight reference floors*
- *Part 12: Laboratory measurement of room-to-room airborne and impact sound insulation of an access floor*
- *Part 13: Guidelines*

- *Part 14: Guidelines for special situations in the field*
- *Part 16: Laboratory measurement of the sound reduction index improvement by additional lining*

The following parts are under preparation:

- *Part 17: Evaluation of the total loss factor*
- *Part 18: Laboratory measurement of sound generated by rainfall on building elements*

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

## Part 11:

# Laboratory measurements of the reduction of transmitted impact sound by floor coverings on lightweight reference floors

## 1 Scope

This part of ISO 140 specifies methods for measuring the acoustic properties of floor coverings from the viewpoint of reducing impact sound transmission. The purpose of this part of ISO 140 is to establish a method for determining the impact sound insulation of a floor covering under standard test conditions. The test is limited to the specification of procedures for the physical measurement of sound originating from an artificial impact source (tapping machine) under laboratory conditions and is not directly related to the subjective significance of the results.

In this part of ISO 140, a test method is described using the standard tapping machine to simulate impact sources like human footsteps with shoes. In addition, methods using a modified tapping machine and a heavy/soft impact source are also introduced in informative Annexes C and E for the assessment of impact sound insulation of a floor covering against impact sources with strong components at low frequencies, such as human footsteps or children jumping. As a simplified method for the measurement of the reduction of floor impact sound pressure level by soft and resilient floor coverings, the method using a wooden mock-up floor is introduced in Annex D.

This part of ISO 140 is applicable to all floor coverings, whether single or multi-layered, as installed on lightweight floors. In the case of multi-layered coverings, they can be factory-assembled or assembled at the test site. The test method is applicable only to laboratory measurements. It does not contain any provision that permits an assessment of the effectiveness of a floor covering *in situ*.

## 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 140-1:1997, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 1: Requirements for laboratory test facilities with suppressed flanking transmission*

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 140-6:1998, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 6: Laboratory measurements of impact sound insulation of floors*

ISO 140-8:1997, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 8: Laboratory measurements of the reduction of transmitted impact noise by floor coverings on a heavyweight standard floor*

ISO 354:2003, *Acoustics — Measurement of sound absorption in a reverberation room*

ISO 9052-1:1989, *Acoustics — Determination of dynamic stiffness — Part 1: Materials used under floating floors in dwellings*

ISO 9053:1991, *Acoustics — Materials for acoustical applications — Determination of airflow resistance*

IEC 61672-1:2002, *Electroacoustics — Sound level meters — Part 1: Specifications*

IEC 60942:2003, *Electroacoustics — Sound calibrators*

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

### 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

#### 3.1

##### average sound pressure level in a room

$L$

ten times the common logarithm 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, etc.) is of significant influence

NOTE 1 If a continuously moving microphone is used,  $L$  is determined by

$$L = 10 \lg \frac{\frac{1}{T_m} \int_0^{T_m} p^2(t) dt}{p_0^2} \text{ dB} \quad (1)$$

where

$p(t)$  is the sound pressure, in pascals;

$p_0$  is the reference sound pressure and is equal to 20  $\mu\text{Pa}$ ;

$T_m$  is the integration time, in seconds.

NOTE 2 If fixed microphone positions are used,  $L$  is determined by

$$L = 10 \lg \frac{\sum_{j=1}^n p_j^2}{n \cdot p_0^2} \text{ dB} \quad (2)$$

where  $p_j$  is the r.m.s. sound pressure at  $n$  different positions in the room.

NOTE 3 In practice, the sound pressure levels  $L_j$  are usually measured. In this case  $L$  is determined by

$$L = 10 \lg \left( \frac{1}{n} \sum_{j=1}^n 10^{L_j/10} \right) \text{ dB} \quad (3)$$

where  $L_j$  is the sound pressure level  $L_1$  to  $L_n$  at  $n$  different positions in the room.

NOTE 4 Sound pressure level is expressed in decibels.



**3.2****impact sound pressure level** $L_i$ 

average sound pressure level in a one-third-octave band in the receiving room when the floor under test is excited by the standardized impact source

NOTE It is expressed in decibels.

**3.3****normalized impact sound pressure level** $L_n$ 

impact sound pressure level  $L_i$  increased by a correction term given in decibels, being ten times the common logarithm of the ratio between the measured equivalent absorption area  $A$  of the receiving room and the reference equivalent absorption area  $A_0$

$$L_n = L_i + 10 \lg \frac{A}{A_0} \text{ dB} \quad (4)$$

with  $A_0 = 10 \text{ m}^2$

NOTE It is expressed in decibels.

**3.4****reduction of normalized impact sound pressure level  
improvement of normalized impact sound insulation** $\Delta L_t$ 

for a given one-third-octave band, the reduction in normalized impact sound pressure level resulting from installation of the test floor covering on a lightweight reference floor

$$\Delta L_t = L_{n,t,0} - L_{n,t} \text{ dB} \quad (5)$$

where

$L_{n,t,0}$  is the normalized impact sound pressure level of the lightweight reference floor without the floor covering;

$L_{n,t}$  is the normalized impact sound pressure level of the lightweight reference floor with the floor covering.

NOTE 1 If the receiving room absorption is unchanged during the test, it is assumed that the reduction in impact sound pressure level is equivalent to the reduction in normalized impact sound pressure level.

NOTE 2 The subscript "t" refers to timber floors as the type of base floor.

NOTE 3 In this part of ISO 140, three types of lightweight reference floors are specified in Annex B. When it is necessary to specify the reference floor used in the measurement,  $\Delta L_{t,1}$ ,  $\Delta L_{t,2}$  and  $\Delta L_{t,3}$  may be used for the reference floors No. 1, No. 2 and No. 3, respectively.

NOTE 4 The reduction of normalized impact sound pressure level is expressed in decibels.

**3.5****top floor**

lightweight floor construction, mounted on top of the sub-floor, on which the floor covering under test is mounted

**3.6****sub-floor**

standard heavyweight test floor as specified in ISO 140-8

**3.7**

**test floor**

combined floor consisting of the top floor mounted on the sub-floor and the sub-floor

**3.8**

**maximum sound pressure level**

$L_{Fmax}$

maximum sound pressure level of an impact sound measured by the dynamic characteristic of F of the sound level meter

NOTE It is expressed in decibels.

**3.9**

**impact sound pressure level**

$L_{i,Fmax}$

average of the maximum sound pressure levels measured in the receiving room when the floor under test is excited by the heavy/soft impact source specified in Annex F

NOTE It is expressed in decibels.

**3.10**

**reduction of impact sound pressure level  
improvement of impact sound insulation**

$\Delta L_r$

for a given one-third-octave or octave band, the reduction in the impact sound pressure level resulting from the installation of the test floor covering on a lightweight reference floor

$$\Delta L_r = L_{i,Fmax,0} - L_{i,Fmax} \tag{6}$$

where

$L_{i,Fmax,0}$  is the impact sound pressure level of the lightweight reference floor without floor covering;

$L_{i,Fmax}$  is the impact sound pressure level of the lightweight reference floor with floor covering under test.

NOTE It is expressed in decibels.

**3.11**

**impact force**

$F(t)$

instantaneous force acting on the floor under test when the heavy/soft impact source is dropped on the floor

NOTE It is expressed in newtons.

**3.12**

**impact force exposure level**

$L_{FE}$

ten times the common logarithm of the ratio of the time-integrated value of the impact force squared to the square of the reference force

$$L_{FE} = 10 \lg \left[ \frac{1}{T_0} \int_{t_1}^{t_2} \frac{F^2(t)}{F_0^2} dt \right] \text{ dB} \tag{7}$$

where

$F(t)$  is the impact force, in newtons;

$F_0$  is the reference force (= 1 N);

$t_2 - t_1$  is the time duration of the impact force, in seconds;

$s$  is the reference time interval (= 1 s).

NOTE The impact force exposure level is expressed in decibels.

## 4 Equipment

The equipment shall comply with the requirements of Clause 6.

The tapping machine shall meet the requirements given in Annex A.

The accuracy of the sound level measurement equipment shall comply with the requirements of accuracy Class 1 defined in IEC 61672-1:2002. The complete measuring system including the microphone shall be adjusted before each measurement using a sound calibrator that complies with the requirements of accuracy Class 1 defined in IEC 60942:2003. For sound level meters calibrated for measurements in sound fields of progressive plane waves, corrections for the diffuse sound field shall be applied.

The filters shall comply with the requirements given in IEC 61260.

The reverberation time measurement equipment shall comply with the requirements given in ISO 354.

NOTE 1 For pattern evaluation (type testing) and regular verification tests, recommended procedures for sound level meters are given in OIML R58 <sup>[3]</sup> and OIML R88 <sup>[4]</sup>.

NOTE 2 A method using a modified tapping machine and that using a standard heavy/soft impact source are also introduced in Annex C (informative) and Annex E (informative), respectively, for the assessment of impact sound insulation of a floor covering against real impact sources such as human walking and stepping.

## 5 Test arrangement

### 5.1 General arrangement

Two vertically adjacent rooms shall be used, the upper one being designated the "source room" and the lower one the "receiving room". They shall be separated by a lightweight reference floor on which the floor covering under test is installed.

The airborne sound from the tapping machine that is transmitted to the receiving room shall be such that the level will be at least 10 dB below the level of transmitted impact sound in each frequency band.

### 5.2 Details of test arrangement

#### 5.2.1 Source room

There are no specific requirements for the size and shape of the source room.

#### 5.2.2 Receiving room

The receiving room shall comply with the requirements of ISO 140-1.

#### 5.2.3 Lightweight reference floor

The reference floor on which the test covering is to be installed shall be chosen from the reference floors described in Annex B.

The surface area, viewed from the receiving room, shall be at least 10 m<sup>2</sup>. On the source side, the permissible test area for installation of floor coverings of category I (see 5.3.1.2) will be the region at least 0,5 m from the edges of the reference floor.

#### 5.2.4 Condition of reference floor surface

It shall be ensured that the surface of the reference floor is flat to within  $\pm 2$  mm in a horizontal distance of 200 mm, and sufficiently hard to endure the impacts of the tapping machine.

### 5.3 Preparation and installation of test specimen

#### 5.3.1 Classification

##### 5.3.1.1 General

Depending upon the type of floor covering, the test specimens should be either slightly larger than the tapping machine including supports or equal to the floor area (see 6.6).

##### 5.3.1.2 Category I (small specimens)

This category includes flexible coverings (plastics, rubber, cork, matting, or combinations thereof) that may be installed loosely or by adhesion to the floor surface. The method of installation shall be clearly described in the test report.

##### 5.3.1.3 Category II (large specimens)

This category includes rigid homogeneous surface materials or complex floor coverings of which at least one constituent is rigid. The assembled floor covering may be tested under load. Normal furnishing should be simulated with a uniformly distributed load of 20 kg/m<sup>2</sup> to 25 kg/m<sup>2</sup>. The distributed load should be arranged with at least one weight-piece per square metre of the flooring area.

##### 5.3.1.4 Category III (stretched materials)

This category includes flexible coverings that cover the floor from wall to wall. Large specimens should be tested, but loading is not required.

##### 5.3.1.5 Materials of uncertain classification

In the case of uncertainty as to the appropriate category for a material, the testing laboratory should decide whether small or large specimens will be tested.

#### 5.3.2 Installation

Follow strictly the manufacturer's installation instructions, paying special attention to the edges of the specimen.

Install coverings to be mounted with adhesive with great care, normally with the adhesive covering the entire surface. If the adhesive is applied in isolated patches, describe the exact procedure. Follow strictly the manufacturer's instructions for use of the adhesive, especially with regard to the amount and the bonding-time. Report the type of adhesive and the bonding-time.

#### 5.3.3 Size and number of specimens

##### 5.3.3.1 Category I

Install three samples, preferably of different production runs but from the same source. Each sample shall be large enough to support the tapping machine.

### 5.3.3.2 Categories II and III

The specimen shall cover the whole surface of the reference floor.

## 5.4 Influence of temperature and humidity

Usually, and always in the case of a surface whose acoustic properties are likely to depend on either temperature or humidity, measure and report the temperature at the centre of the upper floor surface and the humidity of the air in the source room. The floor temperature thus observed should preferably be in the range 18 °C to 25 °C.

## 6 Test procedure and evaluation

### 6.1 Generation of sound field

The impact sound shall be generated by the tapping machine (see Clause 4).

With the exception of testing category I specimens, the tapping machine shall be placed in at least six different positions not symmetrically distributed on the floor under test. The hammer connecting line should be orientated at 45° to the direction of the joists. The distance of the tapping machine from the edges of the floor shall be at least 0,5 m.

The impact sound pressure levels may reveal a time dependency after the tapping is started. In such cases, the measurements should not begin until the sound pressure level has become steady. If stable conditions are not reached after 5 min, then carry out the measurements over a well-defined measurement period. The measurement period shall be reported.

When soft floor coverings are under test, it is necessary that the tapping machine fulfils the special requirements given in Annex A. Advice regarding the mounting of the tapping machine on soft floor coverings is given also in Annex A.

### 6.2 Measurement of impact sound pressure level

#### 6.2.1 General

Obtain the impact sound pressure level 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 [see Equations (1) to (3)] for all positions of the tapping machine.

#### 6.2.2 Microphone positions

As a minimum, four microphone positions shall be used. These should be distributed within the maximum permitted space throughout the room, spaced uniformly. At least one pair of microphones may be related to two impact source positions and the other pair to the other two positions (see 6.6).

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

- 0,7 m between microphone positions;
- 0,7 m between any microphone position and room boundaries or diffusers;
- 1,0 m between any microphone position and the upper floor being excited by the tapping machine.

When using a moving microphone, the sweep radius shall be at least 1 m. The plane of the traverse shall be inclined in order to cover a large proportion 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.

### 6.2.3 Averaging time

At each individual microphone position, the averaging time shall be at least 6 s at each frequency band with centre frequencies below 400 Hz. For bands of higher centre frequencies, it is permissible to decrease the time to not less than 4 s. When using a moving microphone, the averaging time shall cover a whole number of traverses and shall be at least 30 s.

### 6.3 Frequency range of measurements

The sound pressure level shall be measured using one-third-octave band filters having at least the following centre frequencies, in hertz:

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

It is strongly recommended that the measurement be also made in one-third-octave bands with the following centre frequencies, in hertz:

50	63	80
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Guidance is given in ISO 140-6:1998, Annex C, for such additional measurements in the low-frequency bands.

### 6.4 Measurement of reverberation time and evaluation of the equivalent sound absorption area

The correction term of Equation (4) containing the equivalent sound absorption area is evaluated from the reverberation time measured according to ISO 354 and determined using Sabine's formula

$$A = \frac{0,16 V}{T} \quad (8)$$

where

$A$  is the equivalent sound absorption area, in square metres;

$V$  is the receiving room volume, in cubic metres;

$T$  is the reverberation time, in seconds.

In accordance with ISO 354, the evaluation of the reverberation time from the decay curve shall start at 5 dB below the initial sound pressure level. The evaluation range shall be 20 dB. The bottom of the evaluation range shall be at least 10 dB above the overall background noise of the measuring system.

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

### 6.5 Correction for background noise

Measurements of background noise levels shall be made to ensure that the observations in the receiving room are not affected by extraneous sound, such as noise from outside the test room or electrical noise in the receiving system. To check the latter condition, replace the microphone by a dummy microphone. Take care that the airborne noise produced by the tapping machine and transmitted to the receiving room does not influence the impact sound pressure level in the receiving room.

When using the signal levels without corrections, the background level shall be more than 15 dB below the level of signal and background noise combined. If the difference in levels is smaller than 15 dB but greater than 6 dB, calculate corrections to the signal level according to the following Equation:

$$L = 10 \lg \left( 10^{L_{sb}/10} - 10^{L_b/10} \right) \text{ dB} \quad (9)$$

where

$L$  is the corrected signal level;

$L_{sb}$  is the level of the signal and background noise combined;

$L_b$  is the background noise level.

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, the relevant values shall be given in the measurement report so that it clearly shows that the reported values are the limit of measurement.

EXAMPLE Give  $\Delta L$  values as  $\Delta L > \dots$  dB.

## 6.6 Position of the tapping machine

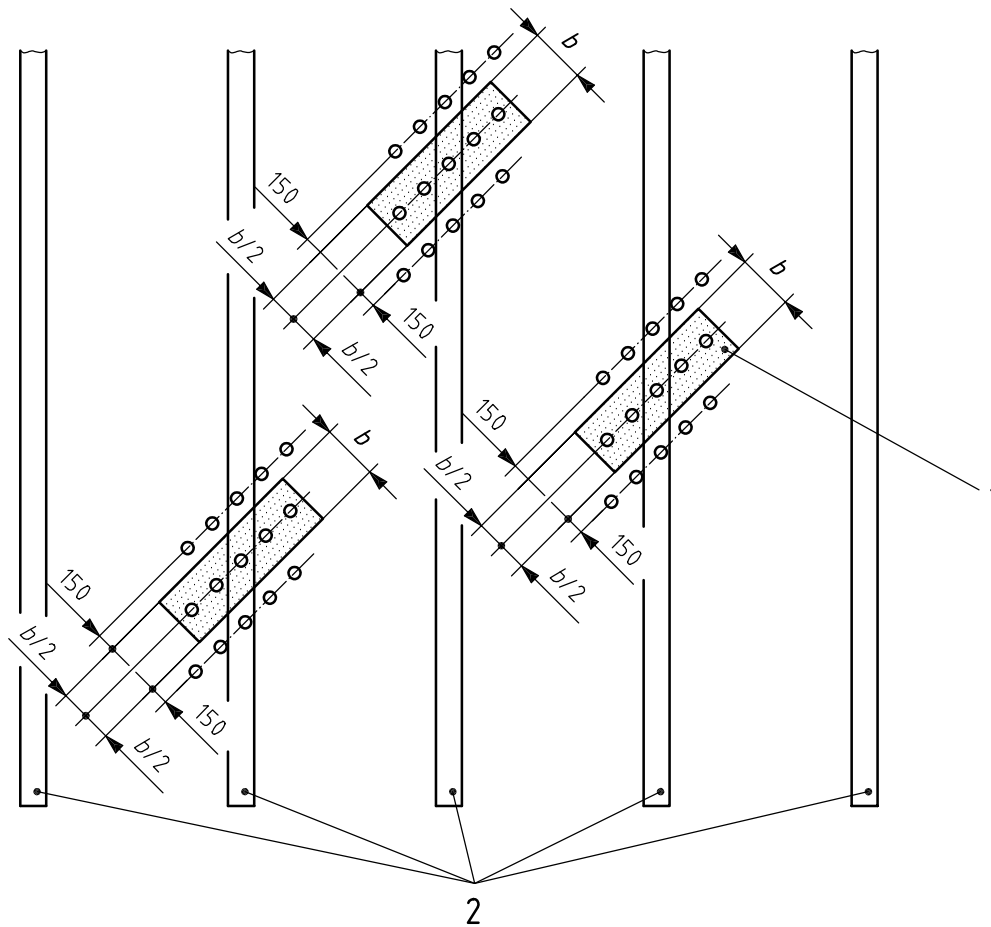
### 6.6.1 Adjustment of the tapping machine

Guidance is given in Annex A on the adjustment of the falling height of the hammers of the tapping machine. When situated on a specimen covering the whole floor, the hammers shall touch the specimen at least 100 mm from the edges. The tapping machine shall be positioned to extend over one of the joists.

### 6.6.2 Materials of category I

Place the tapping machine successively on each specimen of floor covering so that it is wholly on the specimen in each case, and on the uncovered floor on either side of the specimen and as close to it as possible, the axis of the hammers being always parallel to the long dimension of the specimen (see Figure 1).

For each specimen of floor covering, the impact sound pressure level corresponding to the uncovered floor is the arithmetic mean of the level determined for the two machine positions on either side of the specimen.



**Key**

- 1 test specimens (three) (category I);  $b \geq 500$  mm
- 2 joists

NOTE The small circles mark the position where the hammers of the tapping machine should strike the lightweight reference floor or the test specimens.

**Figure 1 — Typical arrangement for specimens of category I floor coverings**

**6.6.3 Materials of category II and III**

Place the tapping machine successively on the uncovered floor and on the floor when entirely covered by the floor covering under test.

Each set of measurements (uncovered floor and covered floor) should be made with as many impact source positions as are necessary to yield a reliable mean value; in any case the number of positions should be not less than six.

**7 Precision**

It is required that the measurement procedure gives satisfactory repeatability. This shall be determined in accordance with the method shown in ISO 140-2 and shall be verified from time to time, in particular when a change is made in the procedure or instrumentation.

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



## 8 Expression of results

For the statement of the test results the normalized impact sound pressure level with and without floor covering and the reduction of impact sound pressure level,  $L_{n,t,0}$ ,  $L_{n,t}$  and  $\Delta L_t$ , respectively, shall be given to one decimal place at all frequencies of measurement. Graphs in the test report shall show the value in decibels plotted against frequency on a logarithmic scale. The following dimensions shall be used:

- 5 mm for a one-third-octave band;
- 20 mm for 10 dB.

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

If the reduction of impact sound pressure level is also needed in octave bands, these values shall be calculated from the three one-third-octave band values in each octave band using Equation (10):

$$\Delta L_{\text{oct}} = -10 \lg \left( \frac{\sum_{n=1}^3 10^{-\Delta L_{1/3\text{oct},n} / 10}}{3} \right) \text{ dB} \quad (10)$$

If the test procedure is repeated, the arithmetic mean of all measurement results at each frequency band shall be calculated.

## 9 Test report

The test report shall state:

- a) reference to this part of ISO 140;
- b) name and address of the testing laboratory;
- c) manufacturer's name and product identification;
- d) name and address of the organization or person who ordered the test (client);
- e) date of test;
- f) size and shape of the receiving room, and the construction and thickness of the walls;
- g) description of the type of reference floor, including dimensions, materials, surface mass, etc.;
- h) for the floor covering, the layers of multi-layered coverings and the adhesive, the names and addresses of the manufacturers, the commercial designation, and the source of supply of the specimen used in the test;
- i) detailed description, including the type, mass, surface dimensions and thickness (under load where specified, see 5.3.2) of the test specimens, with appropriate drawings where necessary;
- j) method of mounting, with particular reference to the adhesive, its mass per unit area and bonding-time;
- k) temperature and humidity of the source room;
- l) number and location of microphones when using the discrete microphone method, or the microphone moving path when using the moving microphone method;
- m) number, location and installation time of the loads, where used;

- n) material and dimensions and number of supports of the tapping machine;
- o) a statement as to whether the test specimen suffered visible damage during the test (e.g. compaction); if so, it is desirable that the tested specimen be retained in the laboratory for subsequent inspection;
- p) normalized impact sound pressure level without the floor covering  $L_{n,t,0}$ , normalized impact sound pressure level with the floor covering  $L_{n,t}$  and the reduction of impact sound pressure level  $\Delta L_t$  as a function of frequency (see Annex G);
- q) brief description of details of the procedure and equipment (see 6.6).

## Annex A (normative)

### Requirements for the tapping machine

The equipment shall be suitable for meeting the requirements given in Clause 6.

The tapping machine shall have five hammers placed in a line. The distance between the centrelines of neighbouring hammers shall be  $(100 \pm 3)$  mm.

The distance between the centre of the supports of the tapping machine and the centrelines of neighbouring hammers shall be at least 100 mm. The supports shall be equipped with vibration insulating pads.

The momentum of each hammer that strikes the floor shall be that of an effective mass of 500 g that falls freely from a height of 40 mm, within tolerance limits for the momentum of  $\pm 5\%$ . As friction of the hammer guidance has to be taken into account, it must be ensured that not only the mass of the hammer and the falling height but also the velocity of the hammer at the impact lies within certain given limits as follows.

The mass of each hammer shall be  $(500 \pm 12)$  g, from which it follows that the velocity at the impact must be  $(0,886 \pm 0,022)$  m/s. The tolerance limits of the velocity may be increased to a maximum of  $\pm 0,033$  m/s if it is ensured that the hammer mass lies within accordingly reduced limits of  $(500 \pm 6)$  g.

The falling direction of the hammers shall be perpendicular to the test surface to within  $\pm 0,5^\circ$ .

The part of the hammer that strikes the floor shall be cylindrical with a diameter of  $(30 \pm 0,2)$  mm. The impact surface shall be of hardened steel and shall be spherical with a curvature radius of  $(500 \pm 100)$  mm. Testing the fulfilment of this requirement may be performed in the following ways.

- a) The curvature of the impact surface is considered in compliance with the specifications if the measurement results lie within the tolerances given in Figure A.1 when a meter is moved over the surface on at least two lines through the centre point and being perpendicular to each other.

The curves of Figure A.1 describe a curvature of 500 mm. The distance between the curves is the smallest distance that will allow both 400 mm and 600 mm radii to fall within the tolerance limits. The accuracy of the measurement shall be at least 0,01 mm.

- b) The curvature of the hammer heads may be tested by using a sphere-meter with three feelers lying on a circle with a diameter of 20 mm.

The tapping machine shall be self-driven. The mean time between impacts shall be  $(100 \pm 5)$  ms. The time between successive impacts shall be  $(100 \pm 20)$  ms.

The time between the impact and the lift of the hammer should be less than 80 ms.

For standard tapping machines which are used for tests of impact sound insulation of floors with soft coverings or uneven surfaces, it shall be ensured that it is possible for the hammers to fall at least 4 mm below the plane on which the supports of the tapping machine rest.

All adjustments on the standard tapping machine and verifications on the fulfilment of requirements shall be performed on a flat hard surface and the tapping machine shall be used in that condition on any test surface.

If the test surface is covered with an extremely soft covering or if the surface is very uneven so that the hammers are not able to fall down to the surface on which the supports rest, pads may be used under the supports to ensure the correct falling height of 40 mm.

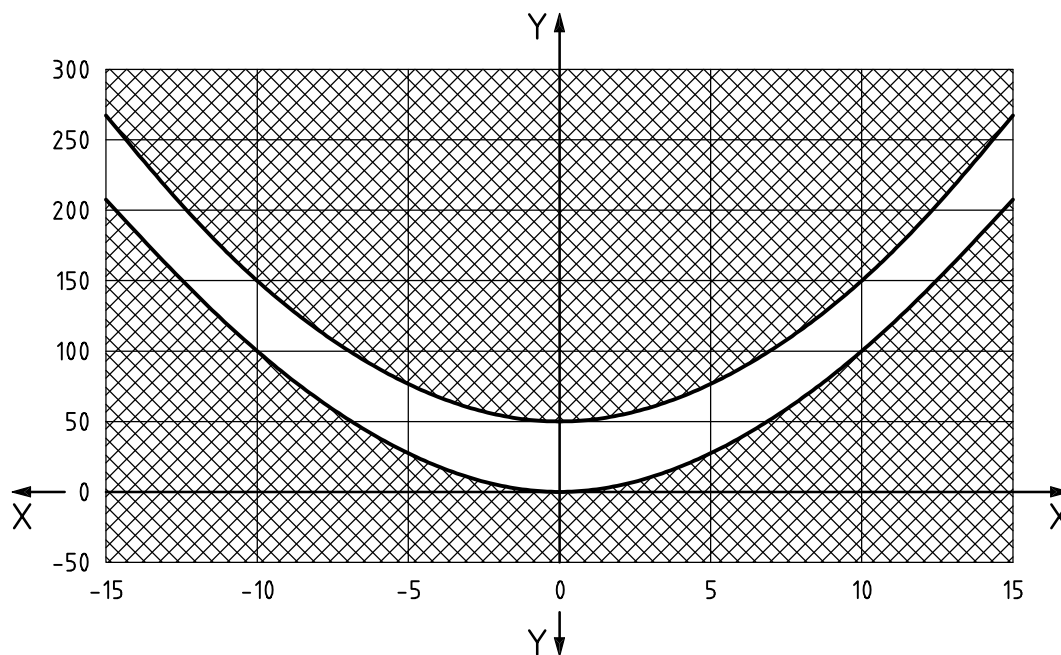
The fulfilment of the requirements shall be verified at regular intervals under standard laboratory conditions. The test shall be performed on a test surface that is planar to within  $\pm 0,1$  mm and horizontal to within  $\pm 0,1^\circ$ .

Some of the parameters only need to be measured once unless the tapping machine has been modified. This concerns the distance between hammers, supports of the tapping machine, diameter of the hammers, mass of the hammers (unless the hammer heads have been refinished), time between impact and lift, and the maximum possible falling height of the hammers.

The velocity of the hammers, the diameter and curvature of the hammer heads, the falling direction of the hammers and the time between impacts shall be verified regularly.

The uncertainty of the verification measurements shall be at most 20 % of the values of the tolerances.

The mass of the tapping machine should be less than 25 kg.



**Key**

- Y relative height ( $\mu\text{m}$ )
- X distance from centre (mm)

NOTE The relative height at the centre can be chosen freely within 0  $\mu\text{m}$  to 50  $\mu\text{m}$  to make the curvature of the hammer head fit within the tolerance limit.

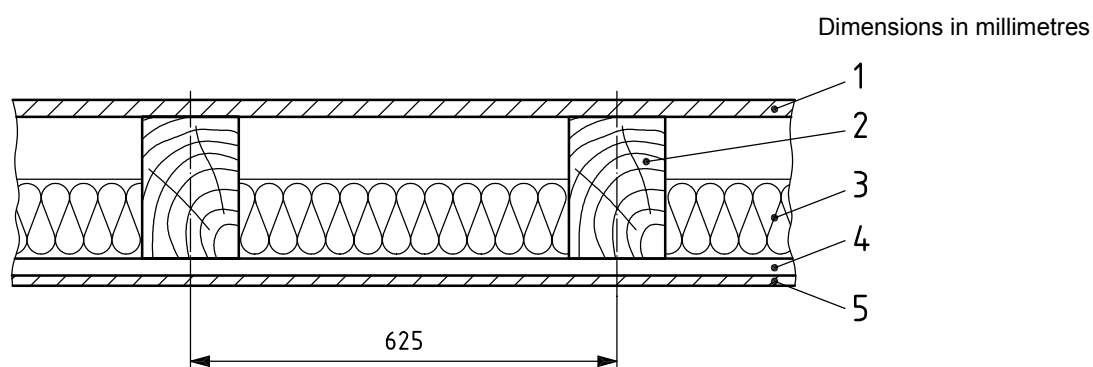
**Figure A.1 — Tolerance limits for the curvature of hammer heads**

## Annex B (normative)

### Types of lightweight reference floors

There are many different kinds of lightweight floor constructions used in countries around the world. However, to allow comparisons of the reduction of impact sound pressure level from different floor coverings, three types of lightweight floor have been chosen to represent the range of different floors (see Figures B.1 to B.4).

If any construction different from the following three types is chosen as the reference lightweight floor, its specification should be described in the test report.



#### Key

##### 1 subfloor

- thickness:  $(22 \pm 2)$  mm
- fastening: screwed to the joists, distance of  $(300 \pm 50)$  mm
- material: wooden chipboard with a mass density of  $(660 \pm 20)$  kg/m<sup>3</sup>

##### 2 wooden joists

- dimensions: 120 mm width and 180 mm height
- spacing: 625 mm between centres

##### 3 absorbent

- material: mineral wool
- dimensions:  $(100 \pm 10)$  mm thickness, completely filling the width and length of the cavity
- airflow resistivity: 5 kPa s/m<sup>2</sup> to 10 kPa s/m<sup>2</sup> in accordance with ISO 9053
- mass density:  $(15 \pm 5)$  kg/m<sup>3</sup>

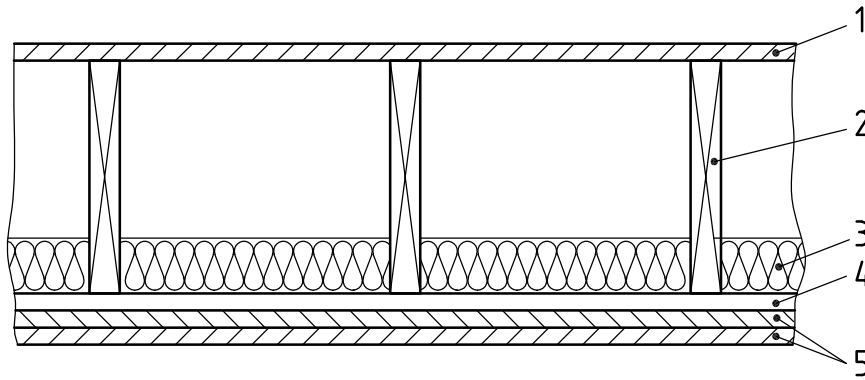
##### 4 wooden ceiling battens

- dimensions: 48 mm width and 24 mm height
- spacing: 625 mm between centres

##### 5 gypsum board ceiling

- thickness:  $(13,5 \pm 1,5)$  mm
- mass density:  $(720 \pm 70)$  kg/m<sup>3</sup>
- fastening: screwed to the battens, distance of screws  $(300 \pm 50)$  mm

Figure B.1 — Reference floor No. 1



**Key**

**1 subfloor**

- thickness: (20 ± 2) mm
- fastening: (50 ± 10) mm screws spaced (150 ± 10) mm along butt joints supported by the joists and (300 ± 10) mm elsewhere
- material 1: tongued and grooved oriented strand board or plywood with a mass density of (580 ± 100) kg/m<sup>3</sup>
- material 2: tongued and grooved chipboard with a mass density of (680 ± 100) kg/m<sup>3</sup>

NOTE Select either sub-floor material 1 or 2 depending on the availability of materials.

**2 joists**

- material: solid soft wood (e.g. spruce, pine or fir)
- dimensions: (42 ± 8) mm width and (225 ± 25) mm height
- mass density: (400 ± 75) kg/m<sup>3</sup>
- spacing: (610 ± 10) mm between centre planes, and if necessary (405 ± 10) mm between centre planes

**3 absorbent**

- material: mineral wool
- dimensions: (100 ± 10) mm thickness, completely filling the width and length of the cavity (placed immediately above the resilient channels)
- airflow resistivity: 5 kPa s/m<sup>2</sup> to 10 kPa s/m<sup>2</sup> in accordance with ISO 9053
- mass density: (15 ± 5) kg/m<sup>3</sup>

**4 resilient metal channels**

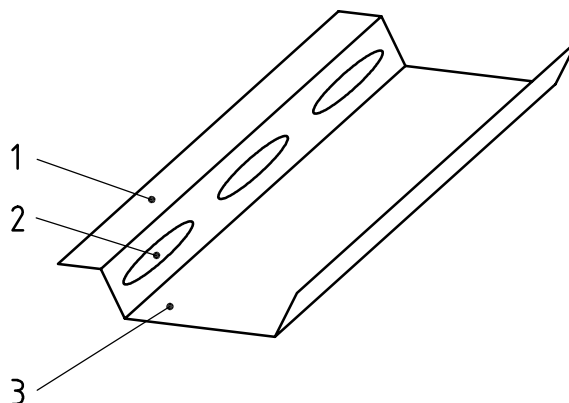
- material: cold rolled steel of thickness (0,5 ± 0,1) mm having a "Z" profile see Figure B.3
- spacing: (405 ± 10) mm oriented perpendicular to the joists

**5 gypsum board ceiling**

- material: two layers of gypsum board [thickness: (13,5 ± 1,5) mm, mass density: (720 ± 70) kg/m<sup>3</sup>]
- fastening: screws spaced (305 ± 5) mm into each resilient channel

NOTE The screw pattern is selected such that the screws penetrate the flange of the resilient channel and not the joists.

**Figure B.2 — Reference floor No. 2**

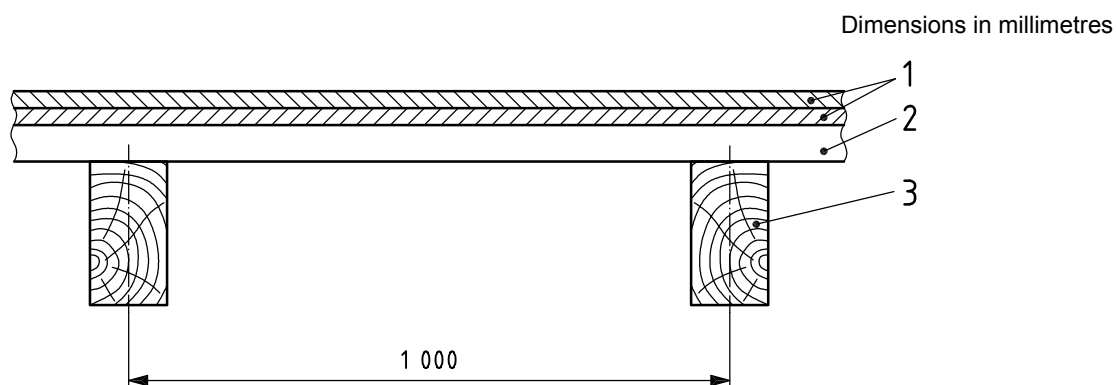


**Key**

- 1 flange used to attach the channel to the framework
- 2 web
- 3 flange used to attach the gypsum board to the channel

NOTE Typical dimensions are: height 13 mm, gypsum board attachment flange 32 mm, framework attachment flange 11 mm. The web may or may not have cut-outs. The flange used to attach the gypsum board may have a more complicated profile (with bumps or ridges).

**Figure B.3 — Sketch of the generic resilient channels used to isolate the gypsum board ceiling**



**Key**

**1 subfloor**

- material: two layers of plywood [thickness:  $(15 \pm 1)$  mm, mass density:  $500 \text{ kg/m}^3$  to  $600 \text{ kg/m}^3$ ]
- fastening: 50 mm screws spaced 500 mm along the joists

**2 joists**

- material: solid soft wood
- dimensions: 45 mm width and 60 mm height
- mass density:  $400 \text{ kg/m}^3$  to  $650 \text{ kg/m}^3$
- spacing: 300 mm between centres

**3 beams**

- material: solid soft wood
- dimensions: 120 mm width and 240 mm height
- mass density:  $400 \text{ kg/m}^3$  to  $650 \text{ kg/m}^3$
- spacing: 1 000 mm between centres

**Figure B.4 — Reference floor No. 3**

## Annex C (informative)

### Measurements using a modified tapping machine

#### C.1 General

When the aim of the impact sound insulation measurements on floor coverings is strong correlation between the “real” impact source (e.g. a walking person) and the artificial impact source (e.g. a tapping machine), both sources shall apply the same input force spectrum to ensure the correct ranking of the floor coverings with the “real” and the artificial impact source. This requires the impedance spectra of the sources to be the same. If the “real” impact source is a walking person without shoes and the artificial source is a standard tapping machine as specified in ISO 140-6, there is not strong correlation. In this annex, a modification of the standard tapping machine is proposed to make its dynamic source characteristics similar to that of a walking person without shoes.

NOTE The static load of the walker is not included, which might be relevant with non-linear floors or floor coverings.

#### C.2 Modified tapping machine

##### C.2.1 Method A

Springs may be inserted between the hammers of the standard tapping machine and the floor surface under test (see Figure C.1). The dynamic stiffness of each spring,  $s$ , shall be  $24 \text{ kN/m} \pm 10 \%$ , and the loss factor  $\eta$  shall be 0,2 to 0,5. To maintain the same contact area compared with the excitation by an unmodified tapping machine, the springs shall have the same cross-section as the hammers. The modified tapping machine shall be adjusted to keep the same falling height of the hammers as with the standard tapping machine.

##### C.2.2 Method B

Place a soft layer onto the floor under the hammer area of the tapping machine. The dynamic stiffness per unit area of the soft layer,  $s'$ , shall be  $34 \text{ MN/m}^3 \pm 10 \%$ , and the loss factor  $\eta$  shall be 0,2 to 0,5. The dynamic stiffness shall be measured according to ISO 9052-1. The loss factor shall be determined from the same measurement by the relationship:

$$\eta = \frac{b}{f_{\text{res}}} \quad (\text{C.1})$$

where

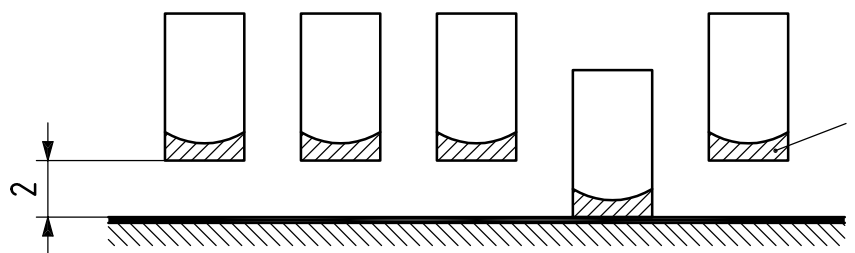
$f_{\text{res}}$  is the resonance frequency of the spring-mass system according to ISO 9052-1:1989, Figure 1;

$b$  is the  $-3 \text{ dB}$  bandwidth at the resonance.

The modified tapping machine shall be adjusted to keep the same falling height of the hammers as with the standard tapping machine as shown in Figure C.1.

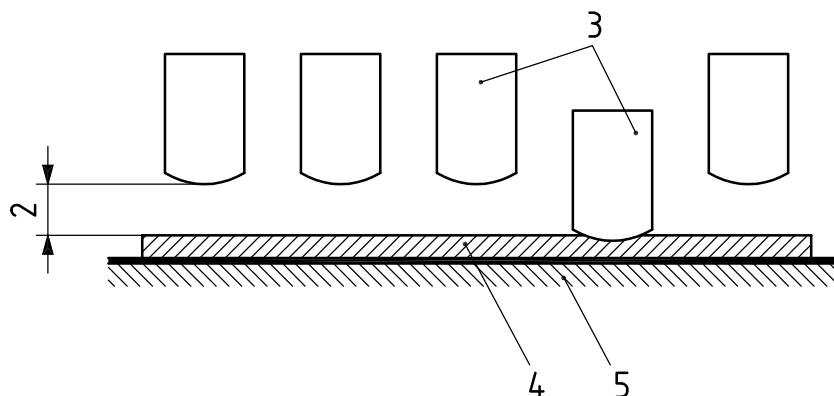
At present no single product is recommended as a soft layer. The layer may be made of rubber, cork, plastic material or similar. It is recommended to create the elastic layer by a number of thin layers (e.g. 3 mm) to ensure a low bending stiffness. For the same reason, the thin layers should be fixed to each other only at single points. The area of the soft layer should be as small as possible, preferably a strip of 45 cm length and 5 cm width. It should be noted that the stiffness of the soft layer could be affected by temperature, non-linear behaviour and the ageing of the material.





NOTE Dynamic stiffness  $s = 24 \text{ kN/m} \pm 10 \%$  each, and loss factor  $\eta = 0,2$  to  $0,5$ .

**a) Single springs fixed to the hammers**



NOTE Dynamic stiffness per unit area  $s' = 34 \text{ MNm/m}^3 \pm 10 \%$ , and loss factor  $\eta = 0,2$  to  $0,5$ .

**b) Elastic layer under the hammers, laid on the test floor under test**

**Key**

- 1 spring
- 2 falling height (40 mm)
- 3 hammers of the tapping machine
- 4 elastic layer
- 5 reference floor

**Figure C.1 — Modified tapping machine (only hammers shown)**

### C.3 Measuring procedure

Use the same procedure as with the standard tapping machine.

### C.4 Expression of results

The following results shall be given in the test report for the modified tapping machine (MTM):

- the normalized impact sound pressure level with floor covering,  $L_{n,t}$  (MTM);
- the normalized impact sound pressure level without floor covering,  $L_{n,t,0}$  (MTM);
- the impact sound pressure level improvement  $\Delta L_t$  (MTM).

## Annex D (informative)

### Measurements using a wooden mock-up floor

#### D.1 General

This annex specifies how to determine the impact sound improvement of floor coverings when mounted on lightweight floor constructions using a wooden mock-up floor.

#### D.2 Field of application

This method is applicable to all kinds of floor coverings. The results are only applicable to mounting conditions similar to those used in the test. To ensure that the results are applicable to the actual lightweight floor, the board material and thickness used in the mock-up floor should be similar to that of the actual lightweight floor. When a different board material and thickness are used, the results may only give an estimate of the improvement on the actual lightweight floor.

**NOTE** There will be two sound transmission paths to the receiving room. One is structure-borne sound via the feet of the top floor and the other is airborne sound from the source room through the concrete slab to the receiving room. In general the structure-borne sound will dominate, but in some cases, particularly at high frequencies, the airborne path will influence the result and cause an underestimation of the impact sound improvement of the structure-borne path. Some lightweight floors have very weak transmission via the structure-borne path (e.g. floors with independent ceilings or with ceilings suspended on resilient hangers), and in such cases the results obtained using this annex may be misleading.

#### D.3 Principle

The effect of a resilient floor covering will depend on the resilience of the floor on which the covering is mounted. The stiffer the floor, the greater is the expected improvement in impact sound insulation due to the floor covering. In accordance with ISO 140-8, the floor covering is mounted on a thick concrete slab, which is approximately infinitely stiff. These results will no longer be relevant if the floor covering is mounted on a much more resilient lightweight floor. The purpose of this method is to simulate the effect of lightweight floor constructions by mounting the floor covering not on an infinitely stiff concrete slab but on a resilient board representative to the upper part of a typical lightweight floor construction. This resilient board is mounted on feet, which in turn rest on a sub-floor identical to the normal ISO test slab. The resilient board on its feet is designated "top floor" and, together with the standard slab, is designated "sub-floor"; these constitute the "test floor".

#### D.4 Equipment

The specifications given in Clause 4 apply.

#### D.5 Test arrangement

##### D.5.1 General arrangement

Two vertically adjacent rooms, as specified in ISO 140-8, are used, the upper one designated the "source room" and the lower one the "receiving room". They are separated by the sub-floor on which the top floor is mounted. The floor covering to be tested is mounted on the top floor.

## D.5.2 Top floor

Unless a specific lightweight floor is to be simulated, the standard top floor shall consist of a 22 mm thick floor particleboard mounted on 20 wooden feet, 600 mm centre-to-centre. The area of the particleboard shall be 2 000 mm × 2 600 mm. If smaller particleboards are used, they shall be glued together using a PVAc glue (polyvinyl acetate). The outermost feet shall be located approximately 100 mm from the edges of the board. The E-modulus of the particleboard shall be 3 000 MPa to 3 500 MPa and the density shall be 700 kg/m<sup>3</sup> to 900 kg/m<sup>3</sup>. Each foot shall be made of spruce wood or similar, with an approx. height of 200 mm and cross-section of 50 mm × 50 mm. The feet shall be screwed and glued on the board.

When the top floor is mounted on the concrete sub floor, it shall be mounted on a thin layer of resilient material (e.g. plastic padding or similar).

During the test, the top floor shall be loaded with five weights, each 20 kg to 25 kg, plus the standard tapping machine. The positions should be fixed with one weight in the middle of the top floor and the remaining four at the corners, 40 cm from top floor edges. The loads shall be applied both when measuring with and without the floor covering.

Optionally, the standard top floor described above may be supplemented by other top floors simulating the upper part of arbitrary lightweight floors. This is done by replacing the 22 mm particleboard by other boards, or combinations thereof.

## D.5.3 Preparation and installation of test specimen

Parquet floors shall cover the whole top floor and soft floor coverings shall be laid loosely on the top floor. For other details, see ISO 140-8.

## D.6 Test procedure

### D.6.1 General

Follow the test procedure given in Clause 6 with the supplements given below.

### D.6.2 Positions of the tapping machine

Follow the specifications of Clause 6 but use at least six positions. The six positions shall be fixed. The same positions shall be used with and without floor coverings. The minimum distance between loads shall be ~ 300 mm.

## D.7 Statement of the results

Follow the specifications of Clause 8 with the supplement that it shall be clearly stated that  $\Delta L$  has been determined for lightweight floors using this method.

## D.8 Expression of results

Follow the specifications given in Clause 8.

## D.9 Test report

Follow the specifications given in Clause 9.

## **Annex E** (informative)

### **Measurements using a heavy/soft impact source**

#### **E.1 General**

This annex describes a method that may be used to measure the acoustic properties of floor coverings from the viewpoint of reducing impact sounds generated by such heavy and soft impacts as human footsteps or children jumping. The purpose of this annex is to establish a method for determining the impact sound insulation of a floor covering under standard test conditions.

#### **E.2 Equipment**

The equipment shall comply with the requirements of E.4.

The heavy/soft impact source shall meet the requirement given in Annex F.

The accuracy of the sound level measurement equipment shall comply with the requirements of accuracy Class 1 defined in IEC 61672-1:2002. The complete measuring system, including the microphone, shall be adjusted before each measurement using a sound calibrator that complies with the requirements of accuracy Class 1 defined in IEC 60942:2003. For sound level meters calibrated for measurements in sound fields of progressive plane waves, corrections for the diffuse sound field shall be applied.

The filters shall comply with the requirements defined in IEC 61260.

#### **E.3 Test arrangement**

Follow the specifications given in Clause 5.

#### **E.4 Test procedure and evaluation**

##### **E.4.1 General**

The measurements shall be made in one-third-octave bands or octave bands as required.

##### **E.4.2 Generation of sound field**

The impact sound shall be generated by dropping the heavy/soft impact source described in Annex F from a height of 100 cm above the surface of the floor covering.

The excitation by the heavy/soft impact source shall be made at four or more different positions on the floor under test. One of these positions shall be above the joists and one position shall be at the centre point of the floor.

### E.4.3 Measurement of impact sound pressure level

#### E.4.3.1 Number of microphones

Measure the impact sound pressure level by an array of fixed microphones.

#### E.4.3.2 Microphone positions

As a minimum, four microphone positions shall be used. These shall be distributed within the maximum permitted space throughout the room, spaced uniformly.

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

- 0,7 m between microphone positions;
- 0,7 m between any microphone position and room boundaries or diffusers;
- 1,0 m between any microphone position and the upper floor being excited by the standard impact source.

#### E.4.3.3 Frequency range of measurements

The sound pressure level shall be measured using one-third-octave or octave band filters having at least the following centre frequencies, in hertz.

a) In case of one-third-octave band measurements:

50    63    80    100    125    160    200    250    315    400    500    630

b) In case of octave band measurements:

63    125    250    500

NOTE Guidance is given in ISO 140-6:1998, Annex C, for such measurements in the low-frequency bands of 50 Hz, 63 Hz and 80 Hz in one-third-octave bands or of 50 Hz in the octave band.

#### E.4.3.4 Measurement of maximum sound pressure level

For each excitation position, measure the maximum sound pressure level at a minimum of four different microphone positions.

#### E.4.3.5 Correction for background noise

Follow the procedure given in 6.5.

### E.4.4 Calculation of impact sound pressure level

The maximum sound pressure levels measured at the different microphone positions shall be averaged for each excitation position by

$$L_{i,Fmax,j} = 10 \lg \left( \frac{1}{m} \sum_{k=1}^m 10^{L_{Fmax,k}/10} \right) \text{ dB} \quad (\text{E.1})$$

where  $L_{Fmax,k}$  is the maximum sound pressure level at  $k$  th microphone position ( $k = 1$  to  $m$ ) in the receiving room.

Then, the impact sound pressure level shall be calculated by averaging the values obtained above for all excitation positions by

$$L_{i,Fmax} = 10 \lg \left( \frac{1}{n} \sum_{j=1}^n 10^{L_{i,Fmax,j}/10} \right) \text{ dB} \quad (\text{E.2})$$

where  $L_{i,Fmax,j}$  is the maximum impact sound pressure level measured for  $j$  th excitation position ( $j = 1$  to  $n$ ).

#### **E.4.5 Determination of reduction of impact sound pressure level (improvement of impact sound insulation)**

From the results of the measurements with and without the floor covering under test, the reduction of impact sound pressure level (improvement of impact sound insulation) shall be calculated according to Equation (6).

#### **E.5 Precision**

Follow Clause 7.

#### **E.6 Expression of the results**

Follow the specifications given in Clause 8.

#### **E.7 Test reports**

Follow the specifications given in Clause 9.

## Annex F (informative)

### Specification of the heavy/soft impact source

#### F.1 General

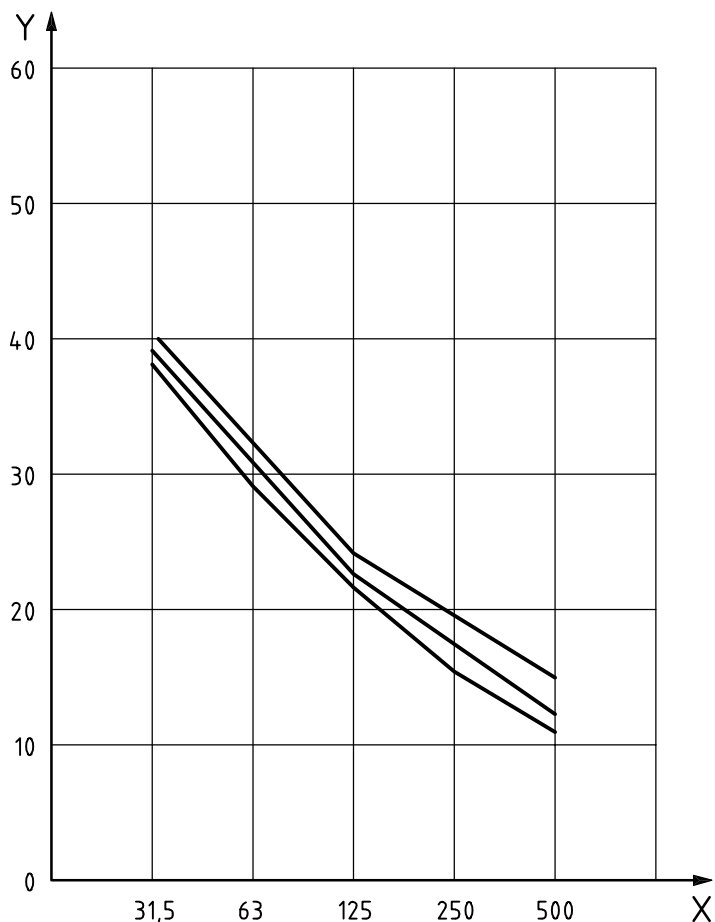
This annex specifies the impact force characteristics of the heavy/soft impact source for the measurements of impact sound pressure level specified in Annex E.

#### F.2 Impact force characteristics

The heavy/soft impact source shall generate the impact force exposure level in each octave band shown in Table F.1 and Figure F.1 when it is dropped from the height of 100 cm (from the bottom of the impact source to the surface of the floor under test).

**Table F.1 — Impact force exposure level in each octave band of the heavy/soft impact source**

Octave band centre frequency Hz	Impact force exposure level dB
31,5	$39,0 \pm 1,0$
63	$31,0 \pm 1,5$
125	$23,0 \pm 1,5$
250	$17,0 \pm 2,0$
500	$12,5 \pm 2,0$



**Key**

- X octave band centre frequency (Hz)
- Y impact force exposure level (dB)

**Figure F.1 — Impact force exposure level in each octave band of the heavy/soft impact source**

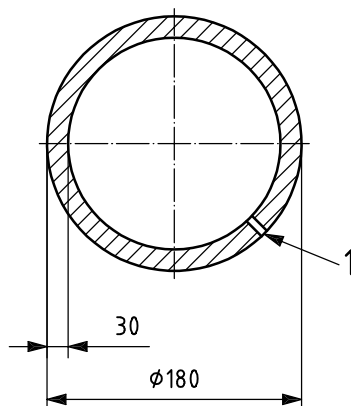
**F.3 Example of the construction of the heavy/soft impact source**

A rubber ball with the following characteristics may be used:

- shape and size: hollow ball with 180 mm in diameter with 30 mm thickness (see Figure F.2);
- composition: see Table F.2;
- effective mass:  $(2,5 \pm 0,1)$  kg;
- coefficient of recovery:  $0,8 \pm 0,1$ .



Dimensions in millimetres



**Key**

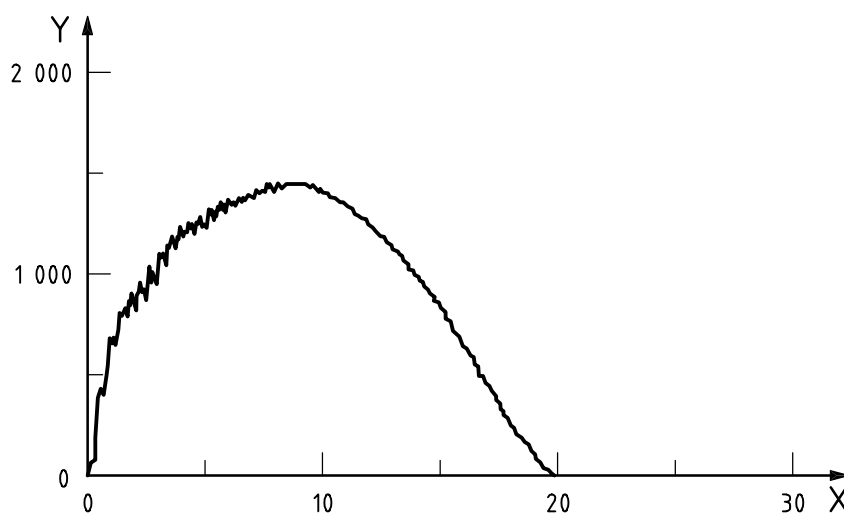
1 pin hole (1 mm in diameter)

**Figure F.2 — Section view of the rubber ball (heavy/soft impact source)**

**Table F.2 — Composition of the rubber ball**

Material	Weight ratio
Silicone rubber	100
Peroxide cross-linking agent	2
Pigment	2
Vulcanizing agent	< 0,1

Figure F.3 shows the impact force waveform of the rubber ball. The rubber ball may either be dropped manually or by using an automated set-up.



**Key**

X time (ms)

Y impact force (N)

**Figure F.3 — Impact force waveform of the rubber ball measured on a heavy concrete floor**

## **Annex G** (informative)

### **Example of form for the expression of results**

This annex gives an example of the form for the expression of results obtained by laboratory measurements of the reduction of transmitted impact sound by floor coverings on a lightweight reference floor.

Users of this part of ISO 140 are allowed to make copies of this form.

### Reduction of impact sound pressure level according to ISO 140-11

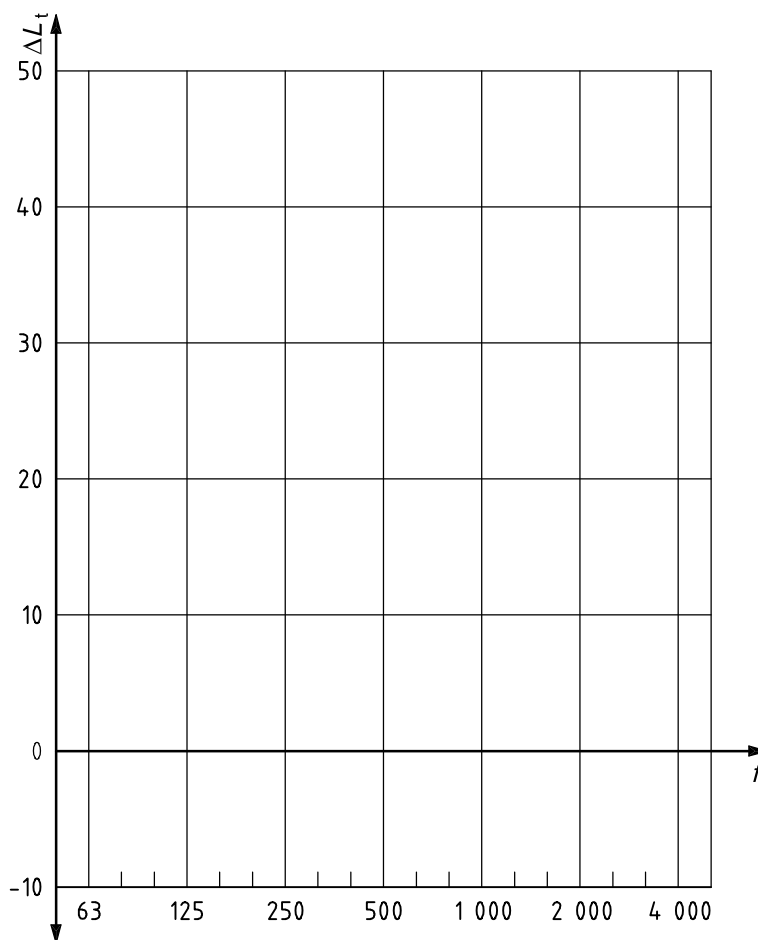
Laboratory measurements of the reduction of transmitted impact sound by floor coverings on a lightweight reference floor

Manufacturer: Product identification:  
 Client: Test room identification:  
 Test specimen mounted by: Date of test:

Description of test facility, test specimen and test arrangement:

Type of reference floor: No.  
 Mass per unit area: kg/m<sup>2</sup>  
 Curing time: h  
 Air temp. in the source room: °C  
 Air humidity in the source room: %  
 Receiving room volume: m<sup>3</sup>

Frequency <i>f</i> Hz	<i>L</i> <sub>n,t,0</sub> 1/3 octave dB	<i>L</i> <sub>n,t</sub> 1/3 octave dB	$\Delta L_t$ 1/3 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			



No. of test report: Name of test institute:  
 Date: Signature:

## Bibliography

- [1] ISO 140-7:1998, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 7: Field measurements of impact sound insulation of floors*
- [2] ISO 717-2:1996, *Acoustics — Rating of sound insulation in buildings and of building elements — Part 2: Impact sound insulation*
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