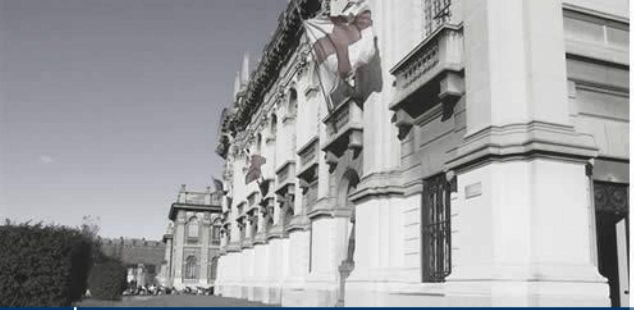

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Impact Sound Insulation: Weighted Normalized Impact Sound Pressure Level Index Evaluation

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Department of Energy

Floor design to comply with DPCM 5.12.97

Weighted Normalized Impact Sound Pressure Level (Index)

Floor design to comply with DPCM 5.12.97

Building Category	R'_W	$D_{2m,n,T,W}$	$L'_{n,w}$	L_{ASmax}	L_{Aeq}
D	55	45	58	35	25
A,C	50	40	63	35	35
E	50	48	58	35	25
B,F,G	50	42	55	35	35

R'_w Weighted Apparent Sound Reduction Index, in dB(A)

$D_{2m,n,T,w}$ Facade Weighted Standardized Level Difference (Index), in dB(A)

$L'_{n,w}$ Weighted Normalized Impact Sound Pressure Level (Index), in dB(A)

L_{ASmax} Maximum A-weighted sound pressure level with time constant slow, in dB(A)

L_{Aeq} Equivalent Continuous Sound Pressure Level, A-weighted, in dB(A)

- Category A: buildings used as residences or similar
- Category B: buildings used as offices and similar
- Category C: buildings used as hotels, guest houses and similar activities
- Category D: buildings used as hospitals, clinics, nursing homes and similar
- Category E: buildings used for school activities at all levels
- Category F: buildings used for recreation or worship or similar activities
- Category G: buildings used for commercial or similar purposes

Relevant EN ISO Standards

- EN ISO 717-2:2013 - Acoustics - Rating of sound insulation in buildings and of building elements - Part 2: Impact sound insulation

  ➔ single-number quantities for impact sound insulation in buildings and of floors (INDICES)

- EN ISO 12354-2:2017 - Building acoustics - Estimation of acoustic performance of buildings from the performance of elements - Part 2: Impact sound insulation between rooms

  ➔ at the design stage, using lab measurement of building elements, or at verification stage, using field measurements.

- EN ISO 16283-2:2018 - Acoustics - Field measurement of sound insulation in buildings and of building elements - Part 2: Impact sound insulation

- EN ISO 10140-3:2010 - Acoustics - Laboratory measurement of sound insulation of building elements - Part 3: Measurement of impact sound insulation

EN ISO 717-2:2013 - Acoustics - Rating of sound insulation in buildings and of building elements - Part 2: Impact sound insulation:

- gives rules for determining single-number quantities for impact sound insulation in buildings and of floors from the results of measurements carried out in one-third-octave bands in accordance with ISO 10140-3 (lab measurements) and ISO 16283-2, and in octave bands in accordance with that option in ISO 16283-2 for field measurements only;
- defines single-number quantities for the impact sound reduction of floor coverings and floating floors calculated from the results of measurements carried out in accordance with ISO 10140-3;
- specifies a procedure for evaluating the weighted reduction in impact sound pressure level by floor coverings on lightweight floors.

NOTE: In order to distinguish clearly between values with and without flanking transmission, primed symbols (e.g. L'_n) are used to denote values obtained with flanking transmission. This note also applies to the other relevant standards.

Weighted Normalized Impact Sound Pressure Level :

single-number quantity for impact sound insulation rating derived from one-third-octave or octave band measurements; it is the value of the relevant reference curve at 500 Hz after shifting it in accordance with the method specified in the standard.

Symbol:	$L'_{n,w}$	with flanking transmission
	$L_{n,w}$	without flanking transmission

It is based on the spectral distribution of the **Normalized Impact Sound Pressure Level, L'_n or L_n**

Normalized impact sound pressure level:

sound pressure level in a specific frequency band in the receiving room when the floor under test is excited by a **Standardized Impact Sound Source**, normalized using the equivalent sound absorption area

$$L'_n = L_P + 10 \cdot \log_{10}\left(\frac{A}{A_0}\right)$$

where

L_p is the measured sound pressure level in the receiving room

A_0 is the reference equivalent sound absorption area (=10 m^2 ISO 10140-3)

A is the equivalent sound absorption area of receiving room, calculated as $A = 0{,}16\,\frac{V}{T_{60}}$ from reverberation time $\boldsymbol{T}_{60}$

Standardized Impact Sound Pressure Level:

sound pressure level in a specific frequency band in the receiving room when the floor under test is excited by a **Standardized Impact Sound Source**, standardized using

$$L'_{nT} = L_P - 10 \cdot \log_{10}\left(\frac{T_{60}}{T_0}\right)$$

dove

L_p is the measured sound pressure level in the receiving room

T_0 is the reference value of the reverberation time (=0,5 s)

T_{60} is the value of the reverberation in the receiving room

Standardized Impact Sound Source

Standardized impact sound generator, tapping machine, compliant with standards UNI-EN-ISO 16283-2 and 10140, DIN 52210, other than D.P.C.M. 05-12-1997. It consists of hammers of standardized weight that drop from a standard height at a standard repetition rate [frequency].

It uses 5 hammers each weighing 500 g and dropping from a height of 40 mm every two seconds, giving an operating frequency of 10 Hz. The hammers are operated by electromagnetic system, no use of electric motor.

High precision of impact

frequency of impact 10 Hz ± 0,01 %

speed of impact 0.886 m/sec ± 3 %

Power:

ac 230 v 0.7a

dc 25.2 v - 5 a

Battery autonomy:

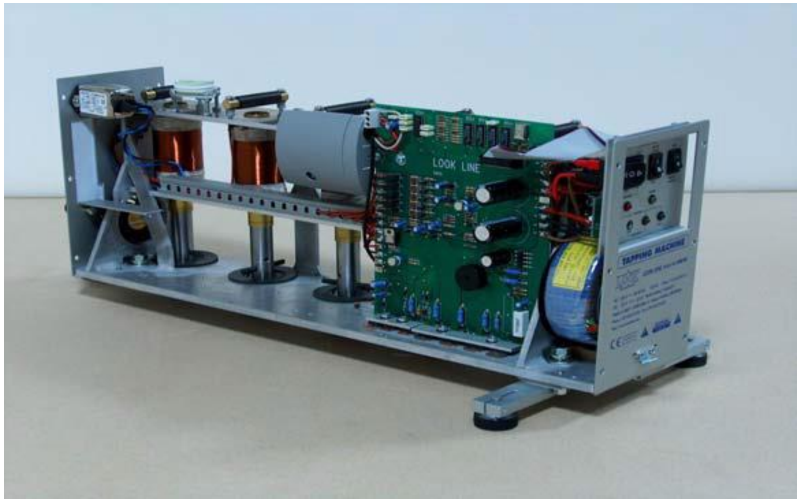
continuous operations 50 minutes

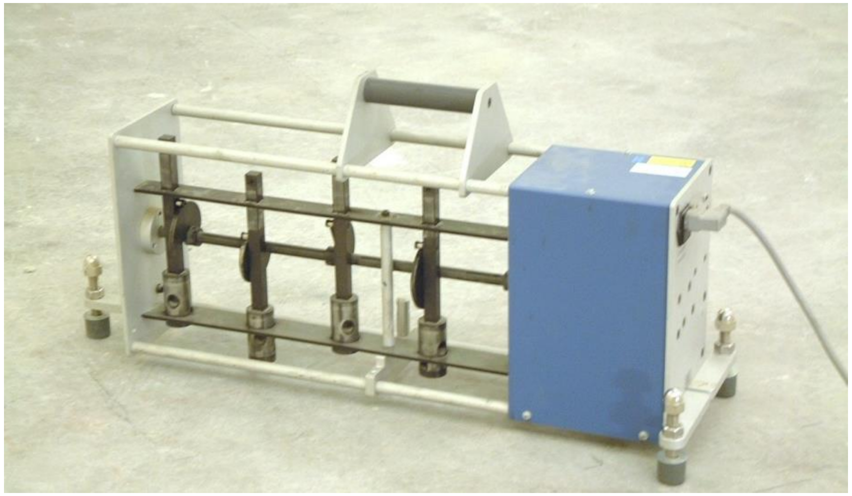
stand-by 50 hours

Impact Sound Insulation: tapping machine

Standardized Impact Sound Source

The vibration from the tapping machine is transmitted through the building structure into the air in the receiving room. This sound level (L_2) is measured and compared to building regulation after correction for reverberation time (T_2) and possible influence of background noise (B_2). Measurements must comply with EN-ISO 10140-5 in lab and ISO 140-7 in field as required by D.P.C.M. 05-12-1997.





5 hammers each weighing 500 g

Dropping from a height of 40

Operating frequency of 10 Hz.

High precision of impact frequency: 100ms ±0.01%

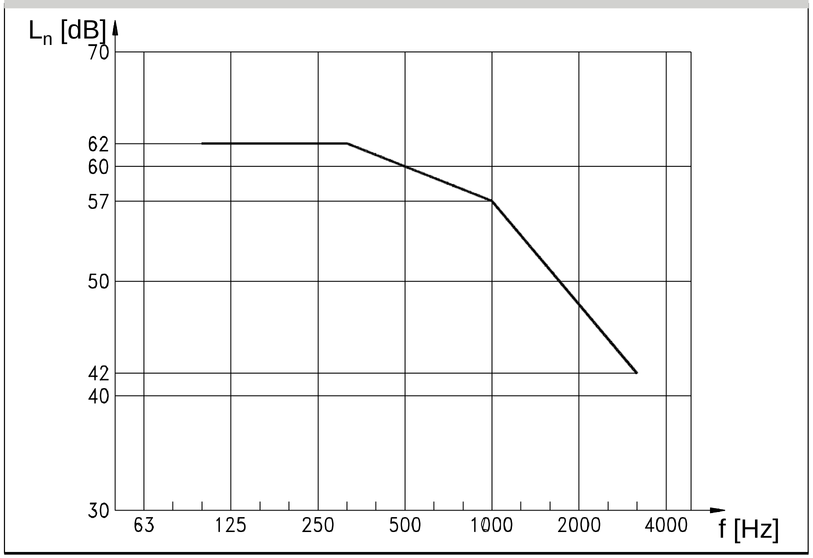
Impact speed : 0.886 m/s

Evaluation of Weighted Normalized Impact Sound Pressure Level : L’n,w

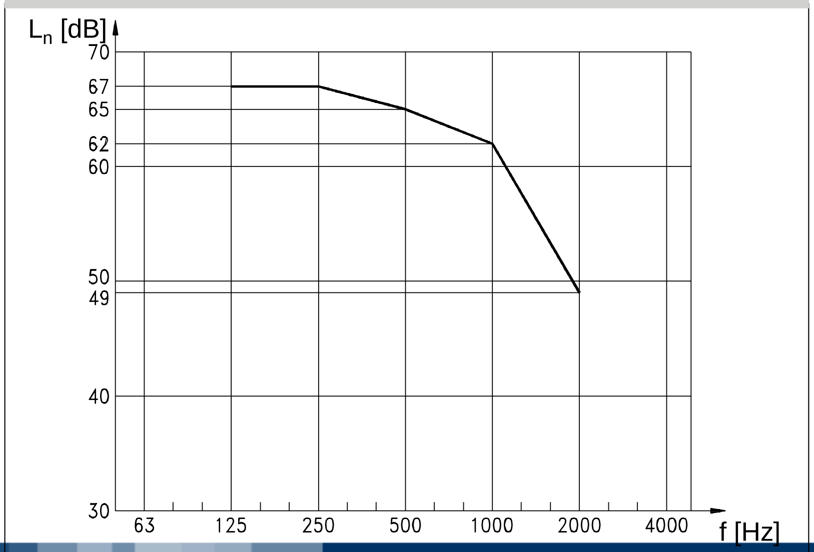
Reference curve

Frequency Hz	Reference Values, dB one-third-octave bands	octave bands
100	62	
125	62	67
160	62	
200	62	
250	62	67
315	62	
400	61	
500	60	65
630	59	
800	58	
1 000	57	62
1 250	54	
1 600	51	
2 000	48	49
2 500	45	
3 150	42	

Octave Bands

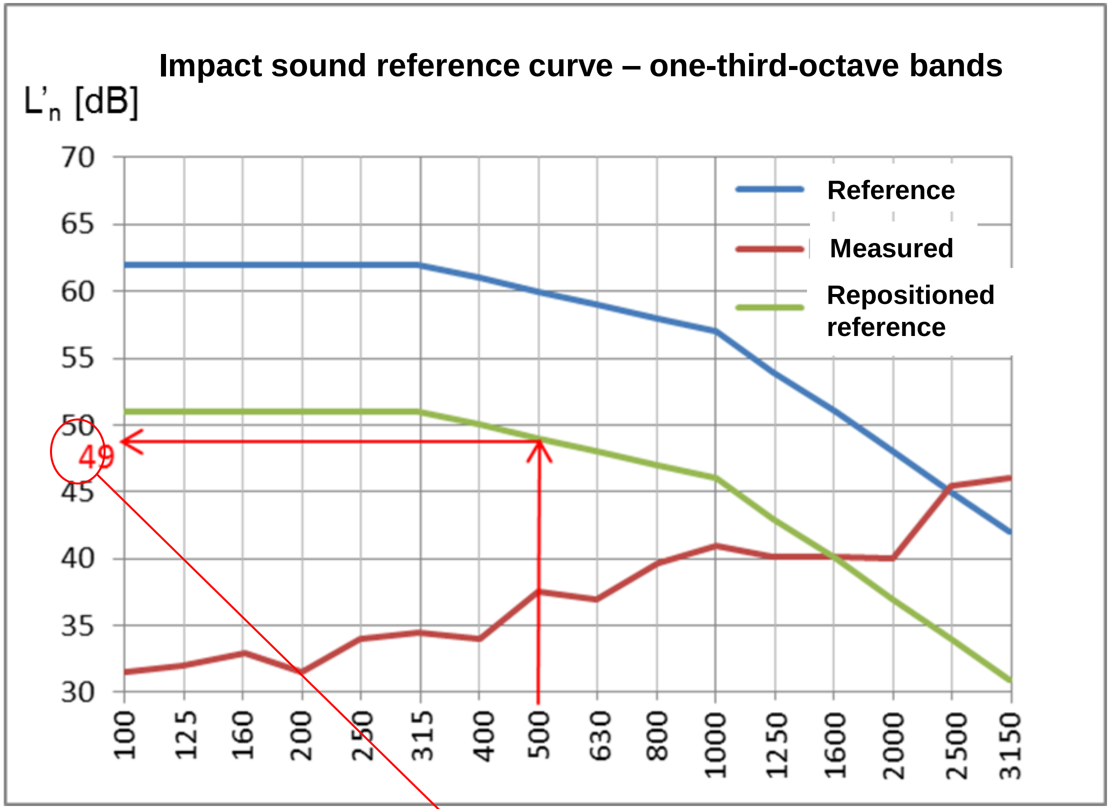


one-third-octave bands



Weighted Normalized Impact Sound Pressure Level (Index) – ISO 717-2

Where it is possible to carry out noise measurements by standardized impact sound source, to obtain a single value indicative of the characteristics of the slab rather than its frequency response, the index **$L'_{n,w}$**, is defined as the value in dB at 500 Hz obtainable from the reference spectrum repositioning against the spectra distribution of the Normalized Impact Sound Pressure Level **L'_n**. This repositioning, obtained by translating down in steps of 1 dB, shall respect:



sum of unfavourable deviations is as large as possible, but not more than :

10 dB octave bands analysis; **32 dB one-third-octave bands analysis**

$L'_{n,w}$

with

unfavourable deviations = $L_{measured} - L_{reference}$

unfavourable deviations < 0 ➔ unfavourable deviations . = 0

EN-ISO 717-2

Normalized Impact Sound Pressure Level between Rooms – Detailed Model (EN ISO 12354-2): L'_n

The sound power radiated into the receiving room is due to sound radiated by each structural element in that room. The sound radiated by each of the structural elements is caused by sound transmitted to that element due to impact on a structural element in the source room. It is assumed that the transmission via each of these paths can be considered to be independent and that the sound and vibrational fields behave statistically, so that the impact sound pressure level ***L'*****n** can be obtained by addition of the energy transmitted via each path. The transmission paths considered are defined in the figure, where ***d*** indicates the direct impact sound transmission and ***f*** flanking impact sound transmission.

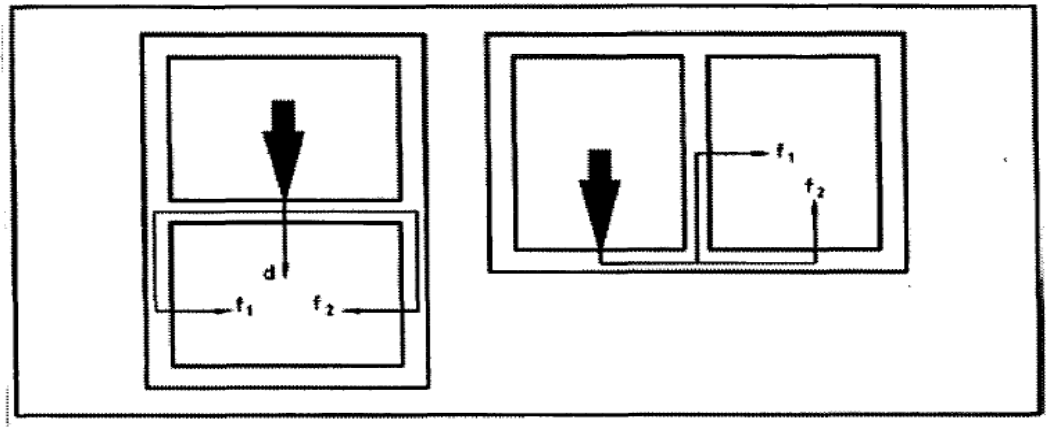
For rooms above to each other the total impact sound pressure level ***L'*****n** in the receiving room is determined by:

$$L'_n = 10\log_{10}\left(10^{L_{n,d}/10} + \sum_{j=1}^{n} 10^{L_{n,ij}/10}\right)$$

where

$L_{n,d}$ direct component

$L_{n,ij}$ indirect components



Simplified evaluation of Weighted Normalized Impact Sound Pressure Level (EN ISO 12354-2) : $L_{n,w}$

The simplified version of the calculation model instead predicts the weighted normalized impact sound pressure level on the basis of weighted values of the elements involved, determined in accordance with the weighting procedure of EN ISO 717-2. Its application is restricted to rooms above each other and a homogeneous basic floor construction. The influence of structural damping is taken into account in an average way.

The weighted normalized impact sound pressure level $L'_{n,w}$ is given by:

$$L'_{n,w} = L_{n,w,eq} - \Delta L_w + K$$

where $L_{n,w,eq}$ is the equivalent weighted normalized impact sound pressure level of the floor base, to which the weighted reduction of impact sound pressure level of the floor covering, ΔL_w, is subtracted and the correction for impact sound transmission over the homogeneous flanking constructions, K, is added. All these quantities are described in EN ISO 717-2, except K.

Simplified Estimation of Weighted Normalized Impact Sound Pressure Level (EN ISO 717-2) : $L'_{n,w}$

- The index $L_{n,w,eq}$ for a generic floor between two rooms is calculated starting from the normalized impact sound pressure level of its structural part (bare floor), $L_{n,0}$, to which the reduction in impact sound pressure level of the reference floor covering, ΔL_r, is added (i.e. subtracted).

- The weighted reduction of impact sound pressure level ΔL_w is determined applying the reduction in impact sound pressure level of the adopted floor covering, ΔL, to the normalized impact sound pressure level of the reference floor, $L_{n,r,0}$.

- Correction index ***K*** for flanking transmission is reported in a table as function of floor areic mass and the mean mass per unit area of the homogeneous flanking elements.

Simplified Estimation of Weighted Normalized Impact Sound Pressure Level (EN ISO 717-2) : $L'_{n,w}$

- The index $L_{n,w,eq}$ for a generic floor between two rooms is calculated starting from the normalized impact sound pressure level of its structural part (bare floor), $L_{n,0}$, to which the reduction in impact sound pressure level of the reference floor covering, ΔL_w, is added (i.e. subtracted).

$$L'_{n,w} = L_{n,w,eq} - \Delta L_w + K$$

- The weighted reduction of impact sound pressure level ΔL_w is determined applying the reduction in impact sound pressure level of the adopted floor covering, ΔL, to the normalized impact sound pressure level of the reference floor, $L_{n,r,0}$.

- Correction index ***K*** for flanking transmission is reported in a table as function of floor areic mass and the mean mass per unit area of the homogeneous flanking elements.

Correction for impact sound transmission over the homogeneous flanking constructions: *K* [dB]

Correction ***K*** for flanking transmission in decibels (EN ISO 12354-2)

Massa per unit area of the separating elements (floor) kg/m²	Mean mass per unit area of the homogeneous flanking elements not covered with additional layers in kg/m²								
	100	**150**	**200**	**250**	**300**	**350**	**400**	**450**	**500**
100	1	0	0	0	0	0	0	0	0
150	1	1	0	0	0	0	0	0	0
200	2	1	1	0	0	0	0	0	0
250	2	1	1	1	0	0	0	0	0
300	3	2	1	1	1	0	0	0	0
350	3	2	1	1	1	1	0	0	0
400	4	2	2	1	1	1	1	0	0
450	4	3	2	2	1	1	1	1	1
500	4	3	2	2	1	1	1	1	1
600	5	4	3	2	2	1	1	1	1
700	5	4	3	3	2	2	1	1	1
800	6	4	4	3	2	2	2	1	1
900	6	5	4	3	3	2	2	2	2

Simplified Estimation of Weighted Normalized Impact Sound Pressure Level (EN ISO 717-2) : $L'_{n,w}$

- The index $L_{n,w,eq}$ for a generic floor between two rooms is calculated starting from the normalized impact sound pressure level of its structural part (bare floor), $L_{n,0}$, to which the reduction in impact sound pressure level of the reference floor covering, ΔL_r, is added (i.e. subtracted).

- The weighted reduction of impact sound pressure level ΔL_w is determined applying the reduction in impact sound pressure level of the adopted floor covering, ΔL, to the normalized impact sound pressure level of the reference floor, $L_{n,r,0}$.

$$L'_{n,w} = L_{n,w,eq} - \Delta L_w + K$$

- Correction index K for flanking transmission is reported in a table as function of floor areic mass and the mean mass per unit area of the homogeneous flanking elements.

Simplified Estimation of Weighted Normalized Impact Sound Pressure Level (EN ISO 717-2) : $L'_{n,w}$

To evaluate the weighted normalized impact sound pressure level, $L'_{n,w}$, using the simplified model, the floor has then to be divided into two parts.

The floor is assumed to consist of two overlapping parts:

1. **the bearing structure (bare floor)**
2. **the finishing**

The bare floor constitutes the structural part and its commonly made of beams and hollow bricks, but can be different according to different buildings use (precast slab, predalle, etc.).

The finishing is composed of the flooring (parquet, tiles, linoleum etc. ..) and the immediately underlying layers through which it can take place the passage of the installations (lightweight screed).

The screed or the floor may rest on the supporting structure or be laid over resilient materials.

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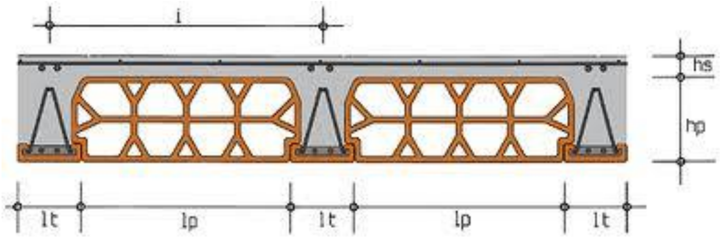
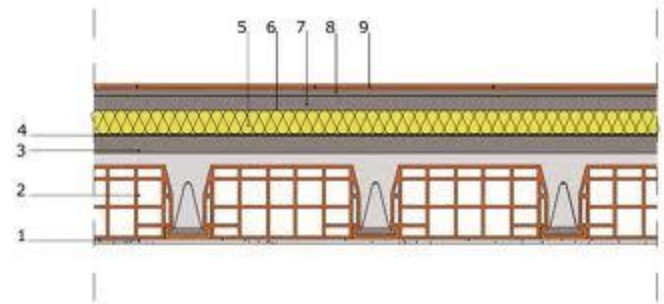
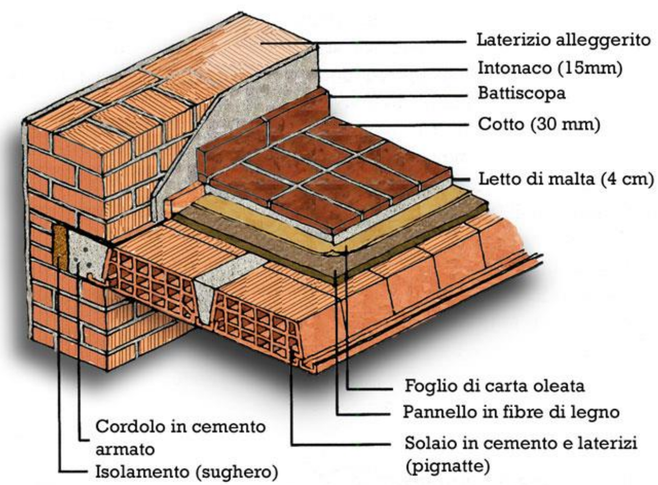
Simplified Estimation of Weighted Normalized Impact Sound Pressure Level (EN ISO 717-2) : $L'_{n,w}$

bare floor



bare floor with finishing over layers





Equivalent weighted normalized impact sound pressure level of the bare floor : $L_{n,w,eq}$

The equivalent weighted normalized impact sound pressure level of the bare massive floor, $L_{n,w,eq}$, is calculated as:

$$L_{n,1}(f) = L_{n,0}(f) - \Delta L_r(f) \qquad \Rightarrow L_{n,1,w}$$

$$L_{n,w,eq} = L_{n,1,w} + \Delta L_{r,w} = L_{n,1,w} + 19 \quad [\mathrm{dB}]$$

where

$L_{n,1,w}$ is the weighted normalized impact sound pressure level of the bare floor with the reference floor covering;

$\Delta L_{r,w}$ is the weighted reduction in impact sound pressure level by reference floor covering;

$L_{n,1}$ is the calculated normalized impact sound pressure level of the actual bare floor with the reference floor covering.

Reduction in impact sound pressure level of the reference floor covering

Reference floor covering

The reference floor covering is defined by the values for the reduction of impact sound pressure level (improvement of impact sound insulation), ΔL_r, given in Table.

The weighted reduction in impact sound pressure level of the reference floor covering, $\Delta L_{r,w}$, is 19 [dB].

Frequency Hz	ΔL_r dB
100	0
125	0
160	0
200	2
250	6
315	10
400	14
500	18
630	22
800	26
1 000	30
1 250	30
1 600	30
2 000	30
2 500	30
3 150	30
Index at 500 Hz	**19**

Calculated normalized impact sound pressure level with reference floor covering: $L_{n,1}$

The weighted normalized impact sound pressure level of the bare massive floor, $L_{n,1,w}$, is calculated starting from the spectral distribution of the normalized impact sound pressure level of the bare floor, $L_{n,0}$ (f), which is subtracted from the frequency distribution the defined reduction in impact sound pressure level of the reference floor covering, $\Delta L_r(f)$, :

$$L_{n,1}(f) = L_{n,0}(f) - \Delta L_r(f) \quad \Rightarrow \quad L_{n,1,w}$$

where

$L_{n,0}$ is the normalized impact sound pressure level of the actual bare floor, **measured or theoretically estimated**;

ΔL_r is the defined reduction in impact sound pressure level of the reference floor covering.

Estimation of normalized impact sound pressure level of bare floor, $L_{n,0}$

The normalized impact sound pressure level $L_{n,0}$ of a bare floor, in a the usual frequency range of impact phenomena, can be estimated with theoretical expressions, that consider the physical and elastic characteristics of the floor, or experimental relationships.

Hypothesis:

The duration of application of each force is short with respect to the highest frequency period considered.

The spectrum, for constant percentage bands of radiated noise from the plate, has a substantially flat trend with the frequency.

Experimental correlations:

1) beam and pot floor, total thickness 20< s <30 [cm]

$$L_{n,0}(f) = 30 + 15\log_{10}(f)$$

f frequency [Hz]

Estimation of normalized impact sound pressure level of bare floor, $L_{n,0}$

Normalized impact sound pressure level of “bare” floor

The impact sound pressure level expresses "the acoustic response of a floor."

Given the nature of the impacts, produced by a standardized generator, this response is of the conventional type, that is it does not express realistically the noise that would occur in an environment due to effect, for example, of real steps on the underlying slab.

Being the forcing functions mechanically and dynamically well defined solicitations, formula based on classical continuum mechanic theory can be derived, at least for certain types of structures .

For monolithic reinforced concrete floor slabs, for instance, the behavior due to impacts produced by the tapping machine is studied taking into consideration the physical problem of a plate excited by periodic pulse forces.

Calculated normalized impact sound pressure level for some monolithic structural elements

Octave bands spectral values of $L_{n,0}$ (Source: EN 12354-2)

1) Floor 100 mm of concrete + 20 mm of finish, m’ 268 kg/m^2

63 Hz	125 Hz	250 Hz	500 HZ	1000 Hz	2000 Hz	4000 Hz	$L_{n,w}$ (dB)	C_1 (db)
65	73	78	78	78	78	76	80	(-11)

2) Floor 180 mm of concrete + 50 mm of finish, m’ 509 kg/m^2

63 Hz	125 Hz	250 Hz	500 HZ	1000 Hz	2000 Hz	4000 Hz	$L_{n,w}$ (dB)	C_1 (db)
64	60	65	66	67	68	66	69	(-11)

3) Floor 200 mm di lightweight concrete , m’ 260 kg/m^2

63 Hz	125 Hz	250 Hz	500 HZ	1000 Hz	2000 Hz	4000 Hz	$L_{n,w}$ (dB)	C_1 (db)
65	72	78	77	77	76	70	77	(-9)

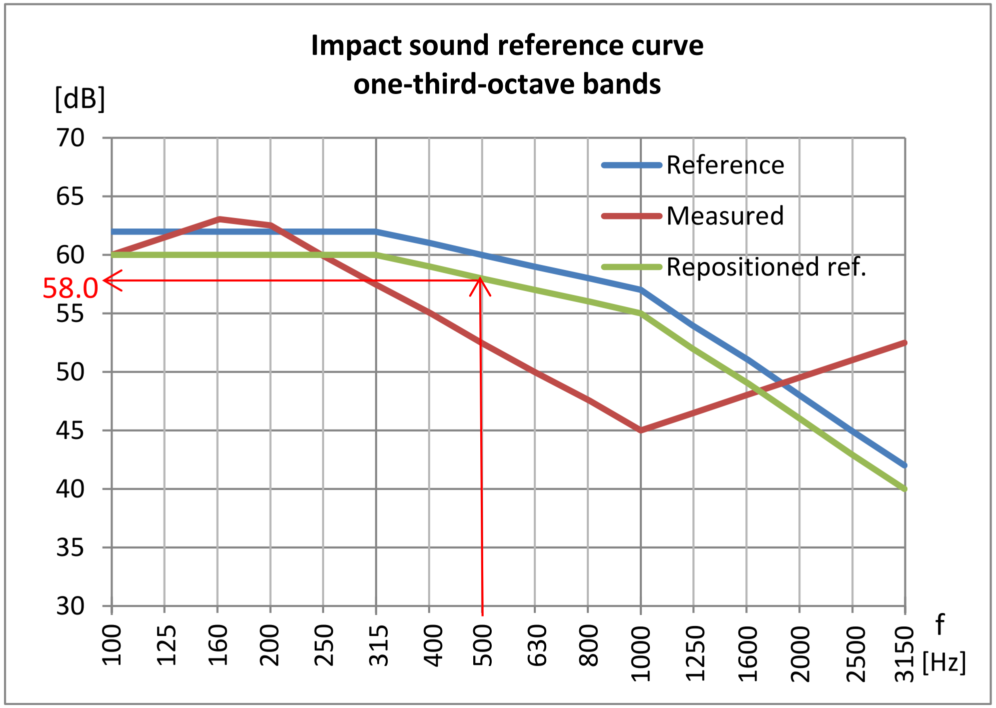
4) Floor 300 mm di lightweight concrete , m’ 390 kg/m^2

63 Hz	125 Hz	250 Hz	500 HZ	1000 Hz	2000 Hz	4000 Hz	$L_{n,w}$ (dB)	C_1 (db)
64	68	70	70	70	70	64	71	(-9)

Calculation example of $L_{n,w,eq}$

Using the correlation for the brick-cement floor of overall thickness 20< s <30 [cm], it gives:

Frequency Hz	$L_{n,0}$ dB	ΔL_r dB	$L_{n,1}$ dB
100	60.0	0	60.0
125	61.5	0	61.5
160	63.1	0	63.1
200	64.5	2	62.5
250	66.0	6	60.0
315	67.5	10	57.5
400	69.0	14	55.0
500	70.5	18	52.5
630	72.0	22	50.0
800	73.5	26	47.5
1 000	75.0	30	45.0
1 250	76.5	30	46.5
1 600	78.1	30	48.1
2 000	79.5	30	49.5
2 500	81.0	30	51.0
3 150	82.5	30	52.5
		$L_{n,1,w}$	**58.0**



$$L_{n,w,eq} = L_{n,1,w} + 19 =$$
$$= 58 + 19 = 77 \quad [\text{dB}]$$

Relationships for **direct estimation** of equivalent weighted normalized impact sound pressure level, $L_{n,w,eq}$, of homogeneous floor constructions

1) reinforced concrete floor, areic mass *m’* 250<m’<500 [kg/m²]

$$L_{n,w,eq} = 183 - 42\log_{10}(m')$$

2) lightweight concrete floor, areic mass *m’* 100<m’<400 [kg/m²]

$$L_{n,w,eq} = 156 - 32\log_{10}(m')$$

3) concrete floor, areic mass *m’* 100<m’<600 [kg/m²]

$$L_{n,w,eq} = 164 - 35\log_{10}(m')$$

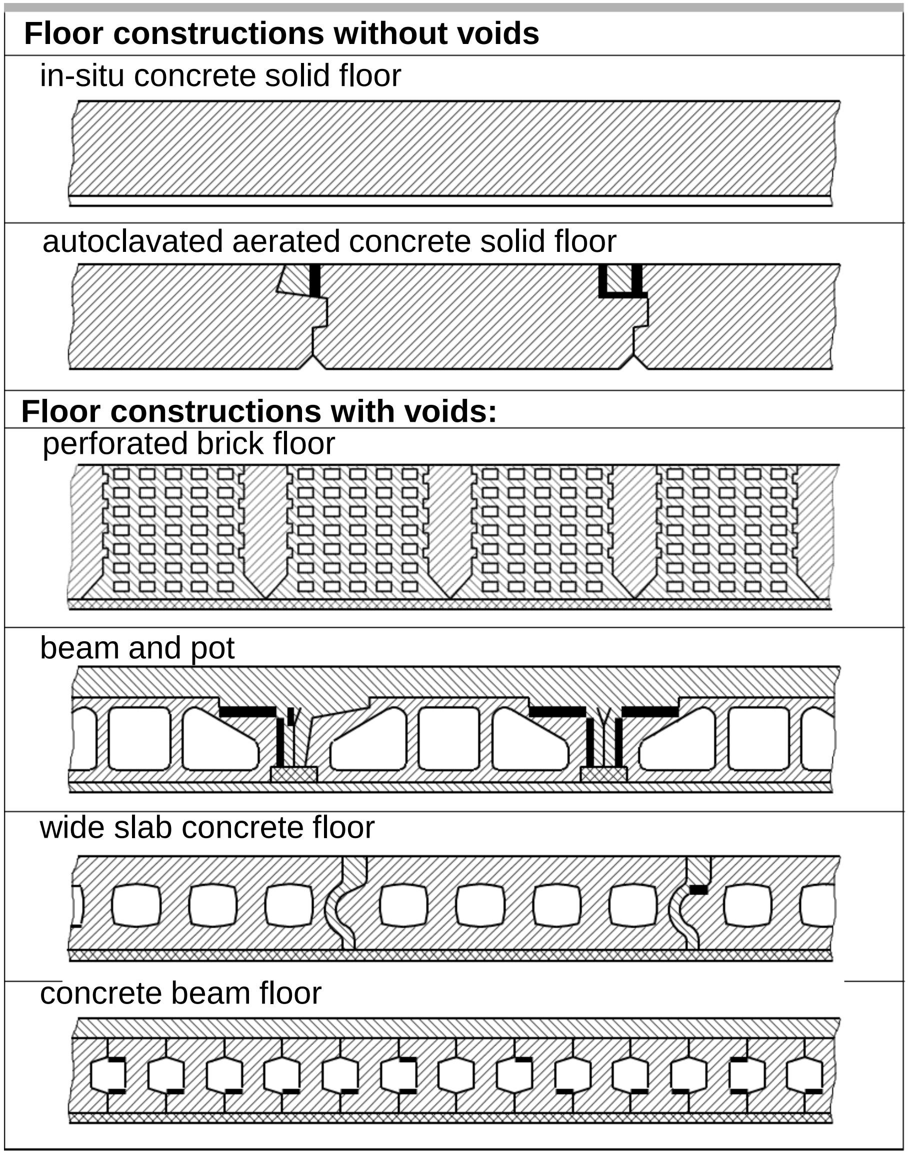
4) reinforced concrete floor, areic mass *m’* 2500 [kg/m²]

$$L_{n,w,eq} = 155 - 30\log_{10}(m')$$

Relationships for direct estimation : relationship 3)

Concrete floor,
areic mass
m' 100<m'<600 [kg/m²]

Source EN 12354-2



Simplified Estimation of Weighted Normalized Impact Sound Pressure Level (EN ISO 717-2) : $L'_{n,w}$

- The index $L_{n,w,eq}$ for a generic floor between two rooms is calculated starting from the normalized impact sound pressure level of its [...]$_0$, to which the reduction in i[...]e reference floor covering, ΔL_r, is added (i.e. subtracted).

$$L'_{n,w} = L_{n,w,eq} - \Delta L_w + K$$

- The weighted reduction of impact sound pressure level ΔL_w is determined applying the reduction in impact sound pressure level of the adopted floor covering, ΔL, to the normalized impact sound pressure level of the reference floor, $L_{n,r,0}$.

- Correction index K for flanking transmission is reported in a table as function of floor areic mass and the mean mass per unit area of the homogeneous flanking elements.

Reduction in impact sound pressure level by floor coverings

Reduction in impact sound pressure level ΔL is due to floor coverings. Their function is determinant.

A load-bearing floor without suitable sound isolation treatment does not provide performances adequate to the values established by law.

For acoustical purposes floor coverings can be classified into two categories.

Floating floors constituted of:

- an insulating material layer laid on the bare floor
- a splitter screed
- a pavement

Resilient flooring which consist in the direct laying on the surface of load-bearing floor of the pavement layer that must have elastic properties

Evaluation of the weighted reduction in impact sound pressure level by floor coverings: ΔL_w

The reduction of impact sound pressure level (improvement of impact sound insulation), ΔL, of floor coverings ΔL_w is calculated, starting from the experimental measurement reduction in impact sound pressure level by floor coverings $\Delta L(f)$, as:

$$L_{n,r}(f) = L_{n,r,0}(f) - \Delta L(f) \qquad \Rightarrow \quad L_{n,r,w}$$

$$\Delta L_w = L_{n,r,0,w} - L_{n,r,w} = 78 - L_{n,r,w}$$

where:

$L_{n,r}$ is the calculated normalized impact sound pressure level of the reference floor with the actual floor covering;

$L_{n,r,0}$ is the defined normalized impact sound pressure level of the reference floor;

ΔL is the reduction in impact sound pressure level measured in accordance with ISO 10140-2;

$L_{n,r,w}$ is the calculated weighted normalized impact sound pressure level of the reference floor with the actual floor covering;

$L_{n,r,0,w}$ is calculated from $L_{n,r,0}$ in accordance with ISO 717-2 curves comparison procedure at 500 Hz and its value is 78 dB.

NOTE: for lightweight reference floors $L_{n,r,0}$ is just replaced by $L_{n,tr,0}$

Normalized impact sound pressure level of the reference floor (EN-ISO 717-2): $L_{n,r,0}$, $L_{n,tr,0}$

bare heavy floors

Frequency Hz	$L_{n,r,0}$ dB
100	67.0
125	67.5
160	68.0
200	68.5
250	69.0
315	69.5
400	70.0
500	70.5
630	71.0
800	71.5
1 000	72.0
1 250	72.0
1 600	72.0
2 000	72.0
2 500	72.0
3 150	72.0
Index 500 Hz	**78.0**

lightweight reference floors

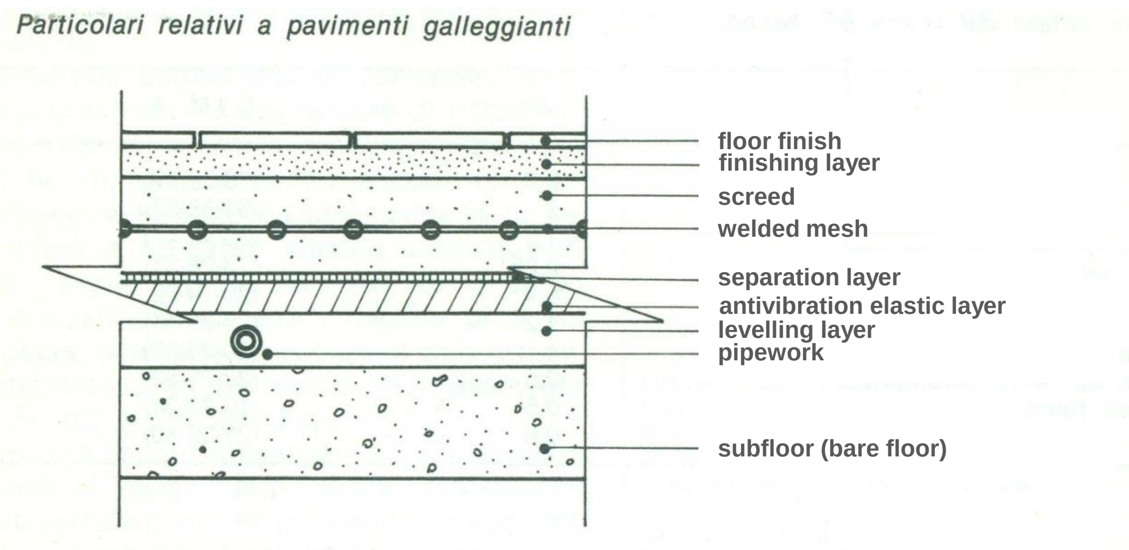
Frequency Hz	$L_{n,t,r,0}$ floor Type 1 , 2 dB	$L_{n,t,r,0}$ floor Type 3 dB
100	78	69
125	78	72
160	78	75
200	78	78
250	78	78
315	78	78
400	76	78
500	74	78
630	72	78
800	69	76
1000	66	74
1250	63	72
1600	60	69
2000	57	66
2500	54	63
3150	51	60
Index 500Hz	**72**	**75**

Estimation of the reduction of impact sound pressure level ΔL

(alternative to the measure in the laboratory in accordance with the EN ISO 10140-3).

According to the classical theory, a system compound of an elastic support loaded by a mass is able to provide a vibration isolation that, starting from the resonance frequency, has a progression of 40 dB per decade.
It is therefore, at a given frequency f greater than f_0, a reduction of impact sound pressure level ΔL equal to

$$\Delta L_n = 40 \log_{10}\left(\frac{f}{f_0}\right)$$



Reduction of impact sound pressure level ΔL: floating floors

The EN 12354-2 standard, if no measured values for the reduction of impact sound pressure level *ΔL* of floating floors are available, suggests to apply the following formulae:

$$\Delta L_n = 30\log_{10}\left(\frac{f}{f_0}\right)$$

for floating floor screeds made of sand/cement or calcium sulphate

f centre frequency of the octave band or third octave band [Hz]

f_0 system resonance frequency [Hz]

$$f_0 = 160\sqrt{\frac{s'}{m'}}$$

s' dynamic stiffness of resilient layer [MN/m^2]

m' mass per unit area of the floating floor [kg/m^2]

$$\Delta L_n = 40\log_{10}\left(\frac{f}{f_0}\right)$$

for asphalt floating floors or dry floating floor constructions

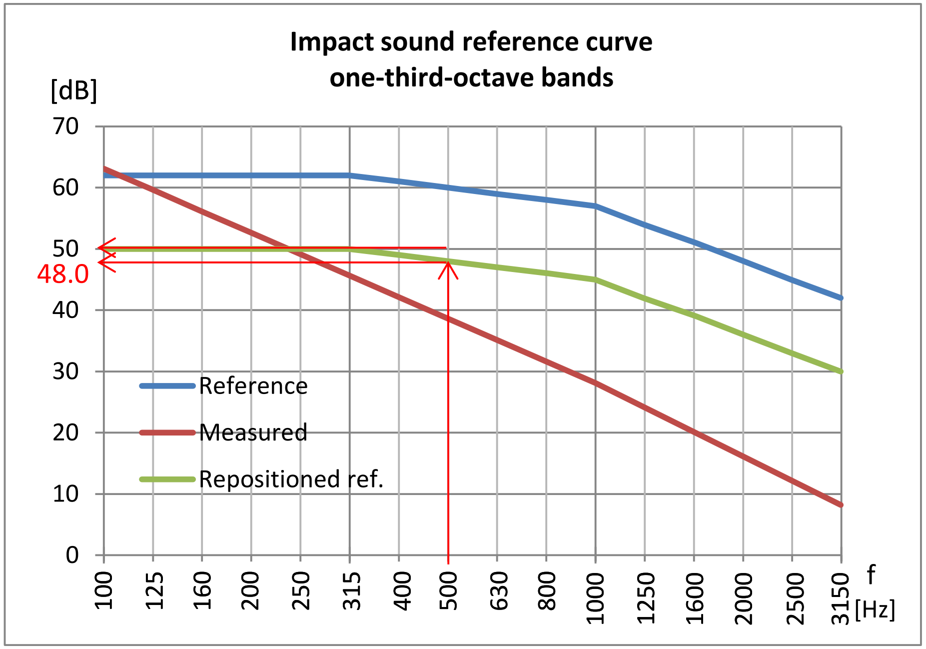
Example of ΔL_w calculation

Using the correlation for dry floors, it results for:

s' = 10 MN/m^3 m' = 40 kg/m^2

$$f_0 = 160\sqrt{\frac{s'}{m'}} = 80 \quad [\mathrm{Hz}]$$

Frequency Hz	$L_{n,r,0}$ dB	ΔL_n dB	$L_{n,r}$ dB
100	67.0	3.9	63.1
125	67.5	7.8	59.7
160	68.0	12.0	56.0
200	68.5	15.9	52.6
250	69.0	19.8	49.2
315	69.5	23.8	45.7
400	70.0	28.0	42.0
500	70.5	31.8	38.7
630	71.0	35.9	35.1
800	71.5	40.0	31.5
1 000	72.0	43.9	28.1
1 250	72.0	47.8	24.2
1 600	72.0	52.0	20.0
2 000	72.0	55.9	16.1
2 500	72.0	59.8	12.2
3 150	72.0	63.8	8.2
		$L_{n,r,w}$	**48.1**

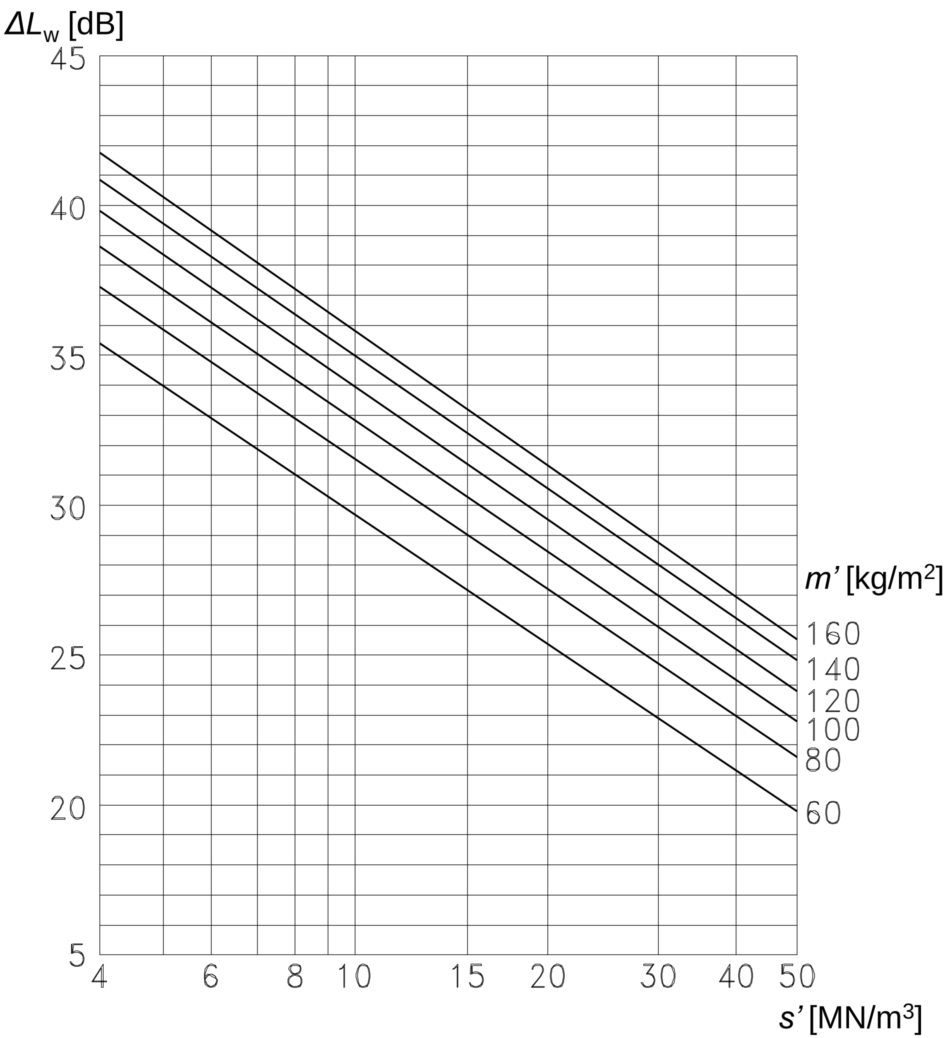


$$\Delta L_w = 78 - L_{n,r,w} =$$

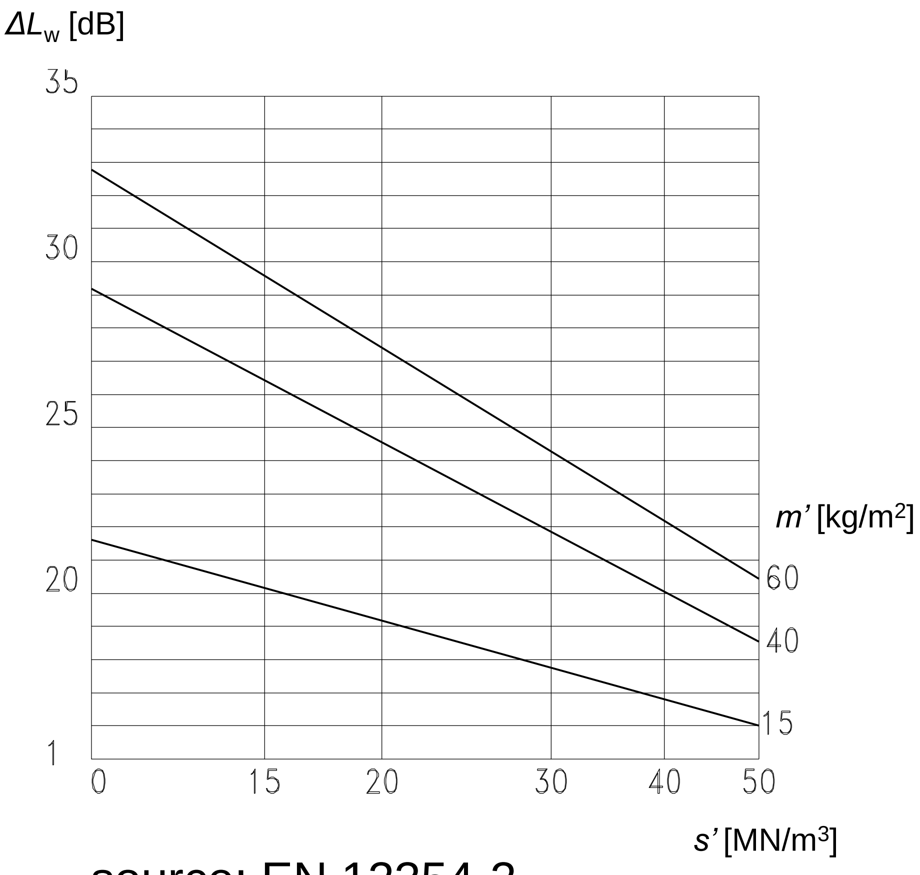
$$= 78 - 48.1 = 29.9 \ \mathrm{dB}$$

Weighted reduction of impact sound pressure level ΔL_w of floating floors as function of dynamic stiffness per unit area *s*'

floating floor screeds made of sand/cement or calcium sulphate



asphalt floating floors or dry floating floor constructions



source: EN 12354-2

Dynamic Stiffness per unit area *s*'

EN 12354-2 standard :

> “*Building acoustics - Estimation of acoustic performance of buildings from the performance of elements - Part 2: Impact sound insulation between rooms*”

REQUIRES

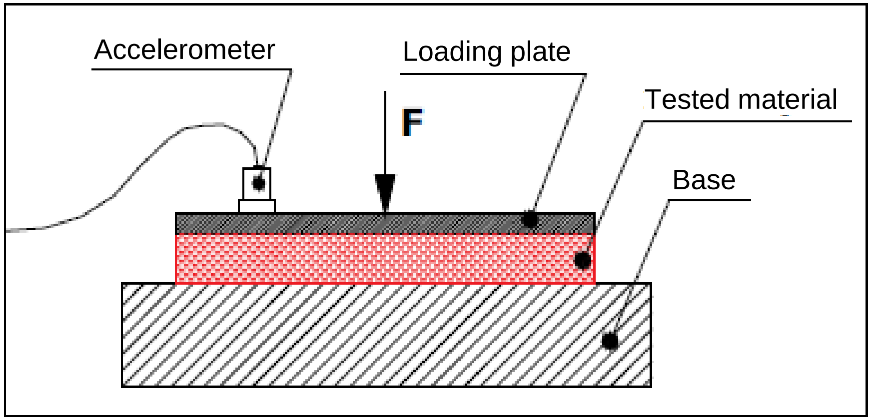
the determination of the dynamic stiffness as a requirement of resilient material placed in the floating floor for an estimate calculation of acoustic performance of a floor about impact noise isolation.

Dynamic Stiffness

Dynamic Stiffness per unit area ***s'*** [MN/m^3] is defined as the ratio of the peak-to-peak force and the peak-to-peak displacement

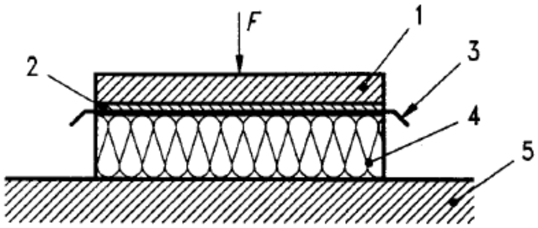
RESILIENT MATERIALS

The dynamic stiffness is determined using the methods of the standard **EN 29052-1** "*Acoustic. Determination of dynamic stiffness -- Part 1: Materials used under floating floors in dwellings*.".



Resonance frequency

Preparing a sample of size 200 x 200 mm and measuring the system resonance frequency $\boldsymbol{f_r}$ (using an accelerometer), it is possible to determine the apparent dynamic stiffness of the specimen under test (apparent because It does not take account of the lateral resistance to air flow which escapes in the test).



The stiffness is determined by measuring the resonance frequency that is given by the following formula

$$f_r = \frac{1}{2\pi}\sqrt{\frac{s_t}{m_t'}} \cong 160\sqrt{\frac{s_t'}{m_t'}}$$

with

s_t areic apparent dynamic stiffness of the specimen [N/m³]

s'_t areic apparent dynamic stiffness of the specimen [MN/m³]

m'_t mass per unit area during the test [kg/m²]

Dynamic Stiffness

The resilient material interposed between the sub-floor (i.e. the bearing structure and its finish layer) and the screed, must be able to damp the vibrations due to impacts on the pavement of the walkway of people, bumps and displacements in general, thus avoiding the propagation of vibrations the other structures of the living spaces.

More a material is stiffer, the dynamic stiffness is high, conversely very elastic materials have a limited dynamic stiffness.

In the choice of the resilient material should be avoided both materials with high dynamic rigidity (too stiff and therefore not able to reduce the transmission of vibrations) that too low (inability to reduce the transmission of vibrations due to the crushing effect: "packing") .

Dynamic Stiffness

Most data sheets do not report the value of dynamic stiffness ***s'*** but that of the apparent dynamic stiffness $\boldsymbol{s_t'}$

The relationship between the two physical quantities is as follows:

$$s' = s_t' + s_a'$$

where

$\boldsymbol{s_a'}$ is the dynamic stiffness per unit area of the gas contained within the material, which depends on the atmospheric pressure, the thickness and the porosity of the material.

$\boldsymbol{s_t'}$ is the apparent dynamic stiffness per unit area (usually cited in the data sheets) is measured in the laboratory

Dynamic Stiffness

If, however, the material is neither porous or fibrous and offers much resistance to the air passage, that is, has a resistance to air flow (r) high and greater than 100 kPa/m^2, the relationship between the dynamic stiffness and the apparent dynamic stiffness becomes

$$s' = s_t'$$

That is, the two dynamic stiffness coincide and the dynamic stiffness of the gas is considered non-existent.

If instead the resistance to air flow is between 10 kPa/m^2 and 100 kPa/m^2, the dynamic stiffness of the gas back to having a significant role within the relationship

$$s' = s_t' + s_a'$$

Dynamic Stiffness of Gases

The dynamic stiffness, per unit area, the gas is defined as

$$s_a' = p_0/(d \cdot \varepsilon)$$

p_0	atmospheric pressure
d	specimen thickness under load
ε	porosity of the specimen

If the atmospheric pressure is of 0,1 MPa and with porosity equal to 0,9, the dynamic stiffness of gas, pursuant to the standard EN 29052, is determined as:

$$s_a'=111 / d$$ with *d* in millimetres.

Dynamic Stiffness of Gases

The value of dynamic stiffness of the gas may also be greater than the apparent dynamic stiffness . For example a fibrous material with 5 mm thickness, and the apparent dynamic stiffness $s_t' = 15\ MN/m^3$, has a dynamic stiffness of the gas of:

$$s_a' = 111/d = 111/5 = 22\ MN/m^3$$

and thus dynamic stiffness becomes:

$$s' = s_t' + s_a' = 15 + 22 = 37\ MN/m^3$$

The data sheets of the material reports just $s_t' = 15\ MN/m^3$, but the dynamic stiffness to be considered for the calculations is equal to $s' = 37\ MN/m^3$, so completely different.

Dynamic Stiffness

it is therefore important to critically verify what is reported in the data sheets of resilient materials to be used under the screed.

Obviously for materials with strong resistance to air passage the situation is different.

In composite materials such as those compound of polyethylene and aluminium layers, the resistance to air flow is higher than the100 kPa/m^2 and thus:

$$s' = s_t'$$

making the dynamic stiffness coincident with the apparent dynamic stiffness .

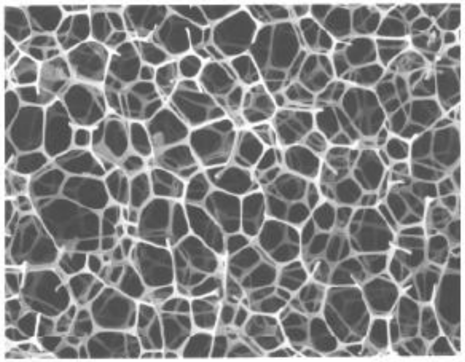
Elastomers

Material	Mass Density Kg/m³	Prevailing use sectors
Foamed elastomers aggregates	120-240	Industry, transportation, appliances

They have limited porosity (~0.8) and can achieve high air flow resistivity and good acoustic performance at medium frequencies

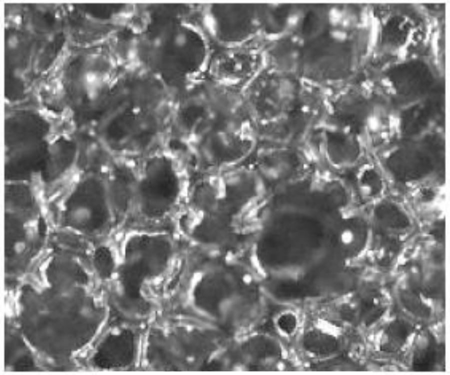
Porous materials

Material	Mass Density Kg/m^3	Prevailing use sectors
polyurethane foams with open cells	20-50	Industry, transportation
melamine resin	10	Building, industry, transportation
Polyethylene foam	10-20	Building, industry



Melamine

Quash®



Polyurethane

Example

Data sheet	
Product name	eco-rubber NG
Composition	agglomeration of EPDM rubber granules bound with polyurethane resins
Colour	Mixing of different colours on black base
Dimensions	slabs of maximum size 2,000 x 1,000 (+/- 1%)
Thickness	standard 4 to 10 mm (+/- 0.5 mm). Larger thicknesses on request
Mass density	750 kg/m^3 (+/- 3%)
Dynamic stiffness	apparent : 65 MN/m^3 according to EN 29052-1 1993 real : 68 MN/m^3 after air flow resistivity correction Test carried out on 5 mm specimen, at acoustic lab of “Istituto Giordano di Bellaria” (RN) on 2005/08/02
Characteristics	walked on without damage prior to casting screed non-deformable over time excellent mechanical resistance allows the use of low thickness ensuring high performance

Dynamic Stiffness: constancy over the time

Durability assessment of dynamic stiffness of the materials under working conditions

The dynamic stiffness by its own is not able to provide information on its value under load during the building lifetime.
DPCM 5/12/97 does not set time limits to the satisfaction of passive acoustic requirements of a building, so it is proper to make evaluations already in the design stage on the maintenance of the floor acoustic performance over time.

Information to that effect is given in **EN 1606** ” Thermal insulating products for building applications. Determination of compressive creep ” and **EN 12431** “Thermal insulating products for building applications. Determination of thickness for floating floor insulating products ” standard.
The former standard defines the **compressibility ratio (C)** between the thickness of the unloaded material and thickness of the material at the end of the loading test.
This value is useful for a quick estimate of the dynamic stiffness after 10 years:

$$s'_{10\ years} = s'/C$$

Dynamic Stiffness: constancy over the time

$s'_{10\ years} = s'/C$

Some examples to better understand the importance of this evaluation:

a) Material with effective dynamic stiffness s'=32,2 MN/m^3 and compressibility ratio C=0,9

$$s'_{10\ years} = s'/C = 32{,}2/0{,}9 = 33{,}94\ MN/m^3$$

b) Material with effective dynamic stiffness s'=32,2 MN/m^3 and compressibility ratio C=0,67

$$s'_{10\ years} = s'/C = 32{,}2/0{,}67 = 48{,}06\ MN/m^3$$

In the latter case, the degradation of the dynamic stiffness change much the value of the sound insulation of the floor compromising compliance with the requirements of the law.

Floating Floor Installation

In order to achieve effective noise reduction to impacts it is crucial to take appropriate actions when installing, such as:

- levelling the screed on which will lay the elastic material and lay the resilient pad so that no discontinuities exist;

- superficially protect the resilient mat (for example with a polyethylene sheet) in order to avoid that, during the casting the screed, any infiltration of fresh concrete can come into contact with the levelling layer, or use a mat already protected with protective sheet waterproof;

- separate the screed from the upper side structures, also along the perimeter of the room, laying a vertical strip of resilient material suitably connected to the horizontal mattress (e.g. with self-adhesive strips of various heights).