# Soundproofing for CLT by Stora Enso

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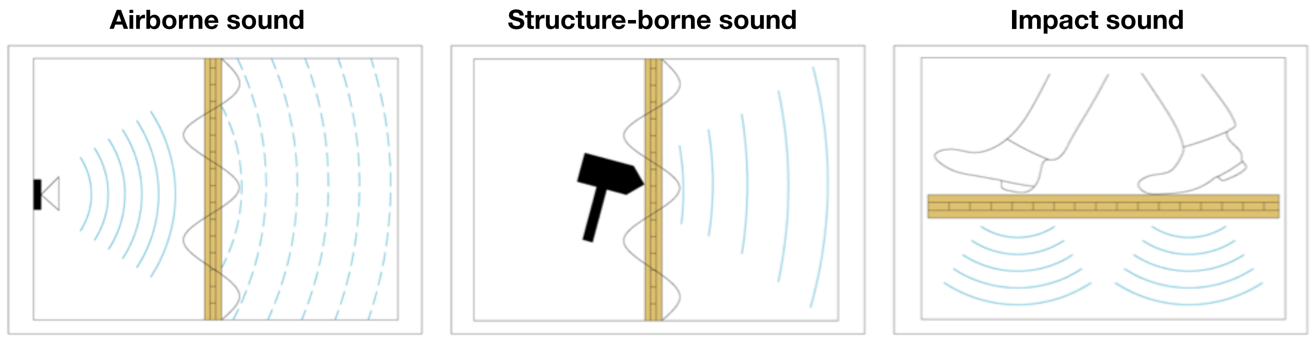
## Contents

# 1. Introduction

Providing adequate protection from noise disturbance is an important factor for ensuring a sense of well-being in buildings. Therefore, sound insulation should be a top priority during the building planning stage.
Sound is defined as mechanical kinetic energy which is transmitted through elastic media by pressure and density fluctuations. Thus, sound is the audible vibration of gases, fluids and solids. After identifying the source of noise to which a component is exposed, acoustic design distinguishes between airborne and structure-borne sound.

- **Airborne sound –** air sound waves cause components to vibrate, and these vibrations are transmitted to adjacent rooms in the building. Sources of airborne sound include traffic, voices or music.
- **Structure-borne sound –** the sound of walking, banging, scraping furniture, etc. is transmitted to components and radiated as airborne sound into adjacent rooms. **Impact sound** is particularly relevant to acoustic design.

Normative sound insulation requirements ensure that persons with normal sensitivities are provided with sufficient protection against noise from outside the building, from other parts of the same building and from adjacent buildings. The role of acoustic design is to reduce disturbing noise in the building to a defined degree.



# 2. Determining the performance of sound insulation

### 2.1 Measuring sound insulation

To determine the sound insulation performance of a building component, a source room is exposed to a source of noise (in a test facility or a building). The incoming sound is then measured in a receiving room.
With airborne sound measurements, the source of noise is a loudspeaker and the sound reduction index R of a component results from the level difference between the source room and the receiving room (the higher the value, the better the sound insulation).
With impact sound measurements, on the other hand, the source of noise is a standard tapping machine and the impact sound pressure level L measured in the receiving room expresses the performance of the structure's soundproofing (the lower the level, the better the soundproofing).
In principle, the extended frequency range (50 Hz to 5000 Hz) is measured, however only the range between 100 Hz and 3150 Hz (acoustic design area) is taken into account to calculate the single-number value. This range is divided into five octave bands (frequency doubling) or into 16 one-third-octave bands (three thirds make up one octave).

### 2.2 Sound insulation parameters

The parameters used to express sound insulation are listed in the individual parts of the ISO 140 series of standards (which are gradually being replaced by ISO 10140 and ISO 16283), and the procedures for rating single-number values are described in standards ISO 717-1 and 717-2:

2.2.1 Airborne sound parameters:

- **Sound reduction index R**

  $$R = 10\log\frac{\mathrm{W1}}{W2}$$

  Ten times the common logarithm of the ratio of the sound power $W_1$ on a test specimen to the sound power $W_2$, transmitted through the specimen.

  If sound pressure is measured, the sound reduction index is calculated as follows:

  $$R' = \mathrm{L1} - \mathrm{L2} + 10\log\frac{\mathrm{S}}{A}$$

- **Apparent sound reduction index R'**
  A prime [′ ] shows that a value measured inside the building including sound transmission through flanking components is involved.

- **Normalised sound level difference $D_n$**
  $D_n = \mathrm{L}_S - \mathrm{L}_E - 10\log\frac{\mathrm{A}}{A_0}$ corresponding to the reference absorption area of 10 m².

- **Standardised sound level difference $D_{nT}$**
  $D_{nT} = \mathrm{L}_S - \mathrm{L}_E + 10\log\frac{\mathrm{T}}{T_0}$ corresponding to the reference value of the reverberation time of 0.5 s.

- **Standard sound level differences have the following relationship with the structural elements sound reduction index:**

  $$D_n = \mathrm{R}' + 10\ \mathrm{lg}\ \frac{10}{S}$$

  $$D_{nT} = \mathrm{R}' + 10\ \mathrm{lg}\ \frac{0{,}32\ \mathrm{V}}{S}$$

2.2.2 Impact sound parameters:

- **Normalised impact sound pressure level $L_n$**

  $L_n = L + 10\log\frac{A}{A_0}$ corresponding to the reference absorption area of 10 m².

  Similarly to the sound reduction index, the normalised impact sound pressure level can also be entered as a building site value ($L'_{n,w}$).

- **Standardised impact sound pressure level $L'_{n,T}$**

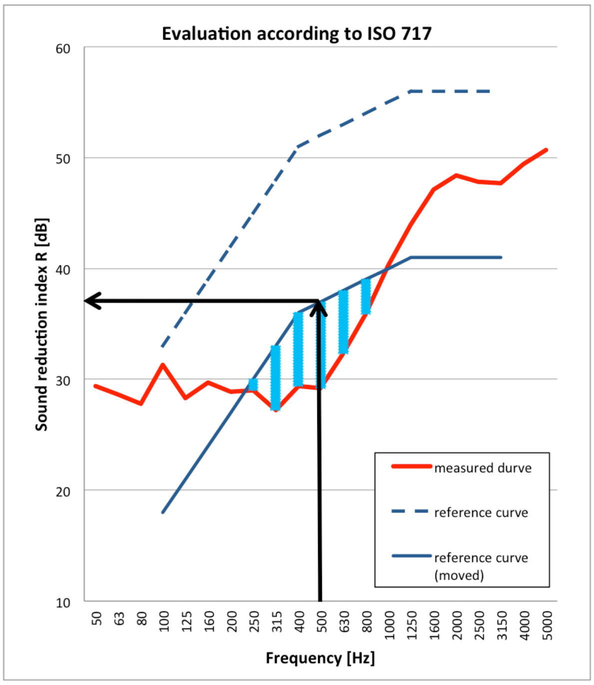
  $L_{nT} = L - 10\log\frac{T}{T_0}$ corresponding to a reference value of the reverberation time of 0.5 s.

- **The standardised and normalised impact sound pressure levels have the following relationship:**

  $L_{nT} = L_n - 10\log 0{,}032 * V$

### 2.3 Rating measured curves

As noise levels are mostly measured in third-octave bands, measured curves are used to rate single-number values in order to improve the comparison of data. These weighted curves are derived from the “curves of equal volume” (the human ear does not perceive low- and high-frequency sounds as equally loud) and thus take into account the human ear’s frequency-based perception of sound levels. When performing this evaluation in accordance with EN ISO 717 (part 1 for airborne sound and part 2 for impact sound), the reference curve is moved towards the measured curve until the sum of the unfavourable deviations is as large as possible, however not more than 32 dB (on average no more than 2 dB per one-third octave band). Favourable deviations are not taken into account. The single-number value is now the reference curve value at 500 Hz.




The additional “w”, which stands for “weighted” (e.g. $R_w$ or $D_{nT,w}$), indicates that this single-number rating is evaluated according to EN ISO 717-1.

| Single-number values from EN ISO 717: 2013 | | | |
|---|---|---|---|
| | airborne sound | impact sound | |
| Soundproofing of components | $R_w$ | $L_{n,w}$ | Shows the test bench situation.<br>Sound transmission through the partition assembly only. |
| Soundproofing between rooms | $R'_w$<br>$D_{n,w}$<br>$D_{nT,w}$ | $L'_{n,w}$<br>$L'_{nT,w}$ | Shows the building site situation.<br>Sound transmission through the separating component and flanking components. |
| Spectrum adaptation values | $C$<br>$C_{tr}$ | $C_I$ | **spectrum C**: residential noise<br>**spectrum $C_{tr}$**: traffic noise<br>**spectrum $C_I$**: impact sound |

## 2.4 Spectrum adaptation values

Calculating single-number values does not always give a sufficiently clear picture of the acoustic strengths and weaknesses of building components (different curve progressions can result in identical single-number values [see illustration]) and residential or traffic noise is not sufficiently taken into account. For this reason, spectrum adaptation values have been included in EN ISO 717:1996 to complement the single-number ratings, and are already being used in certain European countries. This complementary information enables greater account to be taken of special sound spectra:

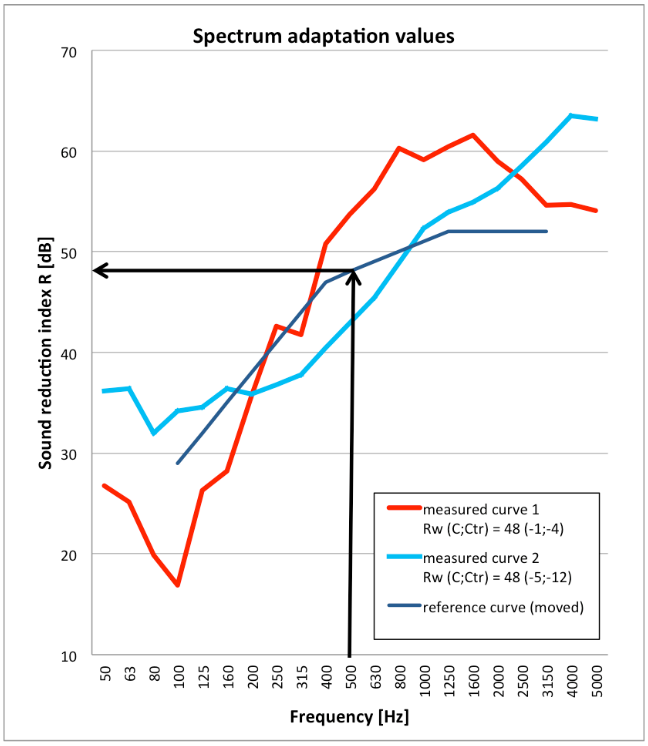
**Airborne sound:**

- $C$ for normal residential noise
- $C_{tr}$ for traffic noise

**Impact sound:**

- $C_I$ for walking noise

Spectrum adaptation values can also be identified for special frequency ranges of less than 100 Hz or more than 3150 Hz (e.g. $C_{50\text{–}5000}$ or $C_{tr,\ 50\text{–}3150}$ ).




## 2.5 Parameters and requirements in European countries

The appropriate standards use various different expressions to specify sound insulation performance. This means that in 35 European countries, seven different parameters to specify airborne sound insulation and five different parameters to specify impact sound insulation are currently used. Eight countries have introduced spectrum adaptation values with one country introducing spectrum adaptation values from 50 Hz. The difference between the minimum requirements for residential buildings is 10 dB for airborne sound and 20 dB for impact sound. Scotland and Austria have the strictest requirements and five countries currently have no standard soundproofing requirements at all. [1]

The COST Action TU0901 “Integrating and Harmonising Sound Insulation Aspects in Sustainable Urban Housing Constructions” is concerned with harmonising the different rating systems of individual European countries and introducing harmonised quality categories to describe sound insulation. A comparison of the minimum requirements for airborne and impact sound for residential buildings and terraced houses in 35 European countries was published in [1] and can be found in the form of a table in the annex. Detailed requirements and special regulations can be found in the respectively valid national standards and building regulations.

# 3. Sound insulation for components

## 3.1 Single-layer components

3.1.1 Berger's mass law

The sound insulation of single-layer solid components is primarily determined by the mass of the components. "Acoustic single-layer" components are those that have points of mass that do not change in relation to each other when the component vibrates (they vibrate as a whole unit). The sound reduction index of such structures can be approximately calculated using Berger's mass law:

$$R = 20\lg\frac{f * m'}{130}\ [dB]$$

which dictates that sound insulation depends on surface-based mass $m'$ and frequency f. Doubling the mass increases sound insulation by 6 dB. High-pitched sounds are attenuated more effectively than low-pitched sounds, therefore, a noise which penetrates a component will sound duller than the source of noise itself.

3.1.2 Coincidence effect

Sound insulation is impaired where there are resonant frequencies and coincidence effects, thus upsetting the prediction of Berger's mass law. Noise emissions increase in the frequency range in which the wavelength of the vibrating panels coincides with the trace wavelength of the sound wave causing them to vibrate (they vibrate coincidently), thus leading to an impairment in the sound insulation. The lowest frequency in which this effect can occur is known as the "coincidence critical frequency" and can be calculated using the following simplified equation [2].

$$f_g = \frac{60}{d} * \sqrt{\frac{\rho}{E_{dyn}}}\ [Hz]$$

This effect leads to greater sound radiation by the component and thus to an impairment of the sound insulation in the corresponding frequency range. Components with a critical frequency that is either far below or far above the acoustic design frequency range exhibit good soundproofing qualities. Components with a low coincidence critical frequency are referred to as "rigid" whereas thin cladding (plasterboard or gypsum fibreboard) with a high critical frequency is known as "flexible". The fact that the coincidence frequency of CLT with the usual thicknesses lies in the acoustic design range (at approx. 250 Hz to 500 Hz) should be taken into account when planning structures.

## 3.2 Multi-layer components

The sound insulation behaviour of multi-layer components can be described as a mass-spring system. The mass of the layers and the dynamic stiffness of the intermediate layer determine the position of the resonance frequency which determines the quality of the sound insulation.
If the resonance frequency $f_0$ is sufficiently low (< 100 Hz), with this type of component, greater sound insulation can be achieved with significantly less mass. The resonance frequency $f_0$ of two masses with a flexible intermediate layer can be calculated according to [ÖNorm B 8115-4] as follows:

$$f_0 = 160 * \sqrt{s'\left(\frac{1}{m'_1} + \frac{1}{m'_2}\right)}\ [Hz]$$

$f_0$ ………….. resonance frequency in Hz
$m'_1$, $m'_2$ …… surface-based mass of layers in kg/m²
$s'$ ………….. dynamic stiffness of intermediate layer (insulation material or air) in MN/m³

The dynamic stiffness s′ of a layer of air is calculated thus:

$$s' = \frac{0{,}14}{d} \quad [MN/m^3]$$

The dynamic stiffness s′ of a sound-absorbing filler is calculated from:

$$s' = \frac{0{,}111}{d} \quad [MN/m^3]$$

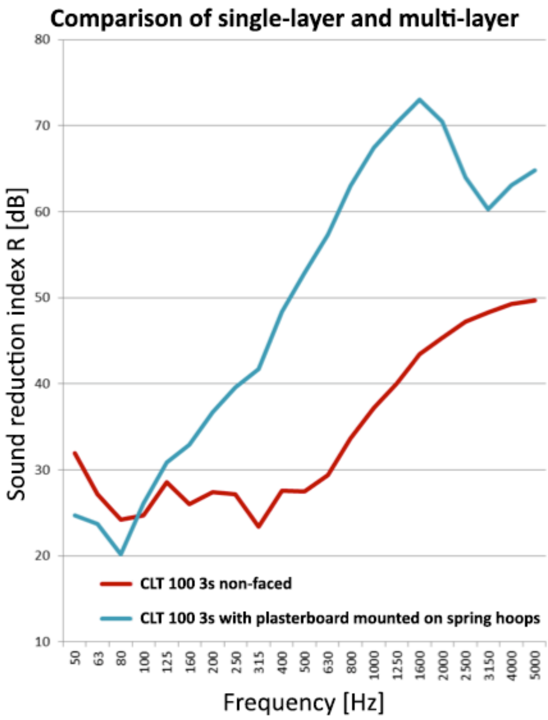
d … distance between layers in metres

**Curve 1: $R_w$ = 34 dB**
CLT 100 3s (as a non-faced component)

Single-layer structure with coincidence critical frequency $f_g$ of the CLT panel at approx. 315 Hz, then increase in sound insulation by approx. 6 dB per octave. The curve progression in the low frequency range is influenced by the panel's natural vibrations due to the geometry.

**Curve 2: $R_w$ = 51 dB**
CLT 100 3s with plasterboard mounted on spring hoops

Double-layer structure with resonance frequency $f_0$ at 80 Hz, then increase in sound insulation by approx. 18 dB per octave, and coincidence critical frequency of the 12.5 mm-thick plasterboard at approx. 2,800 Hz. Due to the mechanically-isolated facing panel, the coincidence frequency of the CLT panel at 315 Hz only has little influence. Cavity resonance can be reduced by filling with mineral wool.



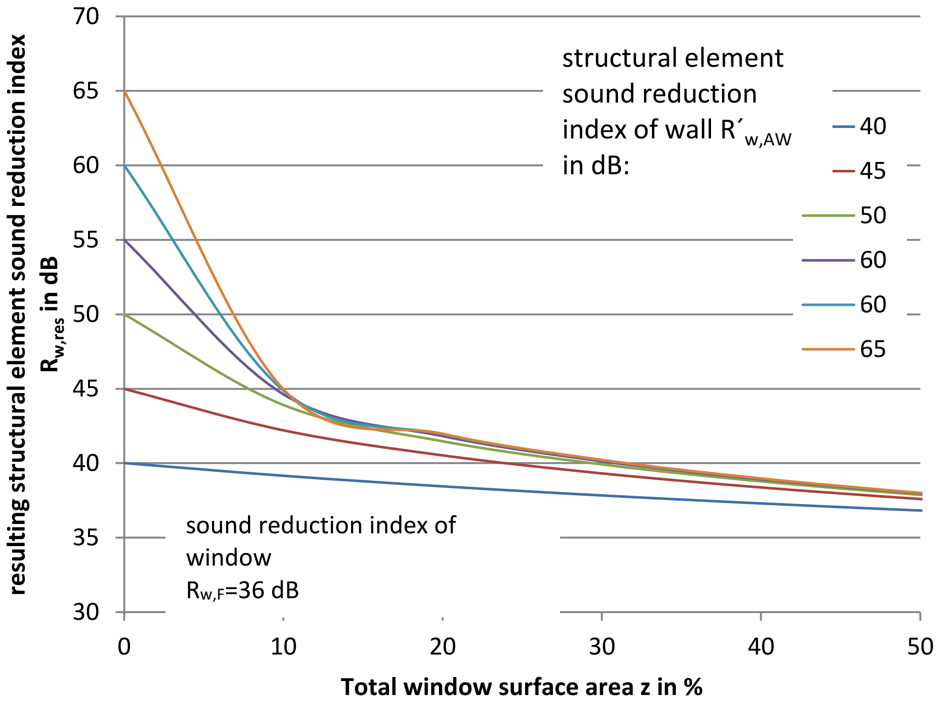

### 3.3 Soundproofing of composite components

When a window or door is installed in an external wall, the weighted resulting apparent sound reduction index $R'_{res,w}$ describes the sound insulation of this component.
To determine the performance of the overall soundproofing, the sound reduction index of the individual component surface areas (window, door, wall) and the respective surface area must be taken into account.

The required evaluated sound reduction index of a window $R_{w,F,\mathrm{erf}}$ is calculated thus:

$$R_{w,F,\mathrm{erf}} = R'_{w,AW} - 10 * \log\left[1 + \frac{S_g}{S_F} * \left(10^{\frac{R'_{w,AW} - R'_{res,w}}{10}} - 1\right)\right]$$

where the weighted apparent sound reduction index of the external wall is ($R'_{w,AW}$), the required resulting apparent sound reduction index is ($R'_{res,w}$) and the total surface area of the wall is ($S_g$) and of the window is ($S_F$).




The diagram shows the $R'_{res,w}$ depending on the window surface area when installing a window with $R_{w,F}$ = 36 dB.

## 4. Sound insulation of CLT components

Noise levels were taken from laboratory and construction site measurements. Details about the construction of connection nodes are available on request.

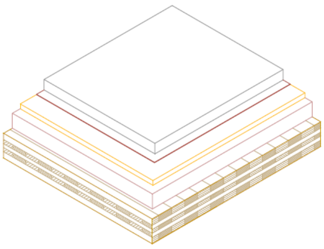
Noise levels of various wall, ceiling and roof structures can be found in the building physics section of the Stora Enso technical folder which can be downloaded from www.clt.info.
Dataholz's publicly accessible component database (www.dataholz.at) and Lignum's component catalogue (http://bauteilkatalog.lignum.ch/) also contain a wide range of tested structures.

### 4.1 Ceiling structures

The sound insulation of ceiling structures can be improved either by increasing the mass or by improving the mechanical isolation of components. Adding mass by ballasting a non-faced ceiling or suspended ceiling reduces vibrations, causing less noise emissions. Above their resonance frequency, the transmission of component vibrations within the structure is reduced. Therefore, the resonance should be as low in frequency as possible (< 80 Hz).
In practice, this means installing relatively heavy screed (5–7 cm cement screed; note: the edge insulation strip is not cropped until the flooring has been laid) on a soft impact sound insulation board (s' ≤ 10) with backfill or bulk to provide additional mass underneath. In the case of non-suspended ceilings, the thickness of the bulk must be increased to approx. 10 cm and, due to its high sound attenuation capacity, the bulk should preferably be un-bonded. The use of loose filling or extremely soft impact sound insulation board should be discussed with the screed floor layer in advance.

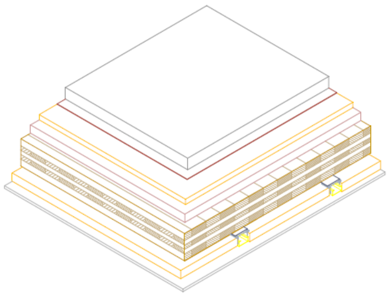
As an alternative to loose filling, elastically-bound filling can be staggered with a latex binder and thus retain its attenuating effect. In terms of sound insulation, ceiling linings are most effective when mechanically isolated (mounted on spring clips or hoops). Cavities should be insulated with mineral wool to prevent cavity resonance. [2]

4.1.1 Examples for ceiling structures:



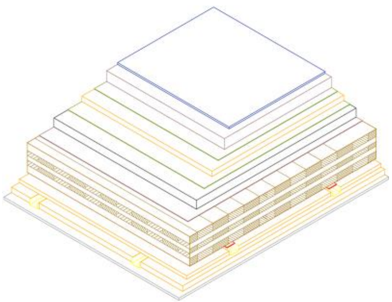
| | |
|---|---|
| 70 mm | cement screed (2200 kg/m³) |
| 0.2 mm | PE membrane |
| 30 mm | soft impact sound insulation (s' < 10 MN/m³) |
| 100 mm | backfill (elastically bound) |
| 140 mm | **Stora Enso CLT** |

**$R_w$ (C;$C_{tr}$) = 63 (–2;–5) dB**
**$L_{n,w}$($C_I$) = 43 (–3) dB**



| | |
|---|---|
| 70 mm | cement screed (2200 kg/m³) |
| 0.2 mm | PE membrane |
| 30 mm | soft impact sound insulation (s' < 10 MN/m³) |
| 50 mm | backfill (loose) |
| 140 mm | **Stora Enso CLT** |
| 70 mm | suspension; 60 mm mineral wool intermediate layer |
| 15 mm | plasterboard |

**$R_w$ (C;$C_{tr}$) = 63 (–2;–6) dB**
**$L_{n,w}$($C_I$) = 46 (1) dB**



| | |
|---|---|
| 10 mm | carpet |
| 60 mm | cement screed |
| 0.2 mm | PE membrane |
| 30 mm | soft impact sound insulation |
| 50 mm | backfill |
| 0.2 mm | trickling protection |
| 165 mm | **Stora Enso CLT** |
| 70 mm | suspension; 50 mm mineral wool intermediate layer |
| 12.5 mm | plasterboard |

**$D_{nT,w}$ (C;$C_{tr}$): 62 (–3;–9) dB**
**$L'_{nT,w}$ ($C_I$): 39 (7) dB**

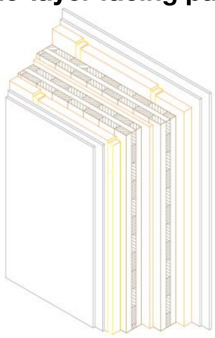
### 4.2 Wall structures

While the soundproofing of single-layer components is determined by their surface-based mass and flexural rigidity, where multi-layer panels are concerned, greater soundproofing can be achieved with less mass. To achieve good sound insulation, the resonance of the facing panels must be as low in frequency as possible (≤ 100 Hz). Resonance frequency can be reduced by increasing the gaps between the layers, increasing the mass of the individual layers and ensuring that facing panels are attached as flexibly as possible to the load-bearing wall. To avoid cavity resonance, the facing panels should be filled with fibrous sound-absorbing insulation material.

#### 4.2.1 Examples for partition structures

Details about the construction of connection nodes are available on request.

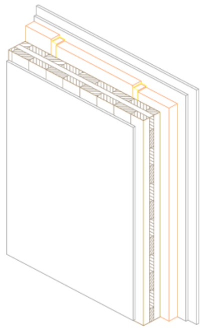
**Double-layer facing panel**



| | |
|---|---|
| 12.5 mm | plasterboard |
| 12.5 mm | plasterboard |
| 50 mm | separate facing panel including 50 mm mineral wool |
| 100 mm | **Stora Enso CLT** |
| 40 mm | mineral wool |
| 100 mm | **Stora Enso CLT** |
| 50 mm | separate facing panel including 50 mm mineral wool |
| 12.5 mm | plasterboard |
| 12.5 mm | plasterboard |

**$D_{nT,w}$ ($C;C_{tr}$): 67 (–1;–4) dB**

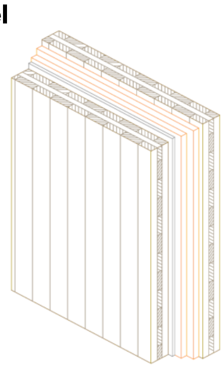
**Single-layer facing panel**



| | |
|---|---|
| 12.5 mm | plasterboard |
| 100 mm | **Stora Enso CLT** |
| 5 mm | glazing gasket |
| 50 mm | separate facing panel CW-profile including 50 mm mineral wool |
| 12.5 mm | plasterboard |
| 12.5 mm | plasterboard |

**$R'_w$ ($C;C_{tr}$): 59 (–2;–8) dB**

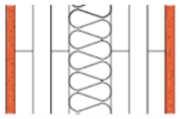
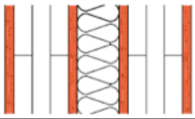
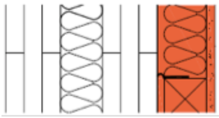
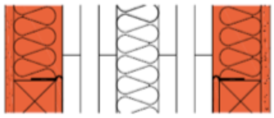
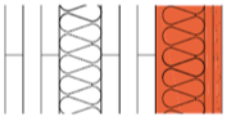
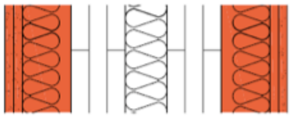
**Double-layer visible CLT panel**



| | |
|---|---|
| 100 mm | **Stora Enso CLT** |
| 12.5 mm | plasterboard |
| 30 mm | mineral wool |
| 30 mm | mineral wool |
| 5 mm | airgap |
| 100 mm | **Stora Enso CLT** |

**$R'_w$ ($C;C_{tr}$): 59 (–3;–10) dB**

Improved with facing panel/service cavity [2]

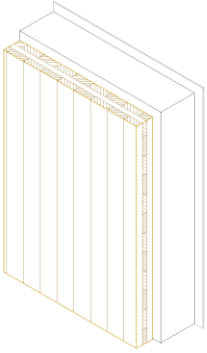
| | Designing interior cladding | Improvement |
|---|---|---|
|  | single-layer cladding with 1 × 12.5 mm plasterboard | 1 dB |
|  | double-layer cladding with 1 × 12.5 mm plasterboard | 2 dB |
|  | single-layer insulated facing panel on spring hoop | < 7 dB |
|  | insulated facing panel on spring hoop on both sides | < 10 dB |
|  | single-layer facing panel, fully mechanically-isolated[1)] with 85 mm cavity (with cavity insulation [50 mm mineral wool between CW profile] and clad with 2 layers of plasterboard) | < 11 dB |
|  | double-layer facing panel, fully mechanically-isolated[1)] with 85 mm cavity (with cavity insulation [50 mm mineral wool between CW profile] and clad with 2 layers of plasterboard) | < 15 dB |

[1)] attached only to the ceiling and floor

**Figure 1:** improvement of airborne sound insulation using different types of internal wall cladding (in red), on a double-layer CLT wall with cavity insulation (60 mm mineral fibres) **(TEIBINGER, MATZINGER, & DOLEZAL, 2013)**.

## 4.2.2 Examples for external wall structures

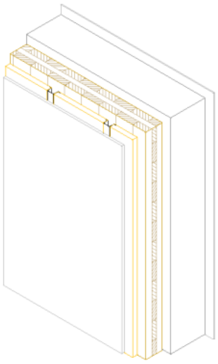
**Thermal insulation system and CLT visible surface**



| | |
|---|---|
| 7 mm | plaster system |
| 160 mm | hemp fibre insulating board |
| 100 mm | **Stora Enso CLT** |

**$R_w$ ($C$;$C_{tr}$): 52 (–2;–8) dB**

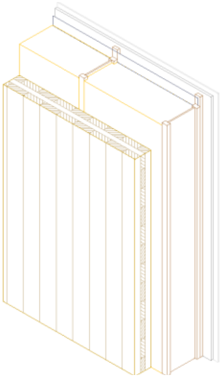
**Thermal insulation system and fire protection plasterboard on spring clips**



| | |
|---|---|
| 5 mm | plaster system |
| 240 mm | EPS rigid foam insulation |
| 90 mm | **Stora Enso CLT** |
| 27 mm | mineral fibre insulation between two spring clips |
| 15 mm | fire-protection plasterboard |

**$R_w$ ($C$;$C_{tr}$): 48 (–3;–10) dB**

**Ventilated façades**

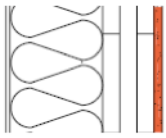
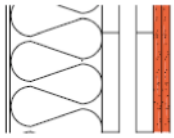
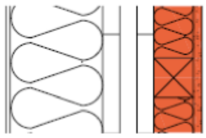
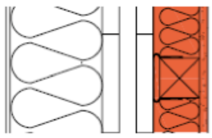
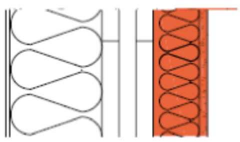
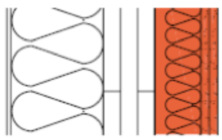


| | |
|---|---|
| 5 mm | mineral plaster |
| 12.5 mm | cement-bound lightweight concrete panel |
| 30 mm | open boarding |
| < 1 mm | roofing felt |
| 200 mm | timber/timber material beam, 200 mm wood-fibre insulation intermediate layer |
| 80 mm | **Stora Enso CLT** |

**$R_w$ ($C$;$C_{tr}$): 43 (–2;–7) dB**

Improved with facing panel/service cavity:

The sound insulation effect of a facing panel in the form of a service cavity is shown quantitatively in the following illustrations. The improvement in dB is a general rule and relates to the direct sound transmission pathway. [2]

| | Designing interior cladding | Improvement |
|---|---|---|
|  | single-layer cladding with 12.5 mm plasterboards | 0–1 dB |
|  | double-layer cladding with 12.5 mm plasterboards | 1–2 dB |
|  | facing panels insulated with mineral wool attached directly to the non-faced wall and clad with 1 × 12.5 mm plasterboard | < 6 dB |
|  | facing panels insulated with battens fastened to spring clips and clad with 1 × 12.5 mm plasterboard | < 15 dB |
|  | fully mechanically-isolated[1)] facing panel, insulated with mineral fibre, with 85 mm cavity (with cavity insulation [50 mm mineral fibre between CW profile] and clad with 1 × 12.5 mm layers of plasterboard) | < 22 dB |
|  | fully mechanically-isolated[1)] facing panel, insulated with mineral fibre, with 85 mm cavity (with cavity insulation [50 mm mineral fibre between CW profile] and clad with 2 × 12.5 mm layers of plasterboard) | < 23 dB |

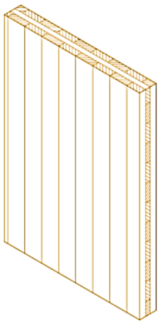
[1)] attached only to the ceiling and floor

**Figure 2:** improvement of airborne sound insulation using different types of internal wall cladding (in red), based on a main wall comprised of CLT elements and a thermal insulation system **(TEIBINGER, MATZINGER, & DOLEZAL, 2013)**.

4.2.3 Examples for internal wall structures

Even if there are no specific soundproofing requirements for individual rooms within an apartment, sound insulation should still be borne in mind when planning buildings to provide protection against noise. Improvements to the soundproofing of internal walls, such as mounting facing panels, should be made in noisy areas as this helps to reduce the transmission of sound into the structure and lowers the proportion of flanking sound.
The sound insulation of a 100 mm-thick CLT wall with different types of cladding was tested in a series of measurements in the laboratory for building physics at the Technical University of Graz.

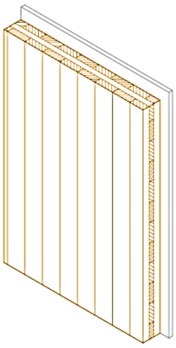
**CLT non-faced wall**



100 mm **Stora Enso CLT**

**$R_w$ (C;$C_{tr}$): 34 (–1;–3) dB**

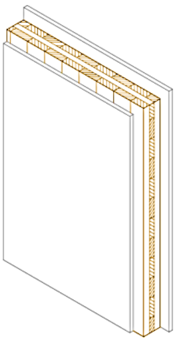
**Fire protection plaster board on one side**



100 mm **Stora Enso CLT**
12.5 mm fire-protection plasterboard

**$R_w$ (C;$C_{tr}$): 37 (–1;–3) dB**

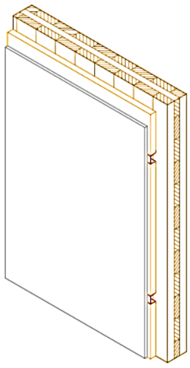
**Fire protection plaster board on both sides**



2.5 mm fire-protection plasterboard
100 mm **Stora Enso CLT**
12.5 mm fire-protection plasterboard

**$R_w$ (C;$C_{tr}$): 37 (–1;–3) dB**

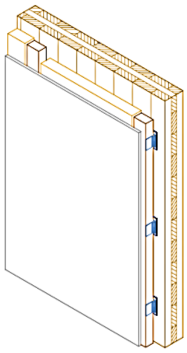
**Spring clip**



100 mm **Stora Enso CLT**
27 mm spring clip
12.5 mm fire-protection plasterboard

**$R_w$ (C;$C_{tr}$): 48 (–5;–12) dB**

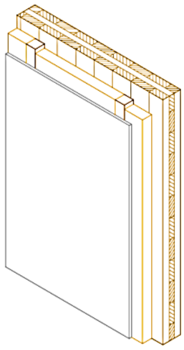
**Spring hoop**



100 mm **Stora Enso CLT**
3 mm joint sealing tape
50 mm spring clip with an intermediate layer of mineral wool
12.5 mm fire-protection plasterboard

**$R_w$ (C;$C_{tr}$): 51 (–2;–8) dB**

**Wooden battens**



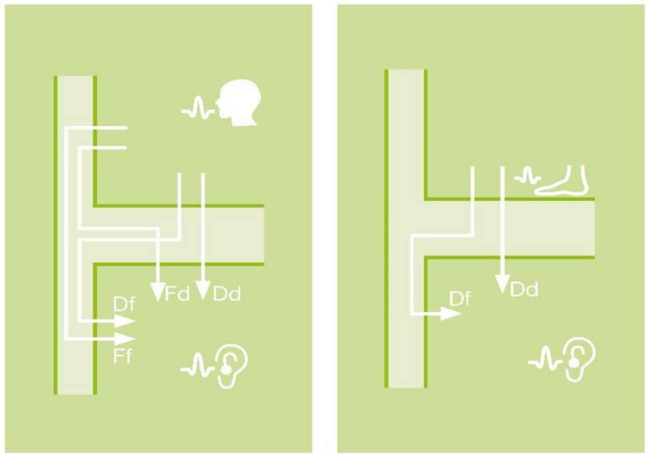
100 mm **Stora Enso CLT**
50 mm wooden batten (intermediate layer of mineral wool)
12.5 mm fire-protection plasterboard

**$R_w$ (C;$C_{tr}$): 45 (–1;–5) dB**

## 5. Sound transmission in buildings

In addition to the sound path directly above the partition assembly, several sound transmission pathways also exist, depending on the design, and these are referred to as flanks.

As the soundproofing requirements of individual countries consist of the sound insulation and transmission pathways, in addition to the partition assembly, the flanking components must also be taken into account. Thus it is important to note that the better the quality of the partition assembly, the greater the proportion of flanking sound in the overall transmission of sound. Flanking sound can be reduced either by mechanically isolating the components (e.g. with elastomers) or by mounting flexible facing panels.
Planning principles related to the requirements for elastic bearings have been published by Holzforschung Austria in [2], part of which is described in the annex to this document.




Sound transmission pathways between two rooms

F …. flanking transmission (indirect)
D …. direct transmission
f …. flanking radiation (indirect)
d …. direct radiation

In principle, soundproofing can be verified either mathematical, based on the calculation method in EN 12354, or through metrological measurements, based on construction site measurements. Despite active research and a few early publications, no sufficiently accurate values for the relatively new product, cross-laminated timber, exist as yet to enable a calculation to be performed in line with EN 12354. Simplified calculation approaches for sound transmission in solid wood construction can be found, for example, in the publications of the Informationsdienst Holz [3] or the Holzforschung Austria [4].
In the meantime, many well-documented construction site measurements are available upon request and can be referred to during verifications.

# Bibliography


[1] B. Rasmussen und M. Machimbarrena, „Existing sound insulation performance requirements and classification schemes for housing across Europe," in *COST Action TU0901 – Building acoustics throughout Europe. Volume 1: Towards a common framework in building acoustics throughout Europe*, 2014.

[2] M. TEIBINGER, I. MATZINGER und F. DOLEZAL, Bauen mit Brettsperrholz im Geschoßbau – Focus Bauphysik, Planungsbroschüre, Holzforschung Austria, Wien, 2013.

[3] F. Holtz, J. Hessinger, H. P. Buschbacher und A. Rabold, „Schalldämmende Holzbalken- und Brettstapeldecken," in *Informationsdienst Holz – Holzbauhandbuch Reihe 3, Teil 3, Folge 3*, München, Entwicklungsgemeinschaft Holzbau (EGH), 1999.

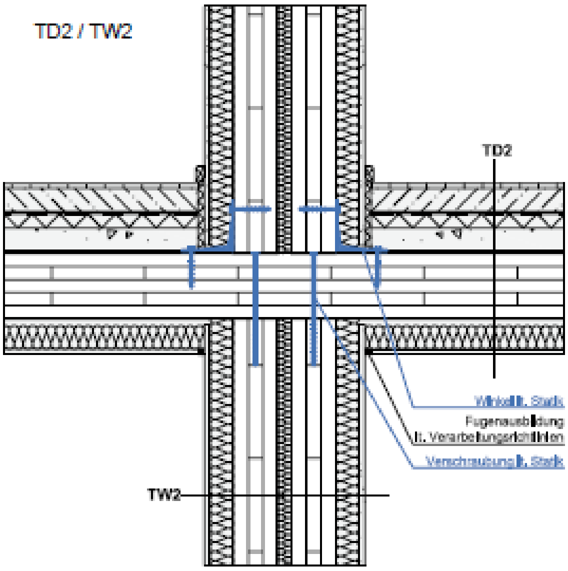
[4] M. Teibinger, F. Dolezal und I. Matzinger, Deckenkonstruktionen für den mehrgeschoßigen Holzbau – Schall- und Brandschutzl, Wien: Holzforschung Austria, 2009.

**Annex A: Comparison of minimum requirements in 35 European countries [1]**

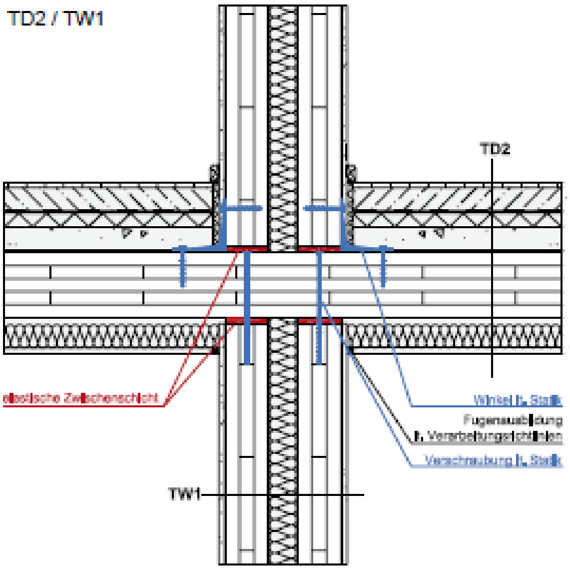
| Airborne sound (status June 2013) | | Residential buildings | Terraced housing |
|---|---|---|---|
| Country | Descriptor | Req. [dB] | Req. [dB] |
| Austria | DnT,w | ≥ 55 | ≥ 60 |
| Belgium | DnT,w | ≥ 54 | ≥ 58 |
| Bulgaria | R′ w | ≥ 53 | ≥ 53 |
| Croatia | R′ w | ≥ 52 | ≥ 52 |
| Cyprus | N/A | N/A | N/A |
| Czech Republic | R′ w | ≥ 53 | ≥ 57 |
| Denmark | R′ w | ≥ 55 | ≥ 55 |
| England & Wales | DnT,w + Ctr | ≥ 45 | ≥ 45 |
| Estonia | R′ w | ≥ 55 | ≥ 55 |
| Finland | R′ w | ≥ 55 | ≥ 55 |
| France | DnT,w + C | ≥ 53 | ≥ 53 |
| Germany | R′ w | ≥ 53 | ≥ 57 |
| Greece | R′ w | ≥ 50 | ≥ 50 |
| Hungary | R′ w + C | ≥ 51 | ≥ 56 |
| Iceland | R′ w | ≥ 55 | ≥ 55 |
| Ireland | DnT,w | ≥ 53 | ≥ 53 |
| Italy | R′ w | ≥ 50 | ≥ 50 |
| Latvia | R′ w | ≥ 54 | ≥ 54 |
| Lithuania | DnT,w or R′ w | ≥ 55 | ≥ 55 |
| Luxembourg | N/A | N/A | N/A |
| Macedonia FYR | N/A | N/A | N/A |
| Malta | N/A | N/A | N/A |
| Netherlands | R′ w + C | ≥ 52 | ≥ 52 |
| Norway | R′ w | ≥ 55 | ≥ 55 |
| Poland | R′ w + C | ≥ 50 | ≥ 52 |
| Portugal | DnT,w | ≥ 50 | ≥ 50 |
| Romania | R′ w | ≥ 51 | ≥ 51 |
| Scotland | DnT,w | ≥ 56 | ≥ 56 |
| Serbia | R′ w | ≥ 52 | ≥ 52 |
| Slovakia | R′ w or DnT,w | ≥ 53 | ≥ 57 |
| Slovenia | R′ w | ≥ 52 | ≥ 52 |
| Spain | DnT,A ≈ DnT,w + C | ≥ 50 | ≥ 50 |
| Sweden | R′ w + C50-3150 | ≥ 53 | ≥ 53 |
| Switzerland | DnT,w + C | ≥ 52 | ≥ 55 |
| Turkey | N/A | N/A | N/A |

| Impact sound (status June 2013) | | Residential buildings | Terraced housing |
|---|---|---|---|
| Country | Descriptor | Req. [dB] | Req. [dB] |
| Austria | L′ nT,w | ≤ 48 | ≤ 43 |
| Belgium | L′ nT,w | ≤ 58 | ≤ 50 |
| Bulgaria | L′ n,w | ≤ 53 | ≤ 53 |
| Croatia | L′ w | ≤ 68 | ≤ 68 |
| Cyprus | N/A | N/A | N/A |
| Czech Republic | L′ n,w | ≤ 55 | ≤ 48 |
| Denmark | L′ n,w | ≤ 53 | ≤ 53 |
| England & Wales | L′ nT,w | ≤ 62 | none |
| Estonia | L′ n,w | ≤ 53 | ≤ 53 |
| Finland | L′ n,w | ≤ 53 | ≤ 53 |
| France | L′ nT,w | ≤ 58 | ≤ 58 |
| Germany | L′ n,w | ≤ 53 | ≤ 48 |
| Greece | L′ n,w | ≤ 60 | ≤ 60 Info |
| Hungary | L′ n,w | ≤ 55 | ≤ 45 |
| Iceland | L′ n,w | ≤ 53 | ≤ 53 |
| Ireland | L′ nT,w | ≤ 62 | None |
| Italy | L′ n,w | ≤ 63 | ≤ 63 |
| Latvia | L′ n,w | ≤ 54 | ≤ 54 |
| Lithuania | L′ n,w | ≤ 53 | ≤ 53 |
| Luxembourg | N/A | N/A | N/A |
| Macedonia FYR | N/A | N/A | N/A |
| Malta | N/A | N/A | N/A |
| Netherlands | L′ nT,w + CI | ≤ 54 | ≤ 54 |
| Norway | L′ n,w | ≤ 53 | ≤ 53 |
| Poland | L′ n,w | ≤ 58 | ≤ 53 |
| Portugal | L′ nT,w | ≤ 60 | ≤ 60 |
| Romania | L′ n,w | ≤ 59 | ≤ 59 |
| Scotland | L′ nT,w | ≤ 56 | none |
| Serbia | L′ n,w | ≤ 68 | ≤ 68 |
| Slovakia | L′ n,w or L′ nT,w | ≤ 55 | ≤ 48 |
| Slovenia | L′ n,w | ≤ 58 | ≤ 58 |
| Spain | L′ nT,w | ≤ 65 | ≤ 65 |
| Sweden | L′ n,w + CI,50-2500 | ≤ 56 | ≤ 56 |
| Switzerland | L′ nT,w + CI | ≤ 53 | ≤ 50 |
| Turkey | N/A | N/A | N/A |

## Annex B: Planning principles related to the requirements for elastic bearings [2]

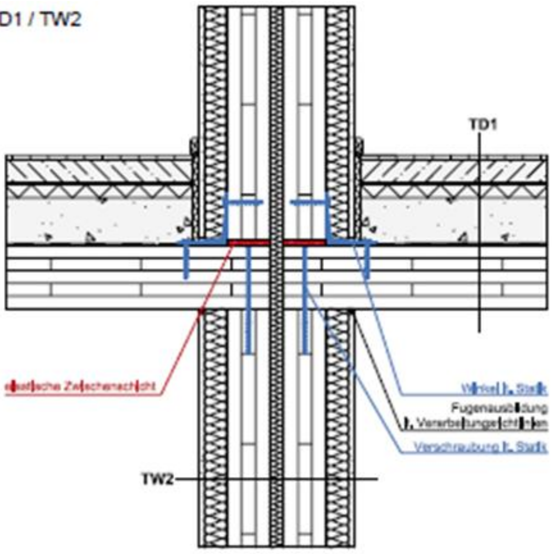



***No bearings*** are required in the case of suspended ceilings and mechanically-isolated facing panels.



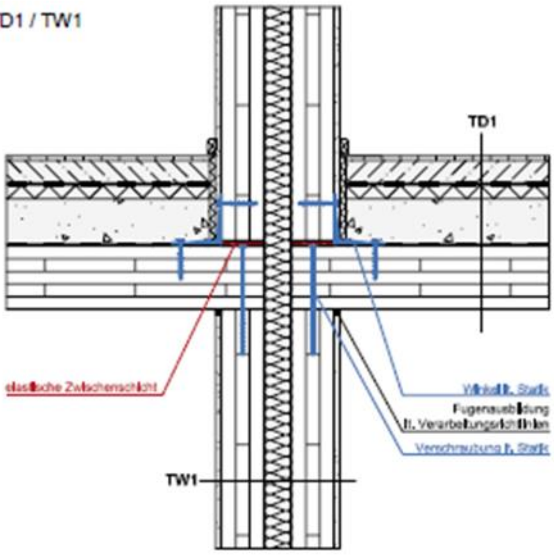

***Elastic bearings*** are required ***above and below the ceiling*** in the case of suspended ceilings without mechanically-isolated facing panels on the walls.

TD1 / TW2



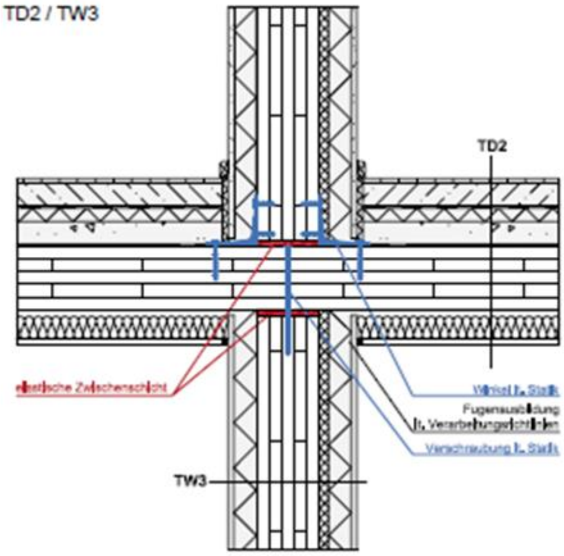

***Elastic bearings*** are required ***above the ceiling*** in the case of cross-laminated timber ceilings with a timber soffit (without a suspended ceiling) and mechanically-isolated facing panels on the walls.

TD1 / TW1




***Elastic bearings*** are required ***above the ceiling*** in the case of cross-laminated timber ceilings with a timber soffit (without a suspended ceiling) and without mechanically-isolated facing panels on the walls.

TD2 / TW3




***Mechanically-isolated facing panels, suspended ceilings and elastic bearings above and below the ceiling*** are always required on continuous ceilings above different parts of the building.

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