BUILDING PHYSICS

SOLID TIMBER MANUAL 2.0

binderholz

Rigips SAINT-GOBAIN

1st edition, May 2019

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Publisher
Binderholz GmbH and Saint-Gobain Rigips Austria GesmbH

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binderholz, Rigips Austria, Rothoblaas, Getzner Werkstoffe

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CONTENT

SOUND INSULATION

SOUND INSULATION

Sound insulation serves the purpose of protecting people adequately from noise in social rooms. In timber construction, the components always comprise multiple layers. This way, the sound encounters multiple resistances on its path in between the individual components. While the sound insulation of single-layer components is based exclusively on their mass and flexural stiffness, smart multi-layer structures with decoupled layers and hollow space insulating materials can reach steady sound insulating values with substantially lesser masses. The construction situation is decisive for the evaluation of sound insulation. This means that given the requirements of sound insulation, a separating component must always be evaluated including the secondary sound paths.

binderholz CLT BBS

In solid timber structures, foremost the total thickness of the cross laminated timber CLT BBS, its surface weight and flexural stiffness play an essential role for the sound insulation of the basic component (without further layers). Generally, the complete component (wall, ceiling, roof) is supplemented by additional layers (façade, installation level, floor structure, etc.) The sound insulation of the complete component is significantly improved by additional cladding. Components made of CLT BBS are made of modular elements. The modular connections required due to the structure are tested comprehensively for sound insulation and designed so that they do not have any negative effects on the indicated sound insulation value.

For the use of CLT BBS as separating ceiling or partition wall in a residential unit, component assemblies have been developed in the course of comprehensive testing at the ift Rosenheim that meet the relevant requirements for sound insulation. The measuring results illustrate clearly that these optimised assemblies also withstand comparisons to reinforced concrete walls and notably so with one-fifth of the mass.

Rigips dry construction systems

Layers with large surface measures, for example, plasterboards have a positive effect on sound insulation. By additionally mounting an installation level, a flexible shell is created that substantially increases sound insulation in high and medium frequency ranges. Here, flexible bearing profiles such as RigiProfil as well as heavy flexible panelling, e.g. Rigips fire protection plates should be used and the largest possible shell spacing should be ensured.

Air-borne sound insulation

A structure is excited to oscillate during sound transmission. In the case of multi-layer structures, the insulating material in the hollow space affects the coupling of the individual layers and the sound distribution inside of the hollow space. The rated sound insulation value R'_w [dB] indicates the sound insulation of a component between two rooms including secondary sound paths (see Figure 1). The sound insulation of multi-layer components depends on the characteristics of each individual layer and on the interaction of all layers. The properties of the individual layers depend on their surface measure (mass inertia) and flexural stiffness. For example, the sound insulation can be improved by mounting an installation level in addition, which consists of plasterboards, meaning a flexible layer with large surface measure.

The sound insulation can be improved, for example, by

- a reduction of the surface connecting points of the individual layers (paying attention to statically required spacing);
- use of flexible bearing profiles such as spring rails, metal stand flexible shells;
- use of heavy flexible panelling such as plasterboards;
- use of soft insulating material in hollow spaces;
- increasing the shell spacing.

Figure 1 – The ceiling test bench in the sound testing lab and arrangement of the measuring instruments

Structure-borne sound / footfall sound

Structure-borne sound is induced in a component through mechanical stimulation (see Figure 2).

Footfall sound is a structure-borne sound that is caused, for example, by children jumping around or knocking. The disruptive sound is mechanically induced directly into the ceiling and deflected to the neighbouring rooms. The insulation of a ceiling is marked by the rated standard footfall sound level $L'_{nT,w}$ [dB]. Consideration of the construction situation including the secondary sound paths is indicated here by the line. For the measurement of footfall sound, the ceiling in the transmitting room is excited by a standard hammer mill and the sound level generated is measured in the receiving room. The lower the level, the better the rating of the ceiling for insulating footfall sound.

The assembly to be selected decisively depends on

- the dynamic stiffness s' of the sound insulation panels,
- the masses of the floor screed or unfinished ceiling,
- the reinforcement of the unfinished ceiling.

The weaker the dynamic stiffness s' the better the footfall sound insulation (the permissible load of the footfall sound insulation must be observed).

It is essentially attempted to prevent or minimise the induction of footfall sound into the structure and its transfer and deflection in the form of airborne noise. The deflection to the receiving room can be reduced by means of facing formwork.

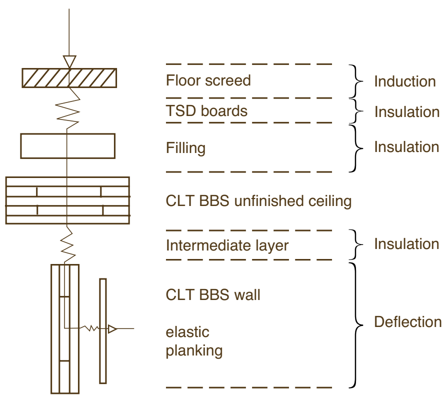


Figure 2 – Reduction of structure-borne sound
Source: HFA planning brochure "Ceiling structures for multi-storey timber construction", 2009

Flanking transmission / secondary sound paths

Besides the separating component, also all flanking building parts are involved in the sound insulation between two rooms. The separating component is just one of the many transmission paths. For separating components with high sound insulation, the sound is transmitted for the most part via the flanking ceilings, roofs, interior and exterior walls. To optimise the sound insulation of components, it must be aimed for the lowest possible transmission via secondary paths. The extent of the transmission via secondary paths depends on the concrete construction situation. The forwarding of the sound is structurally prevented by a bearing on elastic interim layers (see Figure 3).

Figure 3 – On the left, Rothoblaas XYLOFON and on the right, Getzner Sylodyn

By planning in facing formwork and suspended ceiling structures, these additional measures can be reduced and, in part, they can even be omitted entirely.

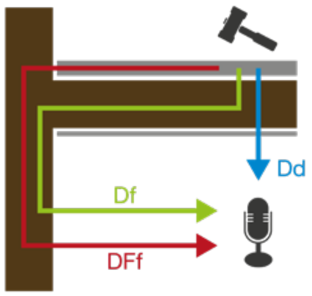
Source: Planning brochure of Holzforschung Austria

The behaviour of solid timber structures is very different from solid mineral construction. Forecast models existing so far do not reflect the actual behaviour of solid timber structures. To be able to reliably fulfil the requirements for sound insulation and suitability for use, the components are frequently overdimensioned through substitute models and simplified conservative approaches and thereby become inefficient.

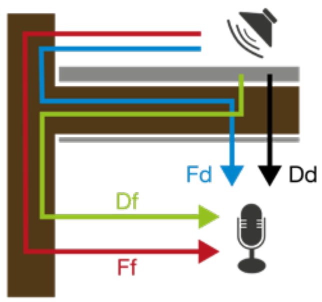
Within the scope of the project "Vibro-acoustics in the planning process for timber structures" that is supported by binderholz and Saint-Gobain Rigips Austria among others, comprehensive measurements of the sound transmission via flanking components have been conducted (see Figure 4).

A prediction model according to DIN EN ISO 12354 was developed, which considers the diverse transmission paths in the construction situation and nonetheless remains applicable for the construction practitioner. The model is being integrated in the new DIN 4109.

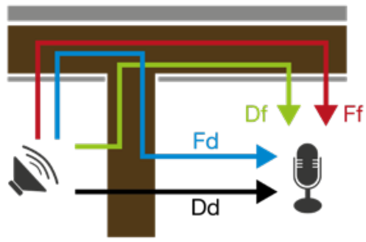
The following illustrations show the various secondary sound paths depending on the construction situation:



Footfall sound transmission



Vertical air-borne sound transmission



Horizontal air-borne sound transmission

Figure 4 – Schematic diagram of the contributions to the sound transmission in timber construction
Source: Vibro-acoustics research project

Model for calculation according to DIN EN ISO 12354

The calculation of single-number ratings of the sound insulation, R'_w and of the standard footfall sound level $L'_{n,w}$ in construction is based on the transmissions paths shown in Figure 4 according to the following equations:

1 $$R'_w = -10 \lg \left(10^{-0,1R_w} + \sum 10^{-0,1R_{ij,w}}\right) \text{ with } ij = Ff, Fd, Df$$

2 $$L'_{n,w} = 10 \lg \left(10^{0,1L_{n,w}} + \sum 10^{0,1L_{n,ij,w}}\right) \text{ with } ij = Df, DFf$$

The footfall sound flank path DFf, going into the floor screed and, via the flanking wall in the transmitting room, down into the flanking wall in the receiving room is not considered yet in the normative calculation according to EN 12354. Acoustics predictions were compared to construction site measurements and a substantial effect of this transmission path can be seen (vibro-acoustics research project). In this planning brochure, the corresponding predictive model is described, which is illustrated in detail in the calculation example provided.

Planning notes for sound insulation

The table below shows recommendations for the sound insulation of apartment ceilings and partition walls for multi-storey buildings for residential housing based on DIN 4109, supplement 2 and respectively ÖNORM B 8115.

The data refers to the construction situation including all secondary sound paths.

Building part	Austria	Germany
Apartment partition wall	$D'_{nT,w} \geq 55$ dB	$R'_w \geq 55$ dB
Apartment separating ceiling	$L'_{nT,w} \leq 48$ dB	Minimum requirement: $L'_{n,w} \leq 53$ dB Enhanced requirement: $L'_{n,w} \leq 46$ dB

Overview of the built examples in solid timber construction, enhanced requirements for apartment separating ceilings according to DIN 4109, supplement 2 are fulfilled

The table below shows structures in finished buildings that fulfil all enhanced requirements for apartment separating ceilings in consideration of all flanking components (vibro-acoustics research project)

BV	Ceiling	Walls	Additional measures	Prediction	Construction measurement
2	80 Concrete floor screed 50 MFT, s' = 6 MN/m³ 85 Lime chippings 200 CLT BBS	100 mm CLT BBS	Elastomer top and bottom	R'_w = 63.8 dB $L'_{n,w}$ = 42.5 dB	R'_w = 66 dB $L'_{n,w}$ = 45 dB
3	65 Concrete floor screed 40 MFT, s' = 6 MN/m³ 90 Lime chippings 100 Glulam	100 mm CLT BBS 12.5 mm Rigips RF fire protection board	Elastomer top	R'_w = 61.3 dB $L'_{n,w}$ = 45.8 dB	R'_w = 63 dB $L'_{n,w}$ = 45 dB
4	60 Concrete floor screed 40 MFT, s' = 6 MN/m³ 15 Fibreboard 447 Wood-concrete compound	≥ 100 mm CLT BBS	Facing formwork		R'_w = – dB $L'_{n,w}$ = 44 dB
5	60 Concrete floor screed 40 MFT, s' = 6 MN/m³ 90 Lime chippings 200 Glulam	2 x 18 mm Rigips RF fire protection board ≥ 100 mm CLT BBS 2 x 18 mm Rigips RF fire protection board	$K_2$60 encapsulation	R'_w = 60.9 dB $L'_{n,w}$ = 44.0 dB	R'_w = 59 dB $L'_{n,w}$ = 43 dB

Improvement possibilities to reduce the flank sound transmission

Based on the accompanying research project “vibro-acoustics in the planning process for timber structures” and a number of planning brochures as well as specialised lectures, binderholz and Saint-Gobain Rigips Austria gained valuable and practically applicable insights for the planning of solid timber construction that is optimised in terms of sound insulation. In the following, these measures are explained and the positive effects are presented in a comprehensible way by means of a calculation example.

Viewed for themselves, CLT BBS solid timber elements for walls and ceilings are rigid discs. This nature of a disc entails that the flanking components made of large-format elements have a poorer effect for the insulation of the flanks than components that consist of CLT BBS 125 elements. For example, the component of a flanking exterior wall consists of many lined-up elements with width of each 1.25 m that are joined with bolts by a wooden riser. The modular panel joint here works like a spring or a separating cut and thereby provides substantial insulation for the flank transmission (see Figure 5). The measurements of the flank insulation value R_{Ff} have been conducted with this modular construction method and the assessed values in the calculation example that are more favourable in terms of sound insulation are applicable only when using this construction method.

Source: Vibro-acoustics research project

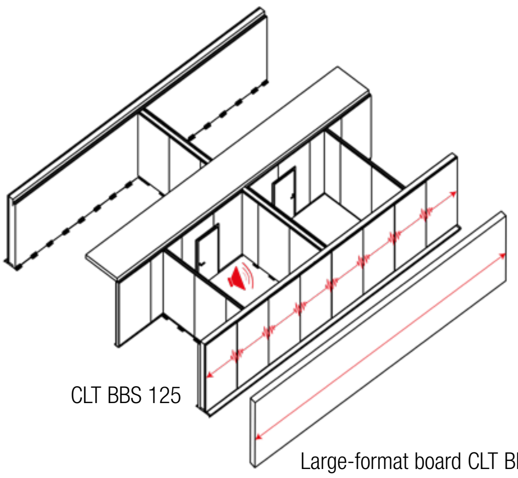


Figure 5 – Difference in the flank sound transmission between CLT BBS 125 and the CLT BBS XL large-format panel

Flanking CLT BBS walls should be provided with a facing formwork that has decoupling effects (installation level on vibration mounts, shell spacing at least 5 mm or use stand-alone facing formwork – see Figure 6).

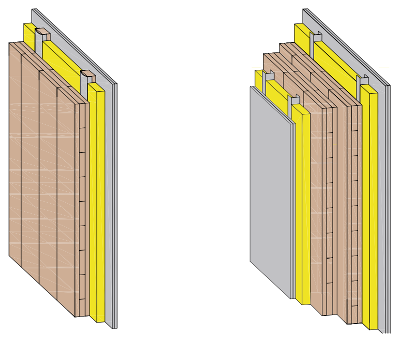
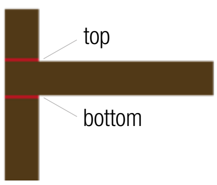


Figure 6 – Facing formwork working with decoupling effect on one or both sides

In the calculation of the sound transmission, the mass of the binderholz cross laminated timber CLT BBS wall and ceiling elements have a strong influence. The measurements show that directly applied plasterboard planking has a positive effect on the flank sound insulation. In detail, this effect is illustrated in the calculation example.

Elastomers can be used for the sound decoupling in the case of vertical flank transmission, for example, on the supports of an apartment separating ceiling. The following table shows the improvement of the joint insulation values (input parameters for calculation of the sound insulation value incl. secondary paths R'_w – see page 17).

Only the upper elastomer has effects on the transmission path Fd and only the bottom elastomer affects the path Df. The paths Ff and DFf are influenced by both elastomers.

Arrangement of the elastomers	Position	Data from the DAGA 2010 conference transcript	New measured data
 top	top or bottom	ΔK_{ij} = 7 … 10 dB	ΔK_{ij} = 4 … 10 dB
bottom	top and bottom	ΔK_{ij} = 8 … 19 dB	ΔK_{ij} = 13 … 15 dB

Source: Vibro-acoustics research project

NOTES

The indicated values have a wide spread, as elastomers of different manufacturers have been used in combination with different wall and ceiling structures. The information applies only to decoupled mounting materials (angles with elastomer boards, bolts with lining and elastic insulating washers – see Figure 7).

If conventional fasteners are used, the decoupled effect of the elastomer will reduce significantly. In that case, a ΔK_{ij} of 2 to 3 dB can be assessed. Further planning bases for the influence of elastomer bearings with and without consideration of the installed fasteners can be found in the planning brochure of Holzforschung Austria entitled "Roof structures for multi-storey timber construction".

Source: Rothoblaas planning brochure

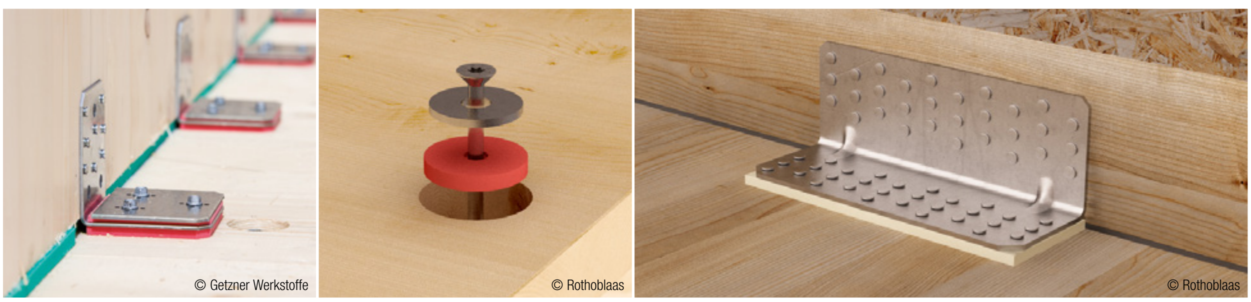


Figure 7 – Decoupled fasteners with elastomer bearings of different manufacturers

CLT BBS ceiling in visual surface quality – optimisation of the flank transmission of the ceiling support on an apartment partition wall

CLT BBS ceilings with wooden surface visible on the bottom side contribute to the flank transmission between adjacent rooms (see Figure 8). Current measurements of the flank insulation value R_{Ff} have shown that a ceiling reinforcement using filling in combination with a wet screed floor structure results in a substantial improvement of the flank insulation (vibro-acoustics research project).

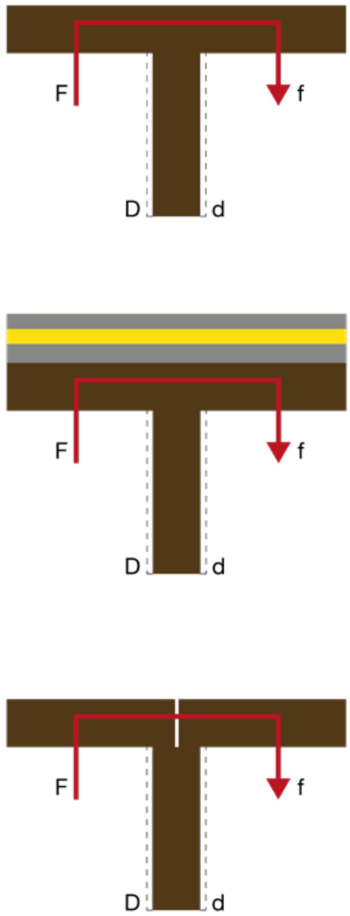


Figure 8 – Different path of the flank sound transmission in the ceiling area

A 150-mm thick binderholz CLT BBS 125 ceiling that rests on an 80-mm thick CLT BBS 125 wall results in a measured $R_{Ff,w}$ of 44 dB. If an element consisting of 60-mm chipping filling, a 40-mm footfall sound insulation board and 50-mm concrete screed is applied on the 1500-mm thick CLT BBS ceiling, the measured $R_{Ff,w}$ increases to 61 dB.

If a continuity effect of the CLT BBS ceiling is dispensable in terms of structural stability, a separation of the ceiling fields in the axes of the apartment partition walls is an effective measure to improve the flank insulation. With a continuous 150-mm thick CLT BBS 125 ceiling, the measured flank insulation value is R_{Ff} 44 dB (as described above); with execution of a separating cut, the measured value for R_{Ff} increases to 49 dB.

Another possibility to improve the flank insulation is to provide the flanking ceilings with an additional suspended ceiling with direct supports with vibration decoupling (see Figure 9). This way, the energy applied on the CLT BBS ceiling in the transmitting room and the deflection into the receiving room is significantly reduced.

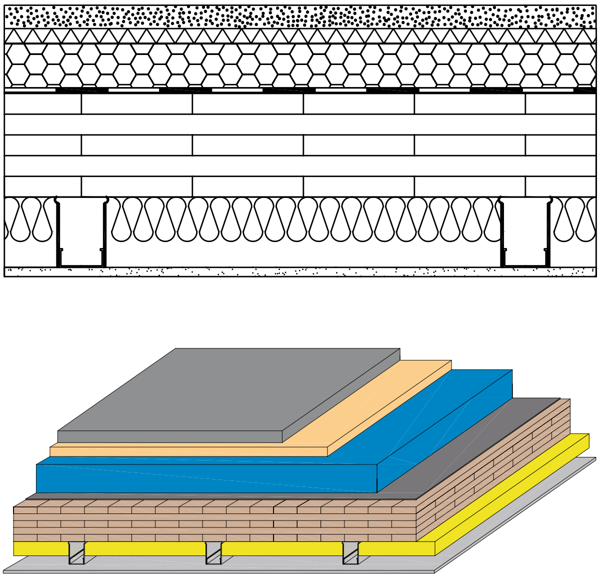
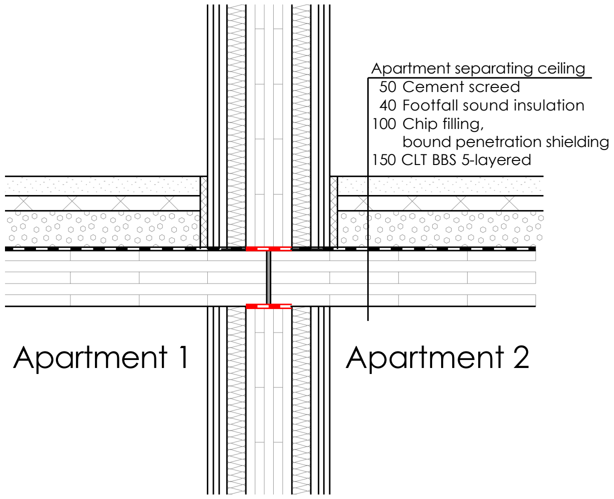
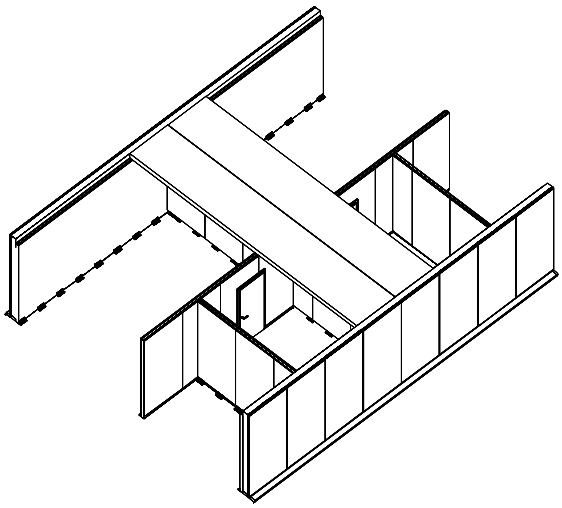


Figure 9 – Suspended ceiling with vibration decoupling

Example for calculating the sound insulation of a planned construction situation in consideration of secondary sound paths





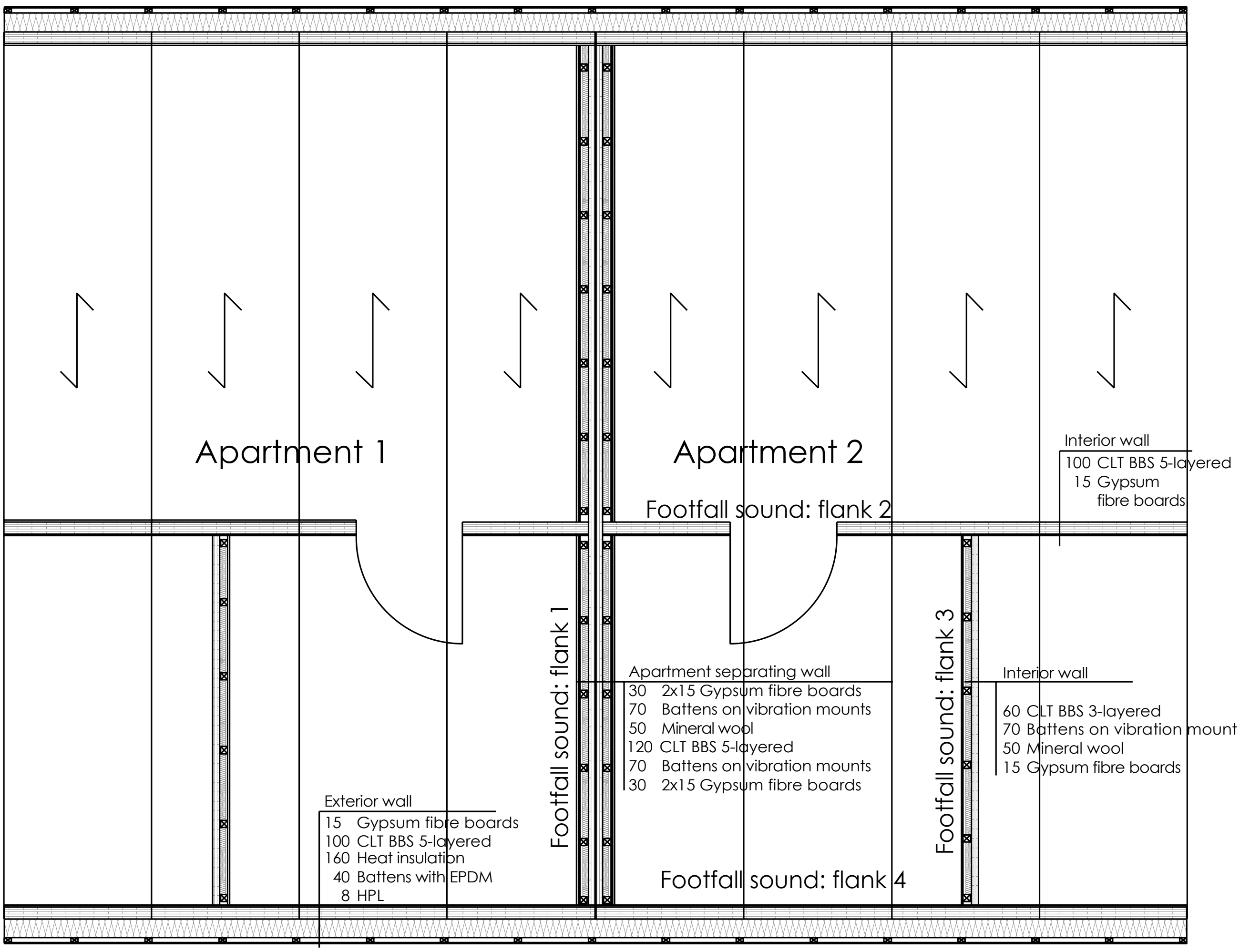


Figure 10 – Illustration of two apartments with apartment partition wall with vibration decoupling

Sound insulation of components without secondary paths as calculation basis

Calculation of R'_w from the mass of a single-shell separating component in CLT BBS construction design without facing formwork where no test results are available:

1 $R'_w = 32.05 * \log(m'_{element}) - 18.68 + K_{wall\ type}$ with $K_{wall\ type} = -2$ dB for large-format elemente

Component	**Component length l_f**	**Component layers** for the flank sound calculation	**$R_{w,r}$** assessed air-borne sound insulation in the flank sound calculation	**$R_{w,P}$** tested air-borne sound insulation of the complete component
Apartment partition wall	3.14 m	5-layered CLT BBS 120 mm (57.6 kg / m²) without assessed mass increase, planking of CLT BBS decoupled by means of vibration mounts	35.7 dB	69 dB
Interior wall	3.12 m	5-layered CLT BBS 100 mm (48 kg / m²) with one-sided planking of 15-mm Rigips RF fire protection board, Additional mass 13.5 kg / m²	36.7 dB	-
Exterior wall (separating cut on the axis of the apartment partition wall)	3.12 m	5-layered CLT BBS 100 mm (48 kg / m²) with one-sided planking of 15-mm Rigips, RF fire protection board, additional mass 13.5 kg / m²	36.7 dB	47 dB*
Apartment separating ceiling	Area across the room viewed: S_S = 3.12 m x 3.14 m = 9.8 m²	5-layered CLT BBS 150 mm (72.0 kg / m²) with assessed mass increase from the floor assembly with heavy filling (196.0 kg / m²) results in a total mass of 268 kg / m²	57.1 dB	$R_{w,P}$ = 77 dB $L_{n,w,P}$ = 38 dB

* The value was measured with 90 mm CLT BBS and 12.5 mm Rigips RF fire protection board

Horizontal sound transmission through the apartment partition wall
Calculation of the sound insulation value in consideration of the secondary paths

The measured sound insulation value R'_w of the apartment partition wall (complete assembly R'_w = 69 dB) can be inserted directly in the formula below:

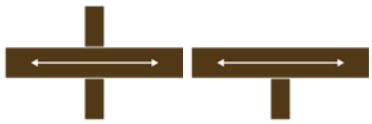
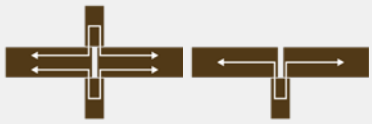
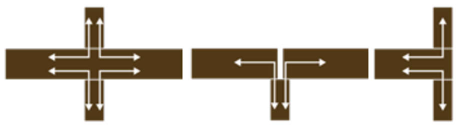
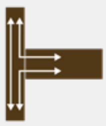
1 $$R'_w = -10 \lg\left(10^{-0,1R_w} + \sum 10^{-0,1R_{ij,w}}\right)$$

The flank insulation values $R_{ij,w}$ are to be calculated:

3 $$R_{ij,w} = (R_{i,w+} R_{j,w})/2 + \Delta R_{ij,w} + K_{ij} + 10 \lg (S_S/l_o l_f)$$

Explanation regarding the joint insulation value K_{ij}

Numerous K_{ij} values were measured in the research project “Vibro-acoustics in the planning process for timber structures”. In addition, measured data of comparable assemblies from different European institutes have been compiled and assessed. The analysis in the table below shows the median values of the joint insulation values for various joint situations.

Case	Joint type	Transmission direction	Joint insulation value
1		“Vertical transmission” Path Ff	K_{Ff} = 20 dB
2		“Horizontal transmission” Path Ff Ceiling, continuous	K_{Ff} = 3 dB
3		“Horizontal transmission” Path Ff Ceiling, separated	$K_{Ff} = 12+10\lg(m_2'/m_1')$
4		“Mixed transmission” Path Df and Fd	K_{Fd} = 14 dB K_{Df} = 14 dB
5		“Horizontal transmission” Paths Ff, Df, Fd Walls of BBS 125	K_{Ff} = 12 dB $K_{Df} = K_{Fd}$ = 16 dB

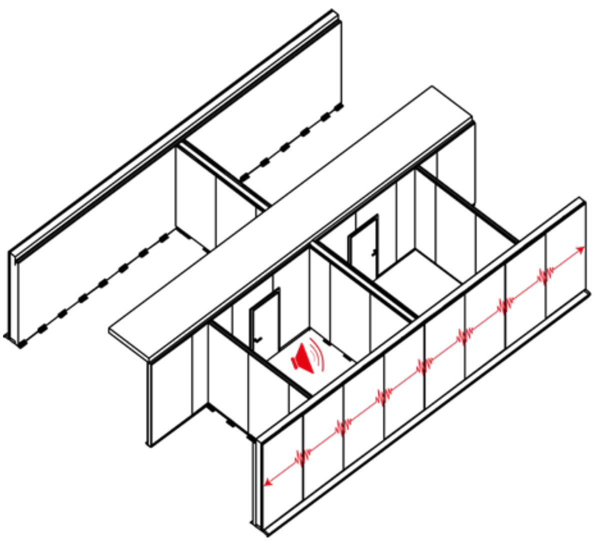


Figure 11 – Flank sound transmission with CLT BBS 125 elements

In the structure consisting of CLT BBS 125, always 1.25-mm wide wall elements are lined up side-by-side and joined with a wooden riser, which has an acoustic effect like a separating cut (see Figure 11).

Consequently, not case 1 must be expected for K_{Ff} with a continuous flanking wall, but the more favourable case 3. This was proven by means of the measurements in the course of the aforementioned research project.

Likewise based on the acoustically favourable construction design using CLT BBS 125 elements, the R_{Ff} measuring results show that with the execution of a separating cut in the flanking wall on the partition wall axis, the K_{Ff} value from case 1 must be used in the calculation for this case.

NOTE

These projections with favourable effects on sound insulation can be chosen only when the exterior wall does not consist of large-format elements. Furthermore, any potentially existing direct planking on the interior side of the flanking wall must not extend beyond the partition wall.

Flank insulation values $R_{ij,w}$ to be considered

1. Flank of apartment partition wall – exterior wall

$R_{Ff,w}$: Sound transmission into the flanking wall and out of the flanking wall again into the receiving room

$R_{F,w}$ = 36.7 dB
$R_{f,w}$ = 36.7 dB
$\Delta R_{Ff,w}$ = 0 dB (no facing formwork present)
K_{Ff} = 20 dB (case 1 based on the modular construction method with 125 cm wide CLT BBS wall elements)
S_S = 8.6 m²
l_o = 1.0 m
l_f = 2.75 m

Calculation result: $R_{Ff,w}$ = 61.6 dB

$R_{Df,w}$: Sound transmission into the partition wall and out of the flanking exterior wall again into the receiving room

$R_{D,w}$ = 35.7 dB (calculation based on the mass of the unfinished CLT BBS 125 wall elements, 12 cm thickness)
$R_{f,w}$ = 36.7 dB
$\Delta R_{Df,w}$ = 18 dB (improvement value of a one-sided facing formwork on vibration mounts with double 12.5 mm planking on CLT BBS 125 wall, 90 mm thickness, measuring results from binderholz / Rigips)
K_{Df} = 16 dB (case 5)
S_S = 8.6 m²
l_o = 1.0 m
l_f = 2.75 m

Calculation result: $R_{Fd,w}$ = 75.1 dB

$R_{Fd,w}$: Sound transmission into the flanking exterior wall and out of the partition wall again into the receiving room

For the calculation, the path Fd is set equal to Df:
$R_{Fd,w}$ = 75.1 dB

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2. Flank of apartment partition wall – interior wall

$R_{Ff,w}$: Sound transmission into the abutting interior wall and out of the abutting interior wall again into the receiving room

$R_{F,w}$ = 36.7 dB
$R_{f,w}$ = 36.7 dB
$\Delta R_{Ff,w}$ = 0 dB (no facing formwork present)
K_{Ff} = 20 dB (case 1 based on the modular construction method with 125 cm wide CLT BBS wall elements)
S_S = 8.6 m²
l_o = 1.0 m
l_f = 2.75 m

Calculation result: $R_{Ff,w}$ = 61.6 dB

$R_{Df,w}$: Sound transmission into the partition wall and out of the abutting interior wall again into the receiving room

$R_{D,w}$ = 35.7 dB (calculation based on the mass of the unfinished CLT BBS 125 wall elements, 12 cm thickness)
$R_{f,w}$ = 36.7 dB
$\Delta R_{Df,w}$ = 18 dB (improvement value of a one-sided facing formwork on vibration mounts with double 12.5 mm planking on CLT BBS 125 wall, 90 mm thickness, measuring results from binderholz / Rigips)
K_{Df} = 16 dB (case 5)
S_S = 8.6 m²
l_o = 1.0 m
l_f = 2.75 m

Calculation result: $R_{Df,w}$ = 75.2 dB

$R_{Fd,w}$: Sound transmission into the abutting interior wall and out of the partition wall again into the receiving room

For the calculation, the path Fd is set equal to Df:
$R_{Fd,w}$ = 75.2 dB

3. Flank of apartment partition wall – ceiling

$R_{Ff,w}$: Sound transmission into the flanking ceiling and out of the flanking ceiling again into the receiving room

$R_{F,w}$ = 57.1 dB
$R_{f,w}$ = 57.1 dB
$\Delta R_{Ff,w}$ = 0 dB (no suspended ceiling present)
K_{Ff} = 5,3 dB (case 3, m_1' = 268 kg/m², m_2' = 57.6 kg/m²)
S_s = 8.6 m²
l_o = 1.0 m
l_f = 3.14 m

Calculation result: $R_{Ff,w}$ = 66.8 dB

$R_{Df,w}$: Sound transmission into the partition wall and out of the flanking ceiling again into the receiving room

$R_{D,w}$ = 35.7 dB (calculation based on the mass of the unfinished CLT BBS 125 wall elements, 12 cm thickness)
$R_{f,w}$ = 57.1 dB
$\Delta R_{Df,w}$ = 18 dB (improvement value of a one-sided facing formwork on vibration mounts with double 12.5 mm planking on CLT BBS 125 wall, 90 mm thickness, measuring results from binderholz/Rigips)
K_{Df} = 14 dB (case 4)
S_s = 8.6 m²
l_o = 1.0 m
l_f = 3.14 m

Calculation result: $R_{Df,w}$ = 82.8 dB

$R_{Fd,w}$: Sound transmission into the flanking ceiling and out of the partition wall again into the receiving room

For the calculation, the path Fd is set equal to Df:
$R_{Fd,w}$ = 82.8 dB

4. Flank of apartment partition wall – floor

The related secondary paths ij = Ff, Df, Fd are not considered, since the sound transmission is prevented structurally by

- heavy floor assemblies with concrete floor screed
- correct installation of the apartment partition wall, as shown in the cut, on the unfinished ceiling using the screed rim insulating strip

Calculation of the air-borne sound insulation value R'_w with consideration of the secondary paths

Based on the above described individual values, the following can be calculated by means of the formula R'_w:

$$R'_w = -10\log(10^{-0,1\times69} + 10^{-0,1\times61,6} + 10^{-0,1\times75,1} + 10^{-0,1\times75,1} + 10^{-0,1\times61,6} + 10^{-0,1\times75,1} + 10^{-0,1\times75,1} + 10^{-0,1\times66,8} + 10^{-0,1\times82,8} + 10^{-0,1\times82,8}) = 57.3\ \text{dB} \tag{1}$$

According to DIN 4109, 2 dB must be considered as forecast unreliability for the air-borne sound:

$R'_w = 57.3$ dB – 2 dB = 55.3 dB > measured $R'_w = 55$ dB

Proof of the air-borne sound is thereby provided.

REMARK regarding R_{Df} and R_{Fd}

These flank insulation values are far above the value of the flank paths R_{Ff} due to the decoupled insulation levels. For simplification, this path can be neglected in the execution of double-sided installation levels (stand-alone or on vibration mounts) on the apartment partition wall or on the interior side on the flanking wall. In the calculation example shown above, the difference when neglecting these flank paths is +0.3 dB for R'_w.

Vertical sound transmission via the apartment separating ceiling

Footfall sound transmission in consideration of secondary paths

The measured standard footfall sound level of the apartment partition wall (complete assembly $R_w = 69$ dB) can be inserted directly in the formula below:

$$L'_{n,w} = 10\ \lg(10^{0,1L_{n,w}} + \sum 10^{0,1L_{n,ij,w}}) \tag{2}$$

The footfall sound flank transmissions on the path Df and DFf are to be calculated:

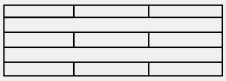
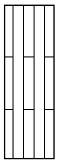
$$L_{n,Df,w} = L_{n,Df,lab,w} - \Delta K_{ij} - \Delta R_{j,w} - 10\lg(S_S/(l_0\, l_f)) \tag{4}$$

$$L_{n,DFf,w} = L_{n,DFf,lab,w} - \Delta K_{ij} - \Delta R_{ij,w} - 10\lg(S_S/(l_0\, l_f)) \tag{5}$$

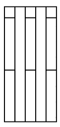
The lab value for the flank transmission of the footfall sound on the path Df is to be calculated according to the following formula:

$$L'_{n,Df,lab,w} = 10\ \lg(10^{0,1(L_{n,w}+K_1)} - 10^{0,1L_{n,w}}) \tag{6}$$

The factor K_1 required for this purpose besides the rated standard footfall sound level $L_{n,w}$ can be found in the following table as dependent on the construction variant: Corrective summand K_1 for consideration of the flank transmission on the path Df.

Wall arrangement in the receiving room	Ceiling assembly
	 CLT BBS ceiling
 CLT BBS wall	K_1 = 4 dB

The lab value for the flank transmission of the footfall sound on the path DFf, $L_{n,DFf,lab,w}$ is shown shaded in grey in the right column of the table below, as dependent on the wall structure and floor assembly. In the table that applies under lab conditions, the value was referred to as $L_{n,DFf,w}$.

Wall assembly in the transmitting and receiving room	Floor screed assembly	Footfall sound transmission on the paths Dd + Df: $L_{n,w} + K_1$ in dB																						
		35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	>5	$L_{n,DFf,w}$ in dB
	a) ZE/HWF	11	10	10	9	8	7	6	5	5	4	4	3	3	2	2	1	1	1	1	1	1	0	n = 1 46
	b) ZE/MF	10	10	9	8	7	6	5	5	4	4	3	3	2	2	1	1	1	1	1	1	0	0	n = 7 45 σσ = 1.5
	c) TE	8	7	6	5	5	4	4	3	3	2	2	1	1	1	1	1	1	0	0	0	0	0	n = 6 42 σσ = 0.9

Floor screed assembly:

a) ZE/HWF mineral-bound screed or cast asphalt
on soft fibre timber footfall sound insulation boards
Rim insulating strips: > 5 mm mineral fibre or PE-foam rim strips

b) ZE/MF mineral-bound screed or cast asphalt
on soft fibre or PST footfall sound insulation boards
Rim insulating strips: > 5 mm mineral fibre or PE-foam rim strips

c) TE dry screed
on mineral fibre, PST or soft fibre timber footfall sound insulation boards
Rim insulating strips: > 5 mm mineral fibre or PE-foam rim strips

With these formulas and the related tables shown, the vertical footfall sound transmission in consideration of secondary paths can now be calculated for the illustrated planning example. In this process, respectively the two flank paths Df and DFf must be examined for all four walls of the analysed room, from which eight values result for $L_{n,ij,w}$. The following plan excerpt (see Figure 12) shows the analysed room with the flanking walls to be considered for the footfall sound transmission.

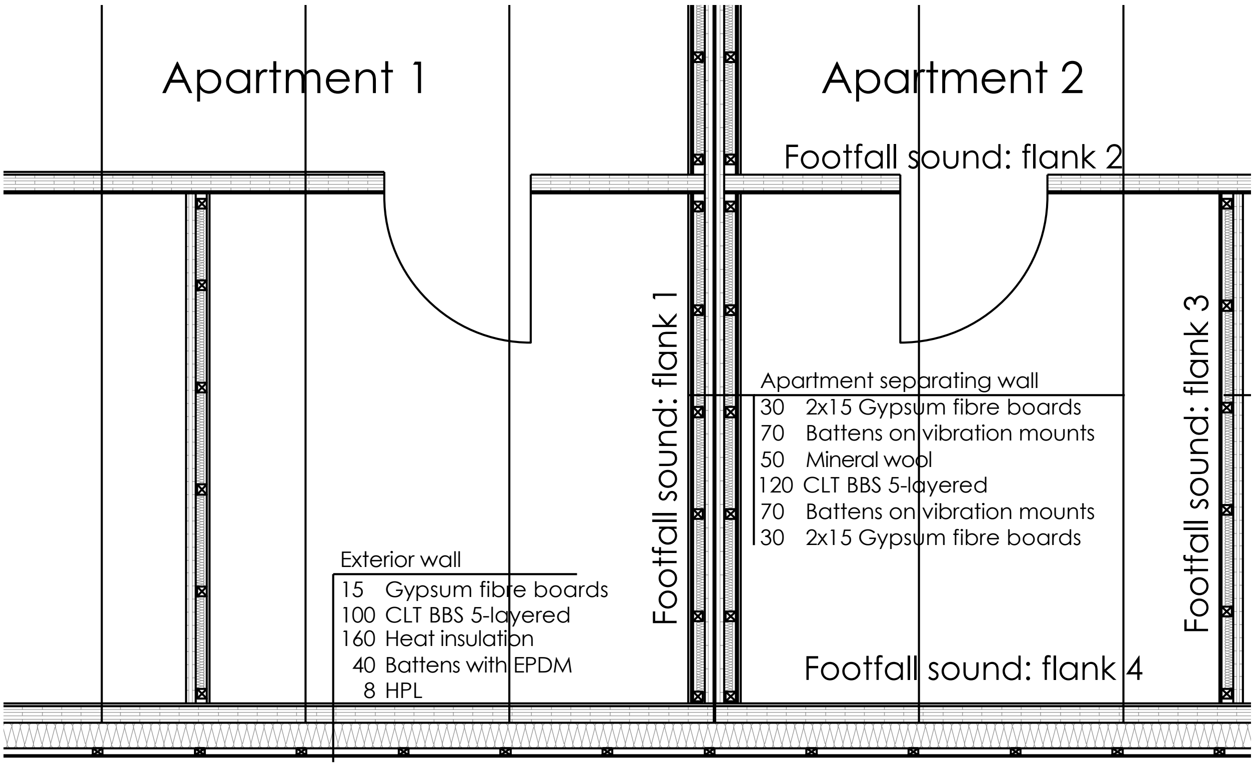


Figure 12 – Optimised apartment partition wall for the prevention of flank sound transmission

Secondary paths to be considered for vertical footfall sound transmission

1. Flank ceiling – apartment partition wall

$L_{n,w}$ = 38 dB
S_S = 9.8 m²
l_f = 3.14 m
K_1 = 4 dB (from Table 1, CLT BBS 125 ceiling in visual surface quality, CLT BBS 125 walls in visual surface quality or directly planked without consideration of potentially planned facing formwork / installation levels)
$L_{n,Df,lab,w}$ = 39.8 dB (calculation according to formula 6)
$L_{n,DFf,lab,w}$ = 45 dB (from Table 2, CLT BBS 125 ceiling in visual surface quality, floor assembly with concrete screed and mineral fibre footfall sound insulation boards, rim insulation strips always required)
ΔK_{ij} = 0 dB (no elastomer at the top)
ΔK_{ij} = 3 dB (elastomer at the bottom, effective for both flank paths)
$\Delta R_{ij,w}$ = 18 dB (improvement value of a one-sided facing form work on vibration mounts with double 12.5 mm planking on CLT BBS 125 wall, 90 mm thickness, measuring results from binderholz / Rigips)

Calculation result:
$L_{n,Df,w}$ = 13.9 dB
$L_{n,DFf,w}$ = 14.1 dB

2. Flank ceiling – interior wall

$L_{n,w}$ = 38 dB
S_S = 9.8 m²
l_f = 3.12 m
K_1 = 4 dB (corresponding to flank 1)
$L_{n,Df,lab,w}$ = 39.8 dB (corresponding to flank 1)
$L_{n,DFf,lab,w}$ = 45 dB (corresponding to flank 1)
ΔK_{ij} = 0 dB (no elastomer at the top)
ΔK_{ij} = 3 dB (elastomer at the bottom, effective for both flank paths)
$\Delta R_{ij,w}$ = 0 dB (no facing formwork planned)

Calculation results:
$L_{n,Df,w}$ = 31.8 dB
$L_{n,DFf,w}$ = 37.0 dB

3. Flank ceiling – interior wall

$L_{n,w}$ = 38 dB
S_S = 9.8 m²
l_f = 3.14 m
K_1 = 4 dB (corresponding to flank 1)
$L_{n,Df,lab,w}$ = 39.8 dB (corresponding to flank 1)
$L_{n,DFf,lab,w}$ = 45 dB (corresponding to flank 1)
ΔK_{ij} = 0 dB (no elastomer at the top)
ΔK_{ij} = 3 dB (elastomer at the bottom, effective for both flank paths)
$\Delta R_{ij,w}$ = 15 dB (improvement value of a one-sided facing formwork on vibration mounts with single 15 mm planking on CLT BBS 125 wall, 90 mm thickness, measuring results from binderholz / Rigips) HolzBauSpezial conference transcript)

Calculation results:
$L_{n,Df,w}$ = 16.9 dB
$L_{n,DFf,w}$ = 22.1 dB

4. Flank ceiling – interior wall

$L_{n,w}$ = 38 dB
S_S = 9.8 m²
l_f = 3.12 m
K_1 = 4 dB (corresponding to flank 1)
$L_{n,Df,lab,w}$ = 39.8 dB (corresponding to flank 1)
$L_{n,DFf,lab,w}$ = 45 dB (corresponding to flank 1)
ΔK_{ij} = 0 dB (no elastomer at the top)
ΔK_{ij} = 3 dB (elastomer at the bottom, effective for both flank paths)
$\Delta R_{ij,w}$ = 0 dB (no facing formwork planned)

Calculation results:
$L_{n,Df,w}$ = 31.8 dB
$L_{n,DFf,w}$ = 37.0 dB

5. Calculation of the footfall sound transmission in consideration of secondary paths

Calculation $L'_{n,w}$ by means of the following formula

(2) $$L'_{n,w} = 10\log(10^{0,1\times38} + 10^{0,1\times13,9} + 10^{0,1\times14,1} + 10^{0,1\times31,8} + 10^{0,1\times37,0} + 10^{0,1\times16,9} + 10^{0,1\times22,1} + 10^{0,1\times31,8} + 10^{0,1\times37,0}) = 43.0 \text{ dB}$$

According to DIN 4109, 3 dB must be considered as forecast unreliability for the footfall sound:

$L'_{n,w}$ = 43,0 dB + 3 dB = 46.0 dB ≤ measured $L'_{n,w}$ = 46 dB

Proof of the footfall sound is thereby provided.

Remarks regarding the calculation example

Since the scientifically proven calculation described here differs from the requirements of DIN 4109, the proof for the separating ceiling must be rendered by means of a construction measurement.

Simplified in-situ correction:
for the calculation, the lab values $L'_{n,w}$ and R'_w of the direct transmission are converted to match the construction situation by means of the structure-borne sound resounding period of the ceiling in the lab, $T_{s,lab}$, and at the construction site, $T_{s,situ}$.

(7) $R'_{Dd} = R'_{situ} = R'_{lab} - 10\lg(T_{s,situ}/T_{s,lab})$ or

(8) $L'_{n,Dd} = L'_{n,situ} = L'_{n,lab} + 10\lg(T_{s,situ}/T_{s,lab})$

The effect of the in-situ correction (measured examples from the vibro-acoustics research project) is not considered in this calculation example; it results in a change of the calculated R'_w or $L'_{n,w}$ values of an averaged ± 1 to 2 dB.

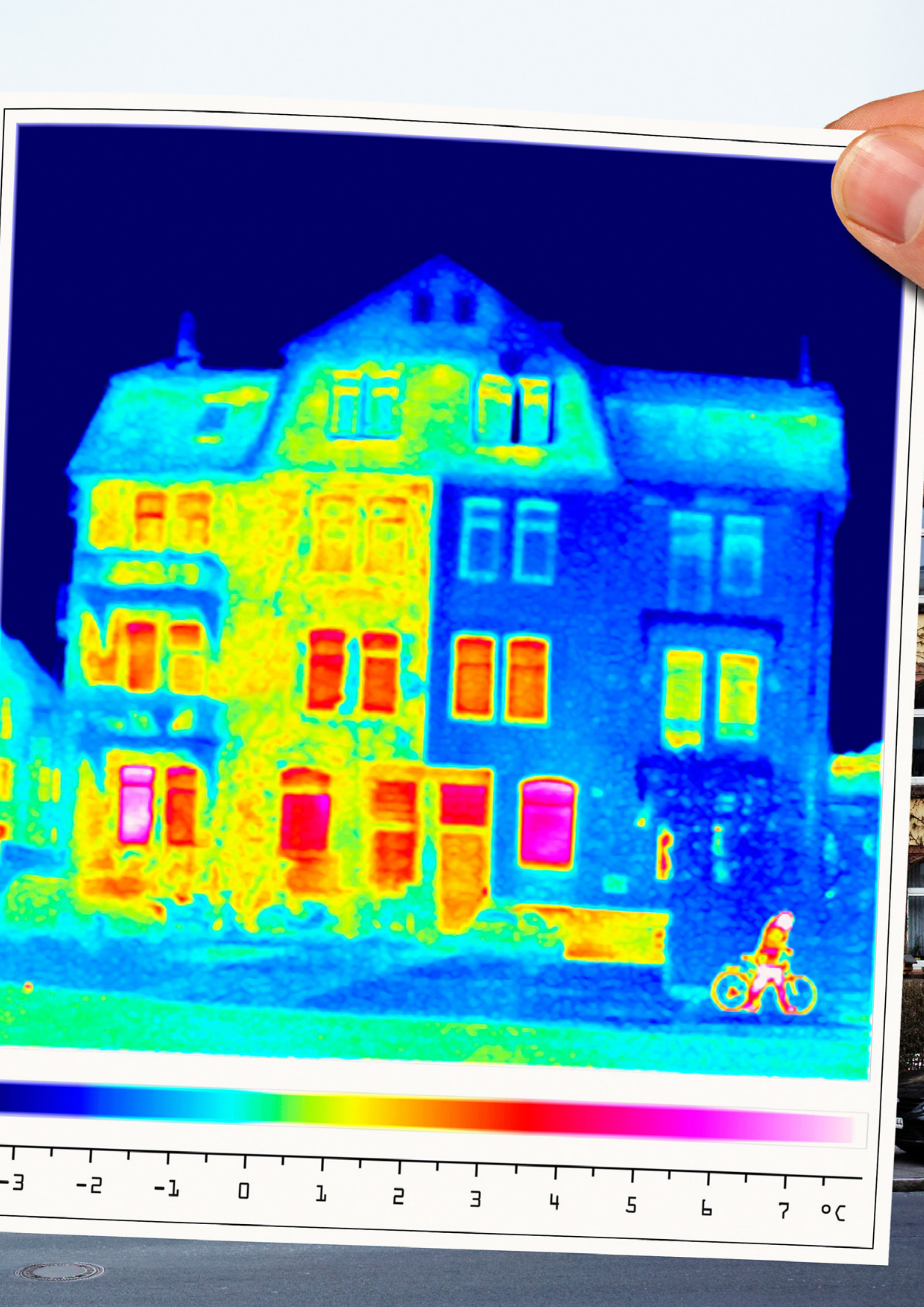
List of formulas on sound insulation

1	R'_{w} [dB]	Rated construction sound insulation value of a separating component (requirement for Germany) in installed condition with secondary paths
2	$L'_{n,w}$ [dB]	Standard footfall sound level (requirement for Germany) in installed condition with secondary paths
3	$R_{ij,w}$	Calculated flank insulation value of a separating component for the individual secondary sound paths with ij = Df, Fd, Ff
4	$L_{n,Df,w}$ [dB]	Footfall sound flank transmission on the path Df, converted to the construction situation
5	$L_{n,DFf,w}$ [dB]	Footfall sound flank transmission on the path DFf, converted to the construction situation
6	$L_{n,Df,\ lab\ w}$ [dB]	Lab value of the footfall sound flank transmission on the path Df
7	R'_{Dd}	Calculated sound insulation value of a separating component (requirement for Germany) with secondary paths and with in-situ correction
8	$L'_{n,Dd}$	Calculated standard footfall sound level of a separating ceiling (requirement for Germany) with secondary paths and with in-situ correction

Table of abbreviations, sound insulation

R_w [dB]	Rated sound insulation value of a component without secondary sound paths
$L_{n,w}$ [dB]	Rated standard footfall sound level of a component without secondary sound paths
$R_{i,w}$ [dB]	Air-borne sound insulation value of the flanking component in the transmitting room
$R_{j,w}$ [dB]	Air-borne sound insulation value of the flanking component in the receiving room
$\Delta R_{ij,w}$ [dB]	Improvement value of the flank sound insulation (air-borne sound and footfall sound) achieved through installation levels or stand-alone facing formwork
S_s [m²]	Surface of the separating component
l_o [m]	Reference length 1.0 m
l_f [m]	Length of the butt joint of the flanking component to the separating component [m]
K_{ij} [dB]	Joint insulation values for calculation of the flank insulation value Rij,w
ΔK_{ij} [dB]	Improvement of the footfall sound flank transmission achieved through decoupling elastomers
K_1 [dB]	Factor to calculate the footfall sound flank transmission on the path Df
K_2 [dB]	Factor to calculate the footfall sound flank transmission on the path DFf
$L_{n,DFf,lab,w}$ [dB]	Lab value of the footfall sound flank transmission on the path DFf
$D'_{nT,w}$ [dB]	Rated standard sound level difference of a separating component (requirement for Austria) in the built-in condition with secondary paths; resounding period in the receiving room is considered in it
$L'_{nT,w}$ [dB]	Standard sound level of a separating ceiling (requirement for Austria) in the built-in condition with secondary paths; resounding period in the receiving room is considered in it
m_1' [kg/m²]	Assessable surface measures of the flanking component (without the mass of potential facing formwork or suspended elements) for the calculation of the joint insulation value K_{ij}
m_2' [kg/m²]	Assessable surface measures of the separating component (without the mass of potential facing formwork or suspended elements) for the calculation of the joint insulation value K_{ij}

HEAT INSULATION


-3 -2 -1 0 1 2 3 4 5 6 7 °C

HEAT INSULATION / HUMIDITY REGULATION

Winter heat insulation

Heat insulation in construction above ground level covers all measures to avoid a need for heating during the winter and cooling during the summer. At the same time, more comfort because of a pleasant room climate and the related significant relief for the environment are key points. With insufficient heat insulation, uncomfortable and unhygienic room climatic living conditions can set in.

Why heat insulation?

- To increase comfort.
- To prevent illnesses.
- To save costs because heating costs can be reduced substantially.
- To increase the value of the building (energy costs).
- To protect our environment because the CO_2 emissions are significantly lowered.

binderholz CLT BBS

With cross laminated timber CLT BBS, low energy, passive energy and plus energy buildings can be constructed. CLT BBS structures fulfil all customary heat insulation values and create a comfortable and balanced room climate due to their permeable design and their capacity to lower the peak values of the humidity in the room.

Since CLT BBS is made of pinewood lamellas, which are subject to strict quality control, the moisture of CLT BBS wood in the condition as delivered is guaranteed to be within a very narrow range at 12 % ± 2 % and a controlled gross density is also assured. For this reason, an improved value for heat conductivity λ of 0.12 W/mK can be assessed for CLT BBS according to the valid ETA-06/0009.

Rigips dry construction systems

Modern timber structures in the passive and multi-comfort design using systems of Saint-Gobain guarantee the highest measure of quality. A comprehensive product range of Saint-Gobain insulating materials is available for floors, walls, ceilings and roofs. The range includes everything from normal heat insulation to complete system solutions for residential areas and for commercial and public buildings (see example in Figure 13).

Mineral fibre insulating materials of Isover with a λ of 0.034 W/mK and WDV systems of Weber offer the greatest comfort at the lowest insulation thicknesses. Rigips facing formwork and suspended ceiling and roof structures with complete hollow space insulation (for example Isover mineral wool) additionally contribute to the reduction of the U-values of building parts.

For the required improvement of the overall energy efficiency also in existing buildings, the dry interior finishing makes one of the most decisive contributions. The energy efficiency of existing buildings can be improved substantially in the finishing of existing roof structures. Besides the short construction periods, the resulting opportunity to update the building technology in the installation levels at the same time represents a particular advantage of dry construction.

Moreover, planking with Rigips boards and a volumetric weight of approx. 800 and up to 1200 kg/m² can contribute to increasing the component mass that has a capacity for storing heat and thereby to the summerly comfort.

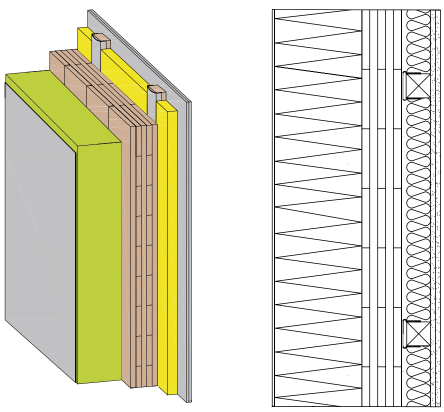


Figure 13 – Exterior wall 22 b

Summer heat insulation

Summer heat insulation (heat protection) helps limit the heat that is created in the interior of the building through the direct or indirect irradiation of the sun, which is usually largely due to irradiation through the windows, to a bearable measure.

This is done primarily by minimising the heat addition from the direct irradiation of the sun, reducing the heat conductivity of wall, roof and ceiling surfaces, and the waste heat of electrical devices and people. Windows without protection from the sun have the biggest effect on the heating of interior rooms.

Summer heat insulation is becoming more and more important, in particular in consequence of global climatic change and the trend toward rising temperatures. This is related to the increasing use of air conditioners, which in turn lead to climbing power and respectively energy consumption, and thereby also to increasing CO_2 emissions especially in the summer months.

This is why summer heat insulation has to be considered already in the building planning phase to avoid that buildings overheat during the summer resulting in uncomfortable room temperatures.

In residential buildings room temperatures in an average summer will remain below 27 °C due to nightly ventilation, low heat dissipation of devices, sun shading and heat storage. During heat waves, they are likely to rise somewhat. In offices, temperatures of below 26 °C are aimed for. In this regard, it is particularly important to pay attention, on the one hand, to corresponding sun shading devices that are installed on the outside of the windows, so that the "glasshouse effect" can be prevented and, on the other hand, to especially understanding and considering the summer behaviour of buildings and that of the users. Not only the occurring maximum temperature but also the period during which a certain temperature threshold is exceeded is significant for the user's subjective perception. The effect of the user behaviour on summerly room temperatures in consideration of various building materials or construction methods applied – light-weight construction, brick construction, concrete construction – has been analysed by measurements in occupied properties within the scope of a research project.

Parameters that influence the behaviour of not actively climate-controlled buildings during the summer or the room heating in consequence of summerly irradiation of heat are:

- the outdoor climate
- the thermal properties of the used components in the exterior area such as surface paint, heat insulation capacity, component assemblies or layer sequence, the capacity to store heat especially of components located on the inside, the overall degree of energy permeation, the size and orientation of the used glazing, existing sun shielding systems and their effects
- orientation of the exterior wall surfaces
- use of possibilities for night-time ventilation and the sun shielding equipment
- release of heat from electrical devices, illumination and people
- storage efficiency of items of furniture and structural design

The results of the research project show that regardless of the construction method, the building materials used, and the existing thermal storage of the mass in the interior room, it is the user behaviour and foremost incorrect use of ventilation possibilities that has a greater effect on the progression of summer room temperatures. At the same time, the nightly dissipation of heat through windows is decisive for the summertime thermal behaviour of rooms.

Ensuring comfort in the living rooms (see Figure 14) during frequently occurring heat periods is a central concern of Saint-Gobain Multikomfort. The aim is to reduce temperature peaks in the summer and increase comfort in the room. The Rigips Alba®balance full-gypsum boards developed for this purpose absorb the room heat that exceeds the comfort zone and release it again when there is sufficient nightly ventilation.

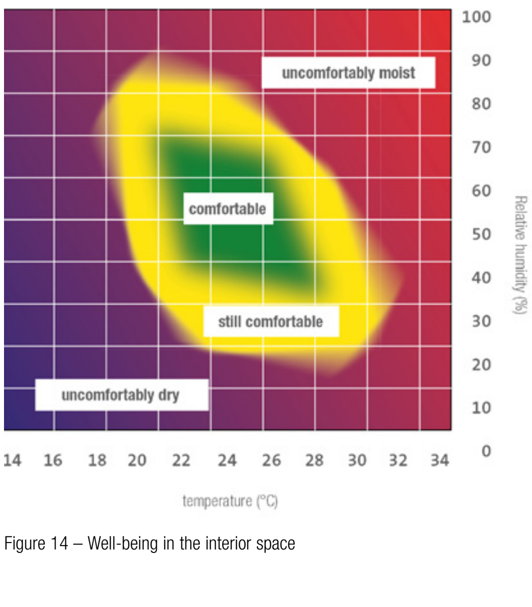


Figure 14 – Well-being in the interior space

Reasons why rapid air exchanges are incorrectly omitted in the summer:

- assumption that ventilation at night is not required in passive houses
- risk of falls in children's rooms (max. tilting of the windows)
- reduced ventilation effect because of insect screens
- pets (windows are tilted at most)
- ground floor apartments (for security reasons, windows are tilted at most)
- restriction of the ventilation effect for the apartment because of closed interior doors
- noise in the surroundings especially at night

In the summer, the daily fluctuations of the outdoor temperature are generally greater than in the winter. Moreover, there is a very high temperature difference on the component surfaces in consequence of the irradiation of the sun.

Measures for optimisation:

- increasing the heat insulation.
- Insulating layers placed on the outside and masses with the capacity of storage have favourable effects on indoor temperatures.
- Choice of windows: according to more recent building physical research, the heat permeability of windows has a much greater effect on the interior room temperature than the capacity of the interior masses to store heat.
- The kind of the chosen insulating material does not have such decisive importance. Instead, the thickness of the provided insulating layer, as well as the material type and thickness of the cladding facing the interior room are in the foreground of the examinations.
- Correct user behaviour: the room climate can be additionally improved by ventilation during the night and keeping windows and doors closed during the day.

The results of the scientific studies show that the summer heat insulation can be equated only to limited extent with the components' storage capacity. With a rising level of heat insulation, the summer temperatures in the room fall to a comfortable measure. CLT BBS elements have a positive effect in this because CLT BBS provides simultaneously good insulation from heat as well as excellent storage capacity. The simulation of a single-family home shows that with increasing heat insulation, temperature exceedances become much less frequent and are by far weaker. The experiences gathered by residents, too, show that comfort and room climate in timber houses are consistently evaluated as being positive also during the summer.

Humidity regulation

Wood as a natural and replenishable raw material has many positive building physical properties. One is the ability to absorb moisture and release it again. Thus, CLT BBS has a reducing effect on the peak values of humidity in rooms (see Figure 15). At a room temperature of 20 °C and relative humidity of 55 %, 1 m³ CLT BBS stores around 43 litres of water. If the relative humidity changes from 55 % to 65 %, 1 m³ CLT BBS absorbs a rounded 7 litres of water from the room air.

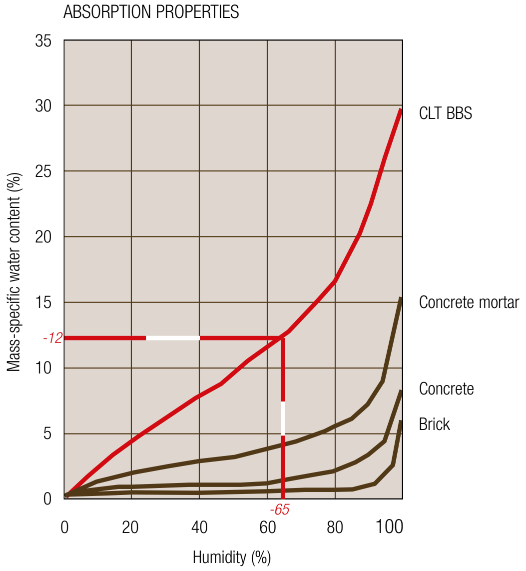


Figure 15 – Absorption behaviour of different building materials

binderholz CLT BBS

Wood is permeable for diffusion and therefore permits the autonomous movement of steam through building parts. This positive building physical attribute of cross laminated timber CLT BBS and its capacity to absorb room humidity without being damaged (absorption property) contribute decisively to a comfortable and balanced room climate.

Steam diffusion

The full-surface adhesive joints of CLT BBS are permeable for diffusion. Attempts by the adhesive manufacturer prove that the common adhesive joint has the same diffusion resistance as a 13-mm thick spruce board. CLT BBS is accordingly permeable for diffusion while it has a steam-reducing effect. These two positive characteristics are important criteria for a comfortable living climate. The glued single-layer CLT BBS boards do not have any effect on the diffusion behaviour of the complete structure. In principle, CLT BBS structures are designed without steam retardants or steam barriers. The suitability of the complete component must be proven in the individual case. All structures contained in this brochure have been tested in terms of building physics.

Rigips dry construction systems

Rigips controls the room climate Gypsum panels contain a great number of pores that absorb and store the moisture in the room when the humidity is temporarily increased. If the room air is dry, it releases the moisture to its environment again. This way, the room climate is automatically regulated. Rigips panels do not contain any health-hazardous substance such as heavy metals, biocides, formaldehyde or fine dust. Therefore, the products have been recommended by the Institut für Baubiologie Rosenheim [Rosenheim Instite for Building Biology] (IBR) and the Österreichisches Institut für Baubiologie und Ökologie [Austrian Institute for Building Biology and Ecology] (IBO) as a building material.

Convention

Due to the full-surface gluing of the CLT BBS elements, there are no hollow spaces that permit a convection. When installing built-in parts, it must be ensured that the construction is provided airtight to prevent convection through leakages.

Building physical parameters of CLT BBS

	Parameter	Remarks
Gross density	450 kg/m³	with a wood moisture of 12 % ± 2 % in the condition on delivery
Heat conductivity λ	0.12 W/mK	according to ETA-06/0009
Specific heat capacity	1,600 J/kgK	c_p according to EN ISO 10456
Water steam diffusion resistance factor μ	40 to 70, dependent on the wood moisture and number of glued joints	according to EN ISO 10456
Airtightness	airtight from 3-layered design	tested by Holzforschung Austria, expert report on request
Flammability	Euro class D-s2, d0	according to EN 13501-1

FIRE PROTECTION

FIRE PROTECTION

Components must maintain their function in the event of a fire during the required period of time. The capacity of a component is dependent on the interaction of the individual layers such as the load-bearing structure, the insulating materials and the planking.

Requirements for fire protection are defined, as described below, by means of fire resistance classes.

Fire resistance of components

In the event of a fire, the period during which a structure remains fire resistant is particularly important (see Figure 16). It is essentially determined by the interior cladding systems when there is a fire load on the inside. Gypsum boards contain crystal-bound water concentrations that serve as “firefighting water” in the event of a fire.

Figure 16 – Fire test with direct flame treatment

The following points have to be considered in a detailed fire protection plan:

- Planking facing away from the fire: ensuring the room partition
- Insulation: contribution to fire resistance, especially temperature distribution
- Load-bearing structure: preservation of the carrying capacity and minimisation of deformations caused by the temperature
- Component joints: prevention of the spreading of the fire and avoidance of hollow space fires, room partition, smoke tightness

Accordingly, the fire resistance of a structure is determined and specified for the entire assembly and not only for individual layers.

The rating of components’ fire resistance is made according to EN 13501-2. In timber construction, commonly the following classes are used (see Figure 17):

- R = carrying capacity
- E = room partition
- I = heat insulation

Carrying capacity R

Room partition E

Heat insulation I

Figure 17 – Designations for the fire resistance according to ÖNORM 13501-2 (Teibinger and Matzinger, 2013)

Example of typical fire resistance classifications of components in timber construction:

Designation	Requirement	Component example
R 30, R 60, R 90	Load-bearing component	supports, wall, beams, ceiling
EI 30, EI 60, EI 90	room partitioning, heat insulating component	non-carrying partitioning components, shaft walls, bulkheading, suspended ceiling
REI 30, REI 60, REI 90	carrying and room partitioning, heat insulating component	carrying partitioning component

Source: Teibinger and Matzinger, 2013

Moreover, special requirements may apply in the individual case such as

- M = resistance to mechanical effects (fire wall replacement wall)
- K_2 30 or K_2 60 for effective protection for 30 and 60 minutes respectively to prevent that timber structures protected by planks also catch fire

In Germany, there are the designations of “fire-retardant” or “highly fire-retardant” according to DIN 4109, which is equivalent of 60 and respectively 90 minutes of fire resistance.

Proof of the fire resistance of timber components is provided either by classification reports pursuant to EN 13501-2 based on large fire experiments or through a measurement pursuant to EN 1995-1-2 in combination with the respective national application document. All component assemblies contained in the Solid Timber Construction Manual have been rated in terms of fire protection by accredited institutes. The rating and the boundary conditions to be kept for this purpose (component dimensions and loads) are indicated on the individual datasheets.

Fire behaviour of building materials

Besides the fire resistance of the components, additional requirements may apply for the fire behaviour of building materials. In the evaluation of the fire behaviour of building materials, numerous characteristics such as ignitability, flammability, flame propagation and smoke development are considered. To make different materials comparable, there is a standardised testing procedure that is regulated by EN 13501-1. This standard evaluates all materials according to the following three criteria:

Fire behaviour

- non-flammable (A1, A2)
- hardly flammable (B, C)
- normally inflammable (D, E)
- easily flammable (F)

Smoke development

- Classes s1, s2, s3 (s1 = lowest value)

Blazing dripping

- Classes d0, d1, d2 (d0 = lowest value, non-dripping)

binderholz cross laminated timber CLT BBS components are attributed pursuant to EN 13501-1 to the Euro class D-s2-d0. This equals a normal flammability, the smoke development is modest and there is no blazing dripping. (see Figure 18)

Gypsum board or gypsum fibre board are attributed to the Euro class A2-s1-d0 and thus non-flammable. Insulating materials made of mineral wool are non-flammable and attributed to the Classes A1 or A2.

Figure 18 – Test procedure pursuant to EN 13501-1 to test the fire behaviour

binderholz CLT BBS in the event of a fire

Wood has the capacity of building up a protective layer of carbon in the event of a fire. It has an insulating effect, delays burn-off and counteracts fire propagation.

The burn-off speed of binderholz CLT BBS has been determined by comprehensive testing at accredited testing institutions. The carrying capacity of CLT BBS components in the event of a fire can therefore be calculated with high accuracy.

Thus, it is understandable that firefighter prefer deployments in plywood board structures over fighting fires in buildings with other construction designs. This is because they know how long they can stay in them without putting themselves in danger.

Classification of the fire resistance of CLT BBS components

To determine the fire resistance, comprehensive fire tests have been conducted on CLT BBS elements at various independent and accredited testing institutions. In the fire tests, not only large-area CLT BBS elements have been tested by themselves but also different connecting joints.

These are, like the component itself as well, smokeproof and gastight and they accordingly do not permit any burn-through (see Figure 19).

The classification of the assemblies in the Solid Timber Manual 2.0 was made by IBS Linz and MFPA Leipzig on the basis of the fire tests explained above. The classification is also shown on the individual datasheets.

Figure 19 – Smoke-tight butt joint through caulking strip and wooden riser

Burn-off behaviour of unprotected plywood boards according to EN 1995-1-2

The burn-off speed or the burn-off rate ß0 for pinewood according to EN 1995-1-2 is 0.65 mm/min and remains constant through the formation of a carbon layer on the surface. The glued layers in the plywood boards lead to local small-area chippings in the carbon layer through the softening caused by the temperature. Before the next layer on which the fire load is working has built up a carbon layer again (25 mm), this effect causes the burn-down rate to double to 1.3 mm/min. Thus, the first 25 mm of each new plywood board layer after a glued joint burns off at this increased speed (Teibinger and Matzinger, 2013).

Tested burn-off rates of binderholz CLT BBS

The burn-off rate β_0 indicates how many millimetres of wood in a large-surface application burn down per minute of the fire duration.

To determine this parameter of binderholz CLT BBS, representative plywood cross sections with and without fire protection planking have been treated with flames in the standard tests at accredited testing institutions. Wall and ceiling components that are or are not exposed to load have been tested this way.

Based on the results of these individual tests, the following burn-off rates can be expected on the safe side for the engineering measurement of the carrying capacity of binderholz CLT BBS in the event of a fire. Any potentially existing planking layers have no negative effects on the burn-off rates, which is why the burn-off rates for CLT BBS with and without initial protection by planking are considered to be equal.

For the protection period t_{ch}, the time until the burn-off starts behind the gypsum board planking, the values specified under β_0 can be measured, when Rigips RF fire protection boards, Rigidur H gypsum fibre boards or Riduro wooden building slabs are used.

Burn-off rate β_0

Component description	Burn-off rate β_0 [mm / min]
Wall, 3 or 5 or more than 5 layers, initially protected or unprotected, 30 to 90 min. fire duration	0.75
Ceiling, 3 or 5 or more than 5 layers, initially protected or unprotected, 30 to 90 min. fire duration	0.90

The measuring rules explained in this Section have been confirmed in an official expert report by an accredited testing institution.

Burn-off behaviour of CLT BBS components protected by gypsum boards

The time when the planking fails, t_f, as well as the time when the burn-off of the CLT BBS elements starts behind the protecting planking, t_{ch}, are required in order to calculate the burn-off of a structure without the good test results of the company binderholz purely on the basis of the Euro standard EN 1995-1-2 requires.

From the time t_{ch}, the carbonisation of the CLT BBS begins at a reduced burn-off speed. After this fire phase, the time t_f occurs, from which the planking fails by falling off. From this moment in time, the CLT BBS begins to burn off, according to the Eurocode model, at an accelerated speed of 1.30 mm/min.

Saint-Gobain Rigips Austria had its products used for fire protection

- Rigips RF fire protection board,
- Rigidur H gypsum fibre board,
- and Riduro wooden building slab

evaluated regarding t_{ch} and t_f on the basis of numerous fire tests. The table shows a summary of the results.

Calculation table for the burn-off rate of protected components

	Wall components	
	Hardwood with direct planking	Facing formwork in solid timber construction
t_{100}	2.8 * d – 22.7	2.8 * d – 22.7
t_{ch}	2.8 * d – 14	2.8 * d – 14
t_f	2.2 * d + 4	1.73 * d + 30.7

	Ceiling components	
	Hardwood with direct planking	Suspended ceiling in solid timber construction
t_{100}	2.8 * d – 22.7	2.8 * d – 22.7
t_{ch}	2.8 * d – 14	2.8 * d – 14
t_f	2.2 * d + 4	2.43 * d + 0.22

d: Plate thickness of the outer layer in mm and 80% of the thickness of the inner layers if multi-layered
t_{100}: Time of overtemperature of 100 K behind the planking
t_{ch}: Beginning of the burn-off behind the planking in minutes
t_f: Time of failure behind the planking in minutes

Advantages from the binderholz tests on the burn-off behaviour of binderholz CLT BBS

The protective effect of the gypsum boards can be assessed up to the time t_{ch} for initially protected components. Thereafter, the residual cross section of the binderholz CLT BBS is to be calculated by means of the average burn-off rate explained under the calculation table. This calculation method results in residual cross sections that come closer to the tested values than the conservative model of the Eurocode EN 1995-1-2.

Assessment software

The assessment program offered free of charge by binderholz contains the tested burn-off rates of CLT BBS. Likewise, the protection times of initially protected components can be entered here. Thus, it is possible to quickly and effectively render proof for the CLT BBS components in the event of a fire and it can be printed out and filed in a transparent manner. For testable structural analysis proof based on the Euro code 5, we can make a free assessment program available to you (see Figure 20) and which can be requested from bbs@binderholz.com. All relevant characteristic product values are saved in this program.

Figure 20 – binderholz DC structural analysis program

Fire stops in timber construction

Installations of building technology are usually also led through components forming fire sections.

In a research project sponsored by binderholz and Saint-Gobain Rigips Austria among others, practical construction solutions have been developed jointly with Holzforschung Austria for the use of fire stop systems in solid timber construction and the solutions have been fire-tested (see Figure 21).

The brochure shows solutions for line passages of water pipes or air conditioning ducts, as well as electrical wiring in solid timber elements, and details of connecting conduits on solid timber walls and ceilings (see Figure 22).

Figure 21 – Test of fire stops with Rigips solutions.

The manufacturers and product names of the various fire stop systems are specified in the planning brochure. The system's fire resistance and the boundary conditions to be observed for the installation are shown in tables.

In addition, in a research project at Technical University Munich, which is supported by binderholz and other companies (development of advanced design rules/details for multi-story buildings in solid timber design of building class 4), detail catalogues have been developed that are applicable in Germany up to the building class 4. Here, too, fire tests have been conducted that support the proposed solutions (see Figure 23).

Figure 22 – Planning brochure for fire stops in timber construction
Source: Holzforschung Austria

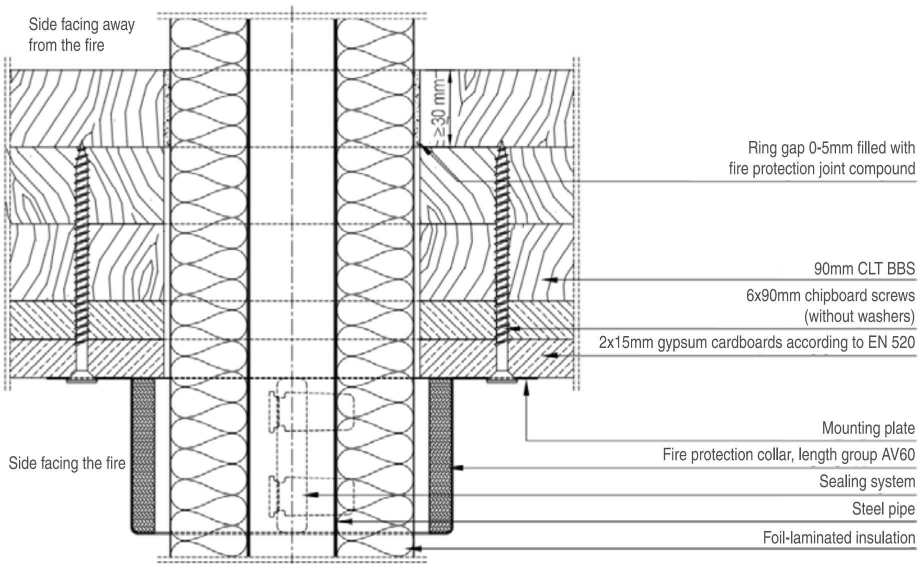


Figure 23 – Rigips classification: Installation of insulated tubes with an annular gap 0-10 mm

Fire protection evaluation of component joints

To prevent fires in buildings, it is not sufficient to know the fire resistance duration of the respective components. The interaction of the components joined with each other must also be considered, meaning the fire behaviour of connecting parts and installations. Spreading of the fire and smoke gases through hollow spaces and joints must be prevented.

Thus, the same requirements of fire resistance are posed for connections and passages as also apply to the respective individual components.

Figure 24 – binderholz processing guideline: Exterior wall-to-ceiling connection detail

To prove the fire resistance of the component joint, for example, between a CLT BBS ceiling in visual surface quality and a wall planked directly with 12.5-mm gypsum fire protection boards, several fire tests have been conducted.

It was shown that with a force-fit connection of the elements (fastener spacing up to 500 mm), a burn-through in the connecting joints can be prevented for 60 minutes. For the solid timber construction, a Sylomer bearing was inserted between the timber elements and the connecting joint was sealed with common retail acrylic or an intumescent product. It was shown that both versions fulfil the requirements for fire resistance.

Source: binderholz processing guidelines

At Technical University Munich, various connecting joints between walls and ceilings made of CLT BBS have been tested. The test duration was 60 minutes, the protection targets for the tested joints to be reached are smoke-tightness and preventing a burn-through for 60 minutes.

The fire protection board planking (gypsum fibre boards) abutted on the CLT BBS of the ceiling. Fire protection acrylic was plastered onto half of the joint length, the corner joint between the timber and the gypsum fibre board and the gypsum fibre board was set abut on the timber “dry” without sealing on the other half of the joint length.

An elastomer bearing was installed in the joint, which was protected on both sides by mineral wool strips. This protection measure is not required if the gap created by the elastomer bearing is filled with stone wool or fire protection mass. If no elastomer bearing is installed, no sealing measure is required. Figure 24 shows a planned joint and Figure 25 shows a realised butt joint before a fire test.

Source: Technical University Munich

Test results and rating in reference to the butt joint:

The butt joint of the wall covering on the uncovered ceiling did not result in a hollow space fire and continued smouldering in the connection area. No traces of fire could be found on the elastomer bearing. The described design of the butt joint with and without fire protection acrylic reached the protection targets, meaning smoke tightness and prevention of burn-through for 60 minutes.

The company Rothoblaas has conducted its own tests for its XYLOFONN elastomer bearings, in which the elastomer bearings were installed as a separating layer between solid timber ceiling elements not covered with planks. This design was tested successfully for smoke tightness and insulating effect for a fire duration of 60 minutes.

Figure 25 – Preparation for the fire testing of the elastomer bearing
Source: Technical University Munich

List of figures

Sources

Planning brochure of Holzforschung Austria	Planning brochure “Ceiling structures for multi-storey timber construction”, Holzforschung Austria
Vibro-acoustics research project	Calculations and measurements in the research project “Vibro-acoustics in the planning process for timber structures” of the collective industrial research 2017
Rothoblaas planning brochure	Rothoblaas planning brochure “Solutions for sound insulation – Flanksound Project”
Data from the DAGA 2010 conference transcript	Conference transcript DAGA 2010 “Butt joints in timber construction –planning, forecast and execution”
Technical University Munich	Technical University Munich “Development of advanced design rules/details for multi-story buildings in solid timber construction for building class 4”
binderholz processing guidelines	
Teibinger and Matzinger, 2013	Fire resistance classification and its requirement
Holzforschung Austria	Planning brochure of Holzforschung Austria, “Fire stops in timber construction”
Rigips Alba®balance brochure	Available online at: www.rigips.com / albabalance
8. HolzBauSpezial conference transcript	Forum Wood | Construction | Physics, Bad Wörishofen, 2017

Compilation of building physical parameters of some relevant materials in the datasheets of the Solid Timber Manual

Layer type	Building material	Heat conductivity λ [W / (m · K)]
Roof cladding	Gravel	0.700
Façade	Wooden exterior wall cladding	0.150
Façade	8 mm HPL-boards on 1.2-mm sealing tape	0.300
Insulation	Wood fibre insulating panel (under-roof panel)	0.045-0.05
Insulation	Wood fibre insulation panel	0.39-0.047
Insulation	Stone wool above-rafter insulation system, e.g. Isover Integra Basic	0.034
Insulation	Stone wool WDVS board Isover Sillatherm WVP 1-035	0.034
Insulation	Stoen wool flat-roof insulation, e.g. Isover S flat roof insulating panel	0.039
Insulation	Full-surface stone wool, e.g. Isover Integra AP Basic	0.034
Insulation	Mineral wool, e.g. Isover Akustic SSP2	0.039
Insulation	Glass wool WDVS Panel Isover Isocompact	0.034
Sealing	fabric-reinforced plastic welded sheeting (> 1.7 kg / m²)	—
Load-bearing structure	CLT BBS, 90 mm, 3-layered*	0.120
Load-bearing structure	CLT BBS, 100 mm, 5-layered*	0.120
Load-bearing structure	CLT BBS, 120 mm, 5-layered*	0.120
Load-bearing structure	CLT BBS, 140 mm, 5-layered*	0.120
Load-bearing structure	CLT BBS, 150 mm, 5-layered*	0.120
Substructures	Pinewood (squared timber, battens)	0.130
Planking	Rigips RF fire protection board	0.25
Planking	Rigidur H gypsum fibre board type GF-C1-I according to EN 15283-2	0.35
Planking	Riduro wooden building slab	0.25
Floor screed	Concrete floor screed	1.33
Floor screed	Rigidur or Rigiplan screed element	0.35
Floor screed	Rigidur screed element	0.35
Footfall sound insulation	Footfall sound insulation Isover Akustic EP1	0.032
Footfall sound insulation	Footfall sound insulation Isover Akustic EP2	0.035
Footfall sound insulation	Footfall sound insulation Isover Akustic EP3	0.04
Filling	Rigips balancing filling	0.16
Filling	Lime chippings filling	0.7

*μ value calculated for pinewood (μmin = 40) with additional assessment of 13 mm pinewood layer per glued joint existing on the cross section

Water steam diffusion resistance factor μ *min – max [—]*	**Gross density** ρ [kg / m³]	**Specific heat capacity** c [J / (kg · K)]	**Flammability class** EN 13501-1
1	1500	1000	A1
50	600	1600	D
17200	1350	—	B
3-7	210-270	2100	E
3-7	110-140	2100	E
1	110	840	A1
1	125	840	A1
1	150	800	A1
1	110	840	A1
1	25	840	A1
1	60	1030	A2
40,000	680	—	E
52	450	1600	D
61	450	1600	D
57	450	1600	D
55	450	1600	D
54	450	1600	D
50	500	1600	D
10	900	1050	A2
19	1200	1200	A1
10	1000	1050	A2
50-100	2000	1080	A1
19	1200	1200	A1
19	1200	1100	A1
1-2	80	840	A2
1-2	150	840	A1
1-2	150	840	A1
2	600	1000	A1
2	1500	1000	A1

1st edition, May 2019

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