Flanking Sound Insulation of Timber Walls combined with different Timber Hollow Box Floors

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Summary

A high quality of the acoustic performance is crucial in multi-storey apartment buildings in Switzerland.

To achieve this demanded high level of acoustic performance, it is of vital importance that the construction sector can calculate, within the design stage, the apparent airborne and impact sound insulation in the building. Therefor one needs numbers of the airborne and impact sound insulation of the used lightweight building elements with a high extent of accuracy. To produce such a database, sound insulation measurements were systematically conducted in a test facility for lightweight timber constructions. Both, the direct and flanking sound insulation of separating and flanking elements have been measured.

As part of these measurements, the flanking airborne and impact sound insulation of different timber wall constructions were measured in combination with different hollow box timber floors. The measurement results for the flanking sound insulation are presented in terms of the normalized flanking level difference, D_{nf} and the normalized flanking impact sound pressure level, L_{nf} for each wall construction. These results demonstrate that there are Swiss timber construction systems available that can provide a high level of acoustic insulation including the low frequencies down to 50 Hz.

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1. Introduction

Timber constructions are used for multi storey apartment buildings in Switzerland. Residents of these buildings demand a high quality of sound insulation between different apartments. Therefor it is crucial for consultants and the construction companies to be able to predict the impact and airborne sound insulation in these lightweight buildings.

Unfortunately there is still no prediction model of the impact and airborne sound insulation, valuable for all lightweight constructions.

As a consequence it is still necessary for each timber construction system to measure the direct impact and airborne sound insulation for the separating element in vertical transmissions and the flanking impact and airborne sound insulation for the flanking walls which are used as input parameters for the calculations of the apparent sound insulation in buildings.

To provide the required numbers for the airborne and impact sound insulation the lightweight construction test facility in Dübendorf (Switzerland) was constructed by the Bern University of Applied Sciences (BFH) in collaboration with the Swiss Federal Laboratories for Material Science and Technology (EMPA).

Both, the direct impact and airborne sound insulation of a variety of separating timber floor constructions and the flanking impact and airborne sound insulation of timber walls have been measured in the test device. This report presents the measurement results of the flanking impact and airborne sound insulation of different timber walls constructions.

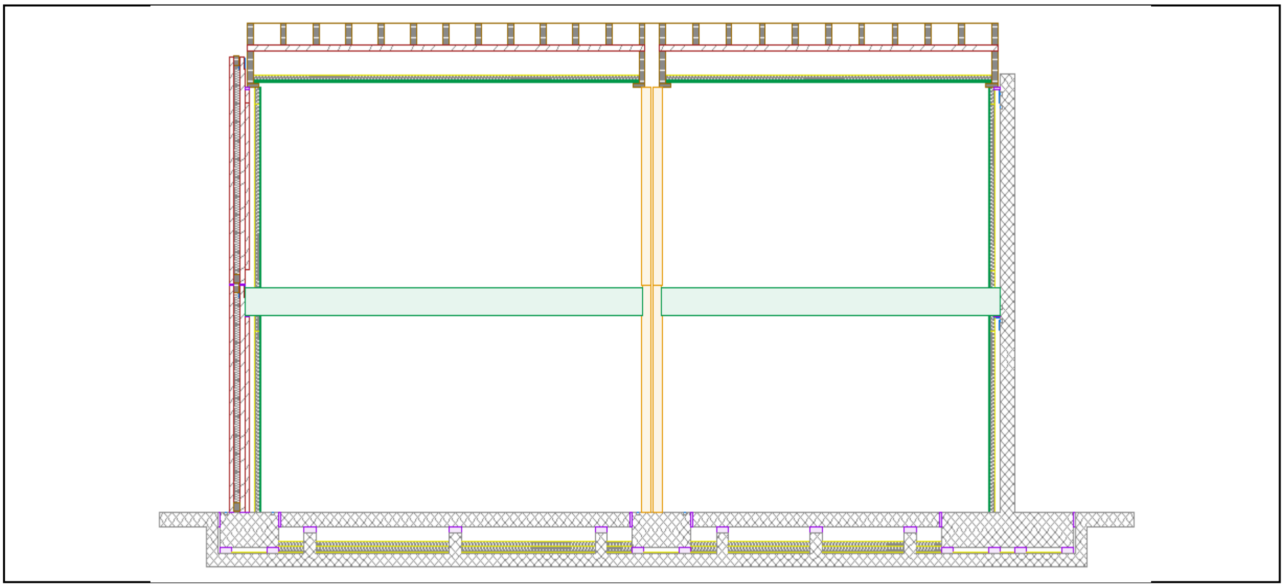


Figure 1.Vertical cut of the lightweight construction test facility with the maximum number of four rooms. The massive elements are grey shaded. The separating test walls are marked in brown. The massive and the *Default Elements* are covered by acoustical linings (green). The joists between the elements are in purple.

2. Construction of the test facility

The test facility consists of two massive concrete walls and a massive concrete plate. Within the massive frame of the laboratory, rooms of maximum 4 together (2 side by side and 2 above the other) can be built with lightweight elements.
Figure 1 shows a vertical cut of the set up with the maximal number of four rooms in the installation. It shows the different construction elements of the test facility: the massive walls and floor slab (grey hatched), the separating walls (brown), the separating lightweight floors (green) and the Default Elements at the left side forming the external walls of the rooms.

3. Measurement method

To separate the direct sound transmission via the separating timber floor from the flanking sound transmission via the flanking timber walls there are two necessary measurements. In the first measurement the direct sound insulation of the timber floor has to be measured. In the second measurement the direct sound transmission together with the flanking sound transmission of the timber post wall is measured. The sound insulation of the flanking timber wall is calculated as a difference of the second and first measurement.

1.1. Direct sound insulation of the separating floor

To distinguish the direct sound insulation of the separating element, the massive walls are covered with high quality acoustic linings. Furthermore special lightweight elements with minimized flanking sound transmission, called *Default Elements* are built in the test device.

Using this test setup for each timber floor the airborne and impact sound insulation between the two rooms are measured. The sound insulation is specified by the normalized level difference, D'_n for airborne noise, and the normalized impact sound pressure level, L'_n for impact noise. The measurements are carried out in accordance with EN ISO 10140-2 [1] for airborne noise and EN ISO 10140-3 [2] for impact noise.

The frequency range of measurements covers all the one third octave bands with center frequencies from 50 Hz to 5000 Hz.

If it is assumed that the direct sound transmission of the separating timber floor is much higher than the flanking sound transmission, the first measurements with *Default Elements* give approximately the direct sound transmission of the separating timber floor, D_n and L_n:

$$D_n \cong D'_{n,1} \tag{1}$$

$$L_n \cong L'_{n,1} \tag{2}$$

1.1.1. Construction of the separating floor

Two constructions of the separating timber hollow box floor have been measured. The major

difference between the two timber floors is the position of the weight load of the timber floor.
The two constructions of the separating floor are described in table 1.

Separating hollow box floor constructions	
Name	Description of the layer
F 1 Concrete plates on top of the hollow box floor	• 80 mm cement plate • foil • 20 mm mineral wool, dynamic stiffness s’= 9 MN/m^3 • 30 mm thermal insulation made of EPS • 60 mm concrete plates (60 cm x 60 cm) as weight load • 27 mm wood based panel • 240 x 80 mm wood beams with a separation of 625 mm and filled in with 160 mm of mineral wool • 27 mm wood based panel • 120 mm elastic slope of the suspended ceiling • 80 mm mineral wool in the cavity • 2 x 15 mm gypsum fibre boards
F 2 Gravel in the cavity of the hollow box floor	• 80 mm cement plate • foil • 2 x 17 mm mineral wool, dynamic stiffness s’= 9 MN/m^3 • 27 mm wood based panel • 240 x 80 mm wood beams with a separation of 625 mm and filled in with 160 mm of gravel • 27 mm wood based panel • 120 mm elastic slope of the suspended ceiling • 80 mm mineral wool in the cavity • 2 x 15 mm gypsum fibre boards

Table 1: construction layers of the two timber hollow box floors.

1.1.2. Measurement results of the direct sound transmission

Table 2 summarizes the measurement results of the direct airborne and impact sound insulation of the different floors in terms of single number ratings, the weighted normalized level difference, $D_{n,w}$, the weighted normalized impact sound pressure level, $L_{n,w}$, and the corresponding spectrum adaption terms in accordance with EN ISO 717-1 [3] and EN ISO 717-2 [4].

Floor	*Airborne sound insulation in dB*			*Impact sound insulation in dB*		
	$D_{n,w}$	C	$C_{50\text{-}5000}$	$L_{n,w}$	C_I	$C_{I,50\text{-}2500}$
F 1	>82	-3	-14	23	2	27
F 2	>85	-4	-8	21	1	19

Table 2: Measurement results of the direct impact and airborne sound insulation in terms of the single number ratings and the corresponding spectrum adaptation terms of the two hollow box floors

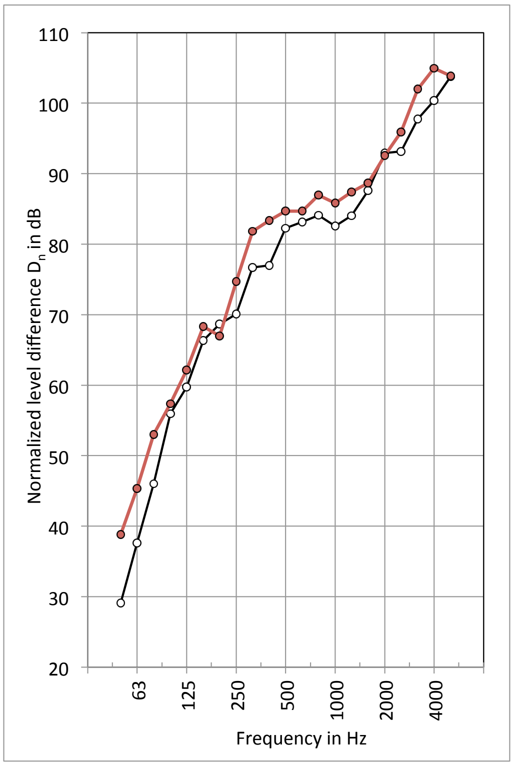


Figure 2: Measurement results of the direct airborne sound insulation of the two timber hollow box floors. The black graph represents the normalized level difference D_n of the timber floor type F1 with the concrete plates as a weight load. The red line shows the corresponding numbers of the timber floor type F2 with gravel as a weight load.

1.2. Flanking timber walls

To measure the flanking sound transmission of the walls a second measurement with the test specimen wall was carried out.

For this measurement two *Default Element* walls, one from the top and one from the bottom room, both on the same side of the laboratory, are replaced by the test wall.

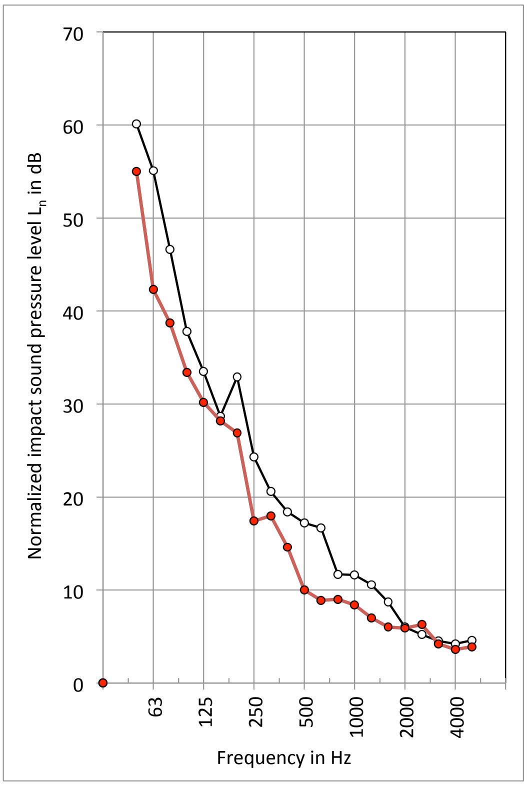


Figure 3: Measurement results of the direct impact sound insulation of the two timber hollow box floors. The black graph represents the normalized impact sound pressure level L_n of the timber floor type F1 with the concrete plates as a weight load. The red line shows the corresponding numbers of the timber floor type F2 with gravel as a weight load.

In a second measurement (in accordance with the same standards as for the direct transmission), the apparent normalized level difference, $D'_{n,2}$ and the apparent normalized impact sound pressure level, $L'_{n,2}$, between the two rooms were measured.

According to the standard EN ISO 10848-1 [5], the normalized flanking level difference, $D_{n,f}$, is defined as:

$$D_{n,f} = L_1 - L_2 - 10\log\left(\frac{A}{A_0}\right) \quad \text{in dB} \tag{3}$$

In which,

- L_1 is the time and space averaged sound pressure level in the source room in dB.
- L_2 is the time and space averaged sound pressure level in the receiving room in dB.
- A is the equivalent sound absorption area in the receiving room in m^2.
- A_0 is the reference equivalent sound absorption area, $A_0 = 10\ m^2$.

The normalized flanking impact sound pressure level $L_{n,f}$ is given as

$$L_{n,f} = L_2 + 10\log\left(\frac{A}{A_0}\right) \quad \text{in dB} \tag{4}$$

In which,

- L_2 is the time and space averaged sound pressure level in the receiving room in dB.
- A is the equivalent sound absorption area in the receiving room in m^2.
- A_0 is the reference equivalent sound absorption area, $A_0 = 10\ m^2$.

Equation (3) and (4) are only valid, if the flanking sound transmission of the test specimen wall is much higher than all other sound transmission paths between the two rooms.

In all other cases the flanking sound transmission has to be extracted out of the two measurements. The normalized flanking level difference $D_{n,f}$ is then calculated from the two measurements of the apparent sound insulation between the rooms, $D'_{n,1}$ and $D'_{n,2}$ according equation (5):

$$D_{n,f} = \begin{cases} D'_{n,2} \\ \quad for\ D'_{n,1} - D'_{n,2} \geq 15\ dB \\ -10lg\left(10^{-\frac{D'_{n,2}}{10\ dB}} - 10^{-\frac{D'_{n,1}}{10\ dB}}\right) \\ for\ 15\ dB > D'_{n,1} - D'_{n,2} > 6\ dB \\ D'_{n,2} + 1.3\ dB \\ \quad for\ D'_{n,1} - D'_{n,2} \leq 6\ dB \end{cases} \tag{5}$$

In which,

- D_{nf} is the normalized flanking level difference of the test specimen
- $D'_{n,1}$ is the normalized level difference between the two rooms, measured with the *Default Elements*.
- $D'_{n,2}$ is the normalized level difference between the two rooms with the test specimen wall

The corresponding formula for the calculation of the normalized flanking impact sound pressure level is given in equation (6).

$$L_{n,f} = \begin{cases} L'_{n,2} \\ \quad for\ L'_{n,2} - L'_{n,1} \geq 15\ dB \\ 10lg\left(10^{\frac{L'_{n,2}}{10\ dB}} - 10^{\frac{L'_{n,1}}{10\ dB}}\right) \\ for\ 15\ dB > L'_{n,2} - L'_{n,1} > 6\ dB \\ L'_{n,2} - 1.3\ dB \\ \quad for\ L'_{n,2} - L'_{n,1} \leq 6\ dB \end{cases} \tag{6}$$

Where

- L_{nf} is the normalized flanking impact sound pressure level of the test specimen
- $L'_{n,1}$ is the normalized impact sound pressure level between the two rooms, measured with the *Default Elements*.
- $L'_{n,2}$ is the normalized impact sound pressure level between the two rooms with the test specimen wall.

1.2.1. Construction of the flanking walls

The flanking sound transmission of different wall timber stud walls was measured. Table 3 presents the different constructions layers of the timber stud walls. These are described from the outside to the inside.

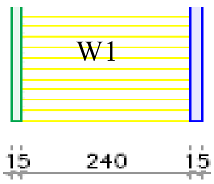
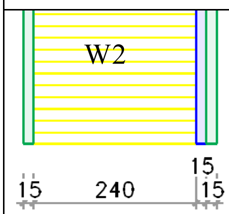
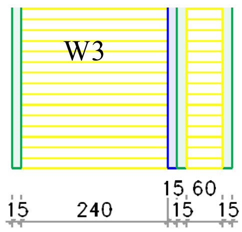
Wall Type	*Construction*
	• 15 mm Oriented strand board • Timber stud (240 mm x 60 mm) in a distance of 625 mm, cavity filled with mineral wool • 15 mm Oriented strand board
	• 270 mm Wall W1 • 15 mm Gypsum fibre board
	• 285 mm Wall W2 • 60 mm sub construction with 60 mm x 40 mm wooden laths, cavity filled with mineral wool • 15 mm Gypsum fibre board

Table 3: construction layers of the flanking timber post walls

1.2.2. Measurement results of the flanking sound insulation

The measurement results of the airborne sound insulation of the flanking walls in terms of the weighted normalized flanking level difference, $D_{n,f,w}$, and the spectrum adaptation terms C and $C_{50\text{-}5000}$ are summarized in table 4.

The measurement results of the flanking impact sound insulation in terms of the weighted normalized flanking impact sound pressure level, $L_{n,f,w}$, and the spectrum adaptation terms C_I and $C_{I,50\text{-}2500}$ are presented in Table 5.

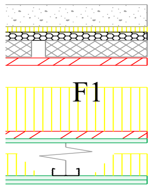
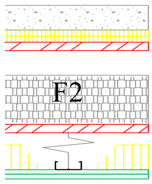
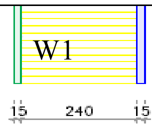
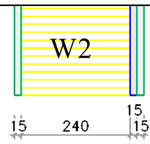
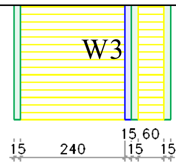
Floor Type		
Wall Type	$D_{nf,w}(C;C_{50\text{-}5000})$ in dB	
	61 (-2;-2)	62 (-2; -2)
	69(-4; -5)	71(-4; -4)
	73(-3; -8)	71(-2; -3)

Table 4: measurement results of the flanking airborne sound insulation of the timber walls in terms of the weighted normalized flanking level difference, $D_{n,f,w}$, and the spectrum adaptation terms C and $C_{50\text{-}5000}$

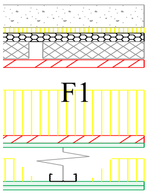
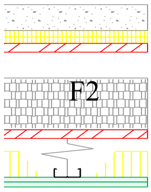
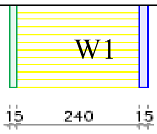
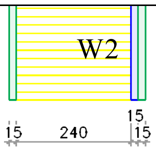
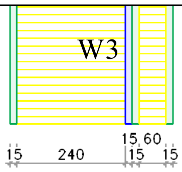
Floor Type	 F1	 F2
Wall Type	$L_{nf,w}(C_I;C_{I50\text{-}2500})$ in dB	
 W1 15 240 15	35(-3; 9)	40(-8; 2)
 W2 15 240 15 15	31(-1; 14)	32(-5; 8)
 W3 15 240 15 60 15 15	30(1; 16)	32(-2; 9)

Table 5: measurement results of the flanking impact sound insulation of the timber walls in terms of the weighted normalized flanking impact sound pressure level, $L_{n,f,w}$, and the spectrum adaptation terms C_I and $C_{I,50\text{-}2500}$

Figure 4 shows the flanking airborne sound insulation of the three wall constructions as normalized flanking level difference D_{nf} for the frequencies between 50 Hz and 5000 Hz.

Acknowledgement

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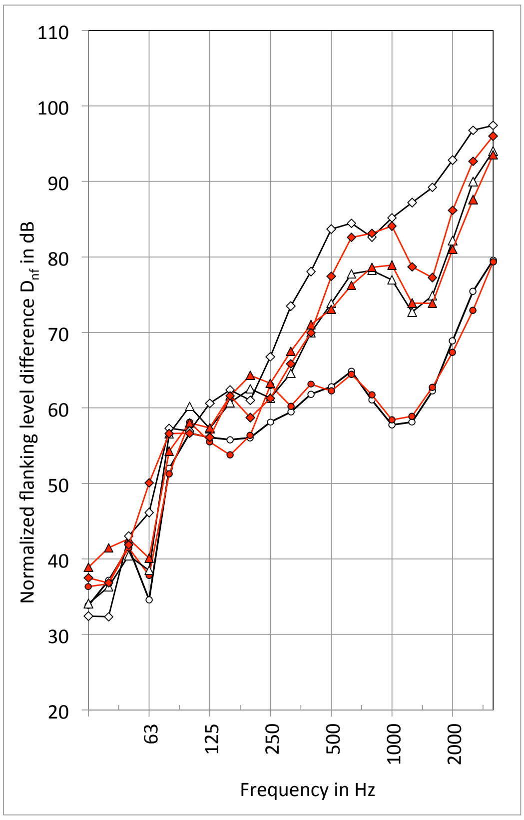

Figure 4: Measurement results of the flanking airborne sound insulation in terms of normalized flanking level difference D_{nf} of the three timber post walls. The circles represents the values for wall typ W1 (black line with timber floor type F1 and red line with floor type F2). The triangles show the values of wall type W2 (black line with timber floor type F1 and red line with floor type F2) and the rhombes mark the values for wall type W3 (black line with timber floor type F1 and red line with floor type F2)

References

[1] EN ISO 10140-2: 2010 Acoustics – Laboratory measurement of sound insulation of building elements – Part 2: Measurement of airborne sound insulation.

[2] EN ISO 10140-3:2010 Acoustics - Laboratory measurement of sound insulation of building elements – Part 3: Measurement of impact sound insulation.

[3] EN ISO 717-1:2013 Acoustics – Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation.

[4] EN ISO 717-2:2013 Acoustics – Rating of sound insulation in buildings and of building elements – Part 2: Impact sound insulation.

[5] EN ISO 10848:2006 Acoustics – Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms- Part 1: frame document.