MEASUREMENTS OF AIRBORNE AND IMPACT FLANKING SOUND INSULATION OF SWISS TIMBER CONSTRUCTIONS

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ABSTRACT

A high quality of building acoustic performance is crucial in multi-storey buildings. A laboratory facility was built in Dübendorf, Switzerland, in order to produce sound insulation characteristics data specific to lightweight constructions. The direct and flanking airborne and impact sound insulation are measured for walls and timber floors respectively, including a variety of constructions. Shown results indicate the presence of timber construction systems that can achieve high levels of acoustic insulation even at low frequencies.

Keywords: Building Acoustic, Sound Insulation, Measurement, Timber Construction

1. INTRODUCTION

Lightweight timber construction in multi-storey buildings is a fast growing market in Switzerland. It is very important that the construction sector can predict the airborne and impact sound insulation of lightweight buildings with a high extent of accuracy within the design stage. For these sound insulation predictions, measurement data of the direct and flanking sound insulation of the building elements are needed.

This document presents the results of airborne and impact flanking sound insulation measurement for six particular timber constructions. A further investigation of reducing flanking sound transmission by using resilient layers within the construction is also presented.

2. FLANKING TRANSMISSION MEASUREMENT PRINCIPLE

The lightweight construction test facility is a collaboration project between Swiss Federal laboratories for Materials Science and Technology (EMPA) and Bern University of Applied

Sciences (BFH) and is situated in Dübendorf, Switzerland. It consists of two massive concrete walls and a massive concrete plate. Within the massive frame of the laboratory, rooms of maximum 4 all together, can be built with lightweight construction elements, one above or side by side the other.

Measurement of normalized flanking airborne sound level difference between two rooms, $D_{n,f}$ and normalized flanking impact sound level, $L_{n,f}$ were conducted in accordance with international standard EN ISO 10848-1:2006 [1].

2.1. Flanking Transmission Of Airborne Sound

Normalized flanking level difference, D_{nf}, is defined in international standard EN ISO 10848-1:2006 [1] as "difference in the space and time averaged sound pressure level produced in two rooms by one or more sound sources in one of them, when the transmission only occurs through a specified flanking path"

$$D_{n,f} = L_1 - L_2 - 10\log\left(\frac{A}{A_0}\right) \quad \text{in dB} \qquad (1)$$

In which,

- L_1 is the average sound pressure level in the source room, in dB;
- L_2 is the average 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 = $10m^2$.

Equation 1 is 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. To achieve the definition given in EN ISO 10848:2006 [1], the following is carried out.

At first, airborne sound level difference, $D'_{n,max}$ is measured between the two rooms, when flanking transmission reduction is at its maximum. This measurement is performed when *Default Elements* are applied within the laboratory flanking paths. The measurement incorporating *Default Elements* is carried out in accordance with EN ISO 10140-2:2010 [2]. Definition and construction build up for the *Default Elements* are provided further in the document.

Secondly two *Default Elements*, one from the top and one from bottom room, both on the same side of the laboratory are replaced by the test specimen wall. In a second measurement, the normalized level difference, D'_n between the two rooms is measured according to procedure given in EN ISO 10140-2:2010 [2].

The normalized flanking level difference, $D_{nf,}$ is calculated from the two measurements of the sound insulation between the rooms $D'_{n,max}$ and D'_n according to:

$$D_{nf} = \begin{cases} D'_n \quad \text{for} \quad D'_{n,max} - D'_n > 15\text{ dB} \\ -10\log\left(10^{\frac{-D'n}{10}} - 10^{\frac{-D'n,max}{10}}\right) \quad \text{for} \quad 6\text{ dB} < D'_{n,max} - D'_n \leq 15\text{ dB} \\ D'_{n,} + 1.3\text{ dB} \quad \text{for} \quad D'_{n,max} - D'_n \leq 6\text{ dB} \end{cases} \qquad (2)$$

In which:

- D'_{nf} is the normalized flanking sound pressure level difference of the test specimen
- D'_{n} is the normalized sound level difference between the two rooms with the test specimen
- $D'_{n,max}$ is the maximal normalized sound level difference between the two rooms, measured with the *Default Elements*.

The corresponding equation for the impact sound is:

$$L_{nf} = \begin{cases} L'_n & \text{for } L'_n - L'_{n,min} > 15\text{dB} \\ 10\log\left(10^{\frac{L'n}{10}} - 10^{\frac{L'n,min}{10}}\right) & \text{for } 6\text{dB} < L'_n - L'_{n,min} \leq 15\text{dB} \\ L'_{n,} - 1.3\text{ dB} & \text{for } L'_n - L'_{n,min} \leq 6\text{ dB} \end{cases} \quad (3)$$

Where:

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

2.2. Default Elements For Maximum Sound Insulation Of The Testing Site

To detect the maximum sound insulation of the laboratory, the massive walls are covered with high quality acoustic linings. The *Default Elements* are double walls with massive timber plates with special lightweight elements which minimize flanking sound transmission used within the construction.

Layer	Thickness (mm)
Solid wood board	80
Cavity filled with mineral wool	100
Solid wood board	2 x 80
Cavity of the acoustic lining with sub construction and 100 mm mineral wool	175
Gypsum fibre board	2 x 12.5

Table 1. Construction build-up of the *Default Elements*.

The sound pressure level in the receiving room for the impact sound measurement was generated by placing a standard tapping machine on the floor. Six positions were used at fixed and randomly distributed locations. For the airborne noise, the sound pressure level was generated by placing a dodecahedron loudspeaker at two positions. Frequency range of measurements covers all the one third octave bands from 50 Hz to 5.000 Hz.

3. TEST SPECIMEN

3.1. Separating Timber Floor

The separating floor consists of a timber construction with timber beams and plates. In table 2 the different floor types that have been measured are described from top to bottom.

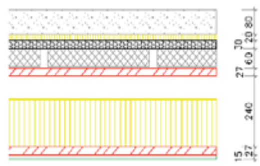
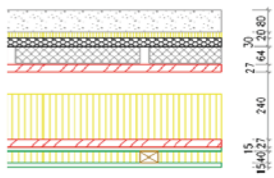
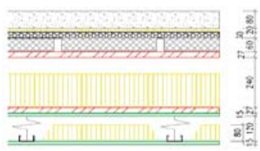
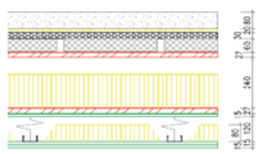
Construction Description	
Cement plate of the floating floor (80 mm)	
Mineral wool as impact sound insulation (20 mm; s'=9MN)	
Thermal insulation made of EPS (30 mm)	
Concrete plates as weight load (60 mm)	
Timber board as upper cladding of the timber floor (27 mm)	
Wooden beam, cavity in between filled with 16 cm mineral wool (240 x 80 mm)	
Timber board as lower cladding of the timber floor (27 mm)	
Gypsum fibre board (15 mm)	
Suspended ceiling with elastic fixings, a double cladding of 15 mm gypsum fibre board and a 80 mm thick layer of mineral wool inside the cavity (135 mm)	
Type Floor 1	
Without a suspended ceiling	
Type Floor 2	
With a suspended ceiling with a stiff sub construction consisting of wooden laths and single cladding of 15 mm gypsum fibre boards	
Type Floor 3	
With a suspended ceiling with fixings using resilient elements and a single cladding of 15 mm gypsum fibre board	
Type Floor 4	
With a suspended ceiling with fixings using resilient elements and a double cladding of 15mm gypsum fibre board	

Table 2. Description of the different floor constructions from top to button.

The following table summarizes the acoustic measurement results, direct airborne and impact sound insulation of the different timber floors in terms of single number values, the weighted normalized sound level difference, $D_{n,w}$ and the weighted normalized impact sound pressure level $L_{n,w}$ and the corresponding spectrum adaption terms according to EN ISO 717 part 1 and 2 [3, 4].

Reference	Airborne Sound $D_{n,w}$ (C; $C_{50-5000}$)	Impact Sound $L_{n,w}$ (C_I, $C_{I,50-2500}$)
Floor Type 1	72 (-6; -13) dB	47 (0; 8) dB
Floor Type 2	74 (-7; -19) dB	43 (3; 15) dB
Floor Type 3	81 (-4; -18) dB	28 (6, 27) dB
Floor Type 4	80 (-3; -13) dB	23 (3; 23) dB

Table 3. Resume of the acoustic measurements of the direct airborne and impact sound insulation of the timber floors.

3.2. Flanking Timber Walls

To analyse the flanking sound transmission for timber stud wall constructions, the following walls have been built up with the Floor Type 3.

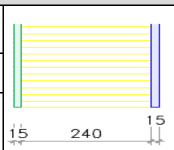
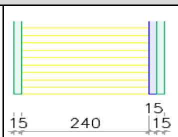
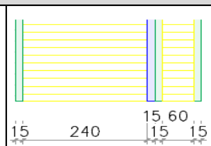
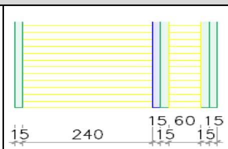
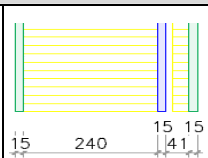
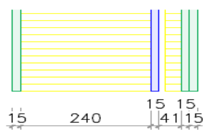
Description	
Wall Type 1	
Oriented strand board (15 mm) Timber stud in a distance of 625 mm, cavity filled with mineral wool (240 x 60 mm) Oriented strand board (15 mm)	
Wall Type 2	
Wall Type 1 + Second cladding of the timber stud wall with a gypsum fibre board (15 mm)	
Wall Type 3	
Wall type 1 + Rigid fixed acoustical lining with a single cladding, consisting of: • Sub construction with 60 mm x 40 mm wooden laths, cavity filled with mineral wool (60 mm) • Cladding of gypsum fibre board (15 mm)	
Wall Type 4	
Wall type 3 + Second cladding of the acoustic lining with a gypsum fibre board (15 mm)	
Wall Type 5	
Wall Type 1 + Elastic acoustic lining with a single cladding consisting of: • Sub construction of 24 mm x 48 mm wooden laths, with elastic fixings, cavity filled with mineral wool (41 mm) • Cladding of gypsum fibre board (15 mm)	
Wall Type 6	
Wall type 5 + Second cladding of the acoustic lining with a gypsum fibre board (15 mm)	

Table 4. Construction specifications for test timber stud walls from outer face to inner face.

The results of the measurements are presented in table 5 in terms of single number values, the weighted normalized flanking sound level difference, $D_{nf,w}$ and the weighted normalized flanking impact sound pressure level, $L_{nf,w}$ and the corresponding spectrum adaption terms.

Reference	Airborne Sound $D_{nf,w}$ (C; $C_{50\text{-}5000}$)	Impact Sound $L_{nf,w}$ (C_I, $C_{I,50\text{-}2500}$)
Wall Type 1	60 (-2; -2) dB	37 (-3; 18) dB
Wall Type 2	69 (-4; -7) dB	32 (1; 22) dB
Wall Type 3	73 (-2; -7) dB [1)]	35 (1, 20) dB
Wall Type 4	76 (-2; -8) dB [1)]	34 (1; 21) dB
Wall Type 5	87 (-5; -18) dB [1)]	28 (4; 26) dB
Wall Type 6	91 (-7; -22) dB [1)]	27 (4; 28) dB

[1)] Measures using the intensity probe. High airborne sound insulation of the flanking timber stud walls have been measured with an intensity probe according to EN ISO 15186 [5, 6].

Table 5. Single number values and the corresponding spectrum adaption terms of the sound insulation of the flanking airborne and impact sound insulation of the flanking timber walls.

3.3. Influence Of Using Resilient Layers

Floor type 3 together with wall type 1 and wall type 2 are used to investigate the influence of using resilient layer in the wall-floor-junction on sound insulation performance of timber construction.

The modifications to the base construction are as follow:

- Resilient layer between the upper and lower wall (position 1 in figure 1)
- Resilient layer between the ceiling and the lower wall (position 2 in figure 1)
- The two above together

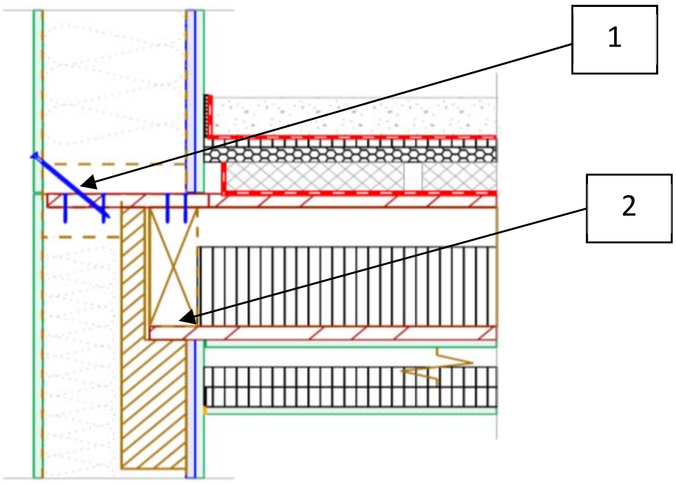


Figure 1. Basic construction of test junction indicating where the resilient layers have been introduced.

The following table shows the results of measurements of the different junction configurations in terms of single number values, the weighted normalized flanking sound level difference, $D_{nf,w}$ and the weighted normalized flanking impact sound pressure level, $L_{nf,w}$ and the corresponding spectrum adaption terms according to EN ISO 717 part 1 and 2 [3,4].

Construction Type	Test Junction Configuration	$D_{n,f}$ (C; $C_{50-5000}$)	$L_{n,f}$ (C_I; $C_{I50-5000}$)
Wall Type 1	Basic Construction	60 (-2; -2) dB	37 (-3; 18) dB
	Resilient layer between upper and lower walls	68 (-3; -5) dB	35 (1; 19) dB
	Resilient layer between ceiling and walls	66 (-2; -5) dB	32 (2; 23) dB
	Resilient layer between ceiling and wall + upper and lower walls	69 (-5; -8) dB	34 (0; 22) dB
Wall Type 2	Basic Construction	69 (-4; -7) dB	32 (1; 22) dB
	Resilient layer between upper and lower walls	76 (-5; -11) dB	33 (2; 22) dB
	Resilient layer between ceiling and wall +upper and lower walls	77 (-6; -15) dB	30 (4; 25) dB

Table 6. Single number values and spectrum adaption terms of the sound insulation of the flanking airborne and impact sound insulation of the flanking timber walls, using different configurations for wall test junctions with resilient layers.

4. CONCLUSIONS

The first measurement results of the sound insulation of Swiss timber floors and timber stud walls indicate that the airborne and impact sound insulation of these constructions are high enough to fulfil the enhanced requirements of the regulations in Switzerland, with a high standard of sound insulation, for multi storey timber construction buildings.

Regarding to the insertion of the resilient layers, it can be said that the airborne flanking sound insulation is improved for single and double leaf layers. The maximum insulation has been achieved when resilient layers are deployed in both locations (position 1 and 2).

The measurements are going on to determine the airborne and impact sound insulation of different types of timber constructions used in Switzerland. In the future, all the measurement results will be included in a web based database to provide input parameters which are required for predicting the sound insulation in lightweight buildings.

5. ACKNOWLEDGMENT

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6. REFERENCES

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

[3] EN ISO 717-1: 1997 Acoustics – Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation

[4] EN ISO 717-2: 1997 Acoustics – Rating of sound insulation in buildings and of building elements – Part 2: Impact sound insulation

[5] EN ISO 15186-1 Acoustics – Measurement of sound insulation in buildings and of building elements using sound intensity – Part 1: Laboratory measurements

[6] EN ISO 15186-2 Acoustics – Measurement of sound insulation in buildings and of building elements using sound intensity – Part 2: Field measurements