25-29 August 2024
inter.noise
NANTES FRANCE

Comparative study of different programs for sound insulation calculations of wooden structures

Klas Hagberg[1]
Luleå Technical University / Acouwood AB
Dockgatan 43
211 73 Malmö
Sweden

Delphine Bard[2]
Acouwood AB

Erik Nilsson[3]
Acouwood AB

ABSTRACT

Engineering programs for calculating sound insulation in wooden buildings are a shortage, especially when it comes to wooden structures. There are some possibilities today to calculate field values using commercial programs following ISO 12354. However, detailed calculations for each construction part are sometimes crucial to optimize correctly, specifically for CLT or wood beam structures since they are far more complex than traditional concrete structures. Now, some programs are available on the market to calculate sound insulation for CLT structures. Stora Enso offers "Calculatis" online for free, and Marshall Day Acoustics provides "INSUL 10". Recently, the company Sonusoft released a software called "Acoulatis". These three programs have slightly different approaches, and their capability to calculate various wall and floor structures differs. Nevertheless, the different programs are all limited to wall or floor construction parts, e.g., the outcome is R_w and $L_{n,w}$ including spectrum adaptation terms, e.g., junctions are not included. In this paper, a comparison is made using the three different programs, including comparisons to measured values when available.

[1] Klas.hagberg@acouwood.com
[2] Delphine.bard@acouwood.com
[3] Erik.nilsson@acouwood.com

Permission is granted for the reproduction of a fractional part of this paper published in the Proceedings of INTER-NOISE 2024 provided permission is obtained from the author(s) and credit is given to the author(s) and these proceedings.

1. INTRODUCTION

Acousticians are lacking helpful engineering prediction tools, especially when it comes to wooden buildings. That is a big problem for the industry in general since the lack of helpful tools creates a tendency to exaggerate necessary margins to fulfil requirements. Hence, the lack of prediction tools creates costly solutions due to these excessive margins usually used to make sure not to fail in the final building. Luckily, at least three different engineering tools are available to optimize the building parts, e.g., walls and floors. Two programs are limited to CLT structures, and one is more comprehensive.

- Acoulatis – CLT structures in the first release. Online software for purchase [1].
- INSUL 10 – CLT structures and any other layup with wood, steel, or concrete. Software requiring dongle [2].
- Calculatis – CLT structures based on StoraEnso CLT panels. Free online software [3].

While other tools are available that address specific transmission paths of walls and floors, such as flanking transmission following ISO 12354-1 and ISO 12354-2 [4,5], this paper concentrates on a comparative analysis of the three engineering tools mentioned above.

2. METHOD AND RESULTS

We have arbitrarily chosen some typical buildups to calculate and evaluate, commonly used in the European market, and then compared them to laboratory values if available. In instances we did not have laboratory values for the exact buildup we have instead recalculated the values based on field measurements of sound insulation values and the vibration reduction index, following ISO 16283-1, ISO 16283-2, and ISO 10848-1 [6,7,8].

Material data, such as dynamic stiffness, elasticity modules, and other important material characteristics vary between the construction elements. In this paper, we have done our best to use the same material data for each element, such as density, in each program. However, some material data cannot be varied in all programs (like the dynamic stiffness in INSUL and the elasticity modules in Calculatis). In this paper, we also limit the comparison to weighted single numbers, including some adaptation terms, due to the limited number of pages for this paper. We are aware that curves which include third-octave bands would be more valuable.

In an extended review article, our idea is to go deeper into details regarding material data but also include third-octave band curves.

2.1. Calculated wall configurations

We have made detailed comparisons of several different wall configurations and compared the results for each program, and if we have the lab values, they are also displayed. The following wall combinations are investigated:

- Calc. 1: CLT panel (CLT 100 C5s), 20/20/20/20/20
- Calc. 2: CLT panel (CLT 80 C3s), layer thicknesses not available
- Calc. 3: CLT panel (CLT 175 C5s), layer thicknesses not available
- Calc. 4, 5 and 6: Walls 4-6 according to Figure 1
- Calc. 7, 8, 9, 10, 11 and 12: Walls 7-12 according to Figure 2
- Calc. 13 and 14: Walls 13 and 14 according to Figure 3

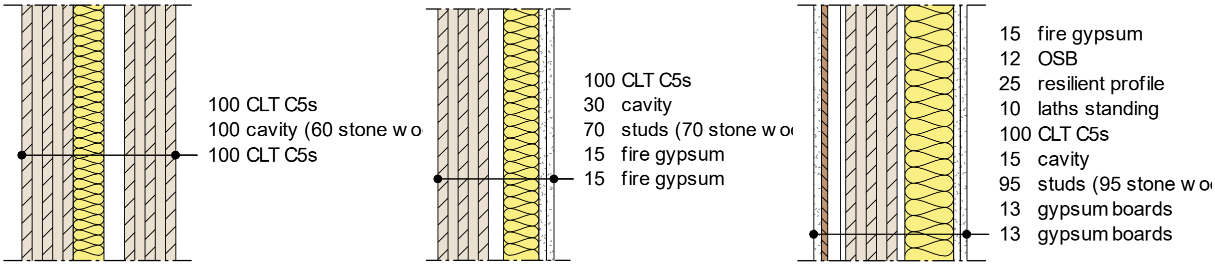

Figure 1: Wall configurations 4 to 6 with 100 CLT C5s (calculation no 4, 5 and 6).

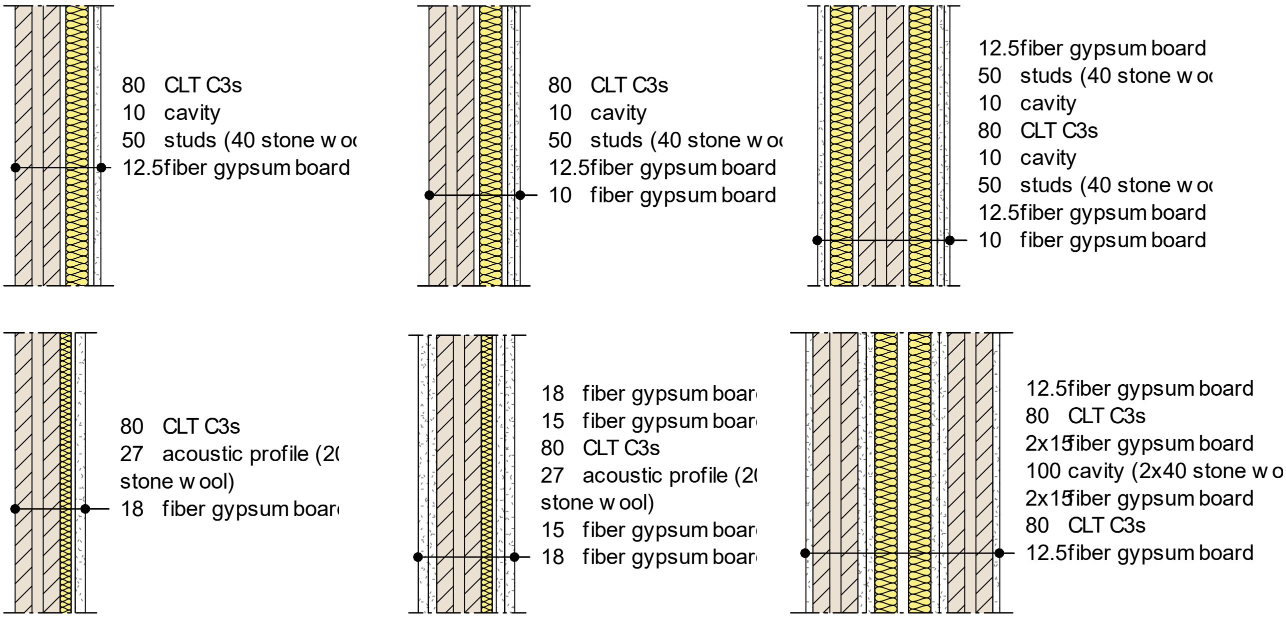

Figure 2: Wall configurations 7 to 12 with 80 CLT C3s (calculation no 7, 8, 9, 10, 11 and 12).

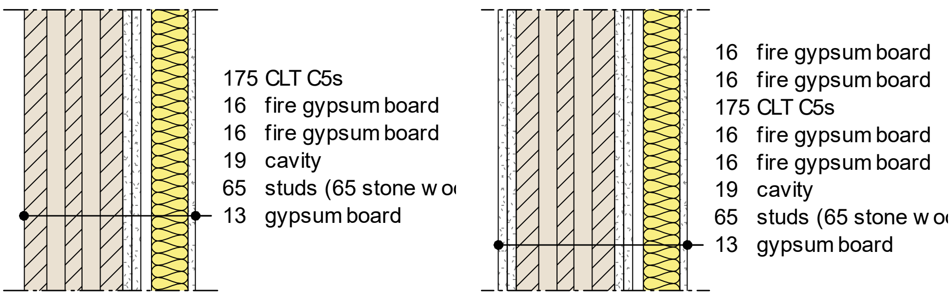

Figure 3: Wall configurations 13 to 14 with 175 CLT C5s (calculation no 13 and 14).

The calculated single numbers and two adaptation terms (*C* and $C_{50\text{-}3150}$) are displayed in Table 1 below.

Table 1: Calculated values R_w (C, $C_{50\text{-}3150}$) for the different walls in Figures 1–3. INSUL 10 and Calculatis are based on Stora Enso panels.

	Lab	Acoulatis	INSUL 10	Calculatis
	R_w (C, $C_{50\text{-}3150}$)			
CLT 100 C5s	--	37 (-1,-1)	33 (-1,-1)	34 (-1,-1)
CLT 80 C3s	33 (-1,-1)	33 (-1,-1)	30 (0,0)	33 (-1,-1)
CLT 175 C5s	39 (-2,-2)	39 (-1,-1)	40 (-1,-1) [4]	35 (-1,-1) [3]
Calc. 04	--	65 (-2,-4)	65 (-4,-7)	64 (-3,-5) [1]
Calc. 05	--	66 (-3,-10)	67 (-3,-13)	68 (-3,-7)
Calc. 06	--	70 (-6,-19)	72 (-12,-19)	67 (-3,-9)
Calc. 07	56 (-3,-5)	54 (-3,-7)	53 (-2,-7)	58 (-2,-6)
Calc. 08	61 (-2,-6)	60 (-2,-10)	59 (-2,-10)	64 (-3,-9)
Calc. 09 [2]	71 (-8,-13)	71 (-6,-23)	72 (-12,-25)	77 (-5,-23)
Calc. 10	49 (-2,-3)	48 (-3,-4)	45 (-4,-5)	41 (-1,-2)
Calc. 11	62 (-3,-5)	58 (-2,-6)	54 (-7,-8)	58 (-1,-2)
Calc. 12	78 (-1,-3)	74 (-2,-4) [5]	73 (-1,-2)	91 (-2,-9) [5]
Calc. 13	61 (-3,-6)	60 (-3,-6)	59 (-3,-6) [4]	62 (-2,-3) [3,5]
Calc. 14	60 (-2,-4)	61 (-3,-5)	60 (-2,-5) [4]	66 (-3,-4) [3,5]

1. Space between the panels and mineral wool thickness are equal.
2. The bad low frequency performance is more obvious when studying only single numbers from the calculations since no background noises are present compared to the laboratory.
3. Maximum size of calculation is CLT 160 for walls.
4. CLT 180 is the closest available in INSUL 10.
5. Boards cannot be placed inside a cavity. Instead, the directly attached boards are located to one side.

2.2. Calculated floor configurations

For floors, we have made detailed comparison of several different floor configurations and compared the results for each program, and in case we have the lab values they are also displayed. The following floor combinations are investigated:

- Calc. 1: CLT panel (CLT 140 C5s), 20/40/20/40/20
- Calc. 2, 3, 4, 5, 6 and 7: floors 2 to 7 according to Figure 4

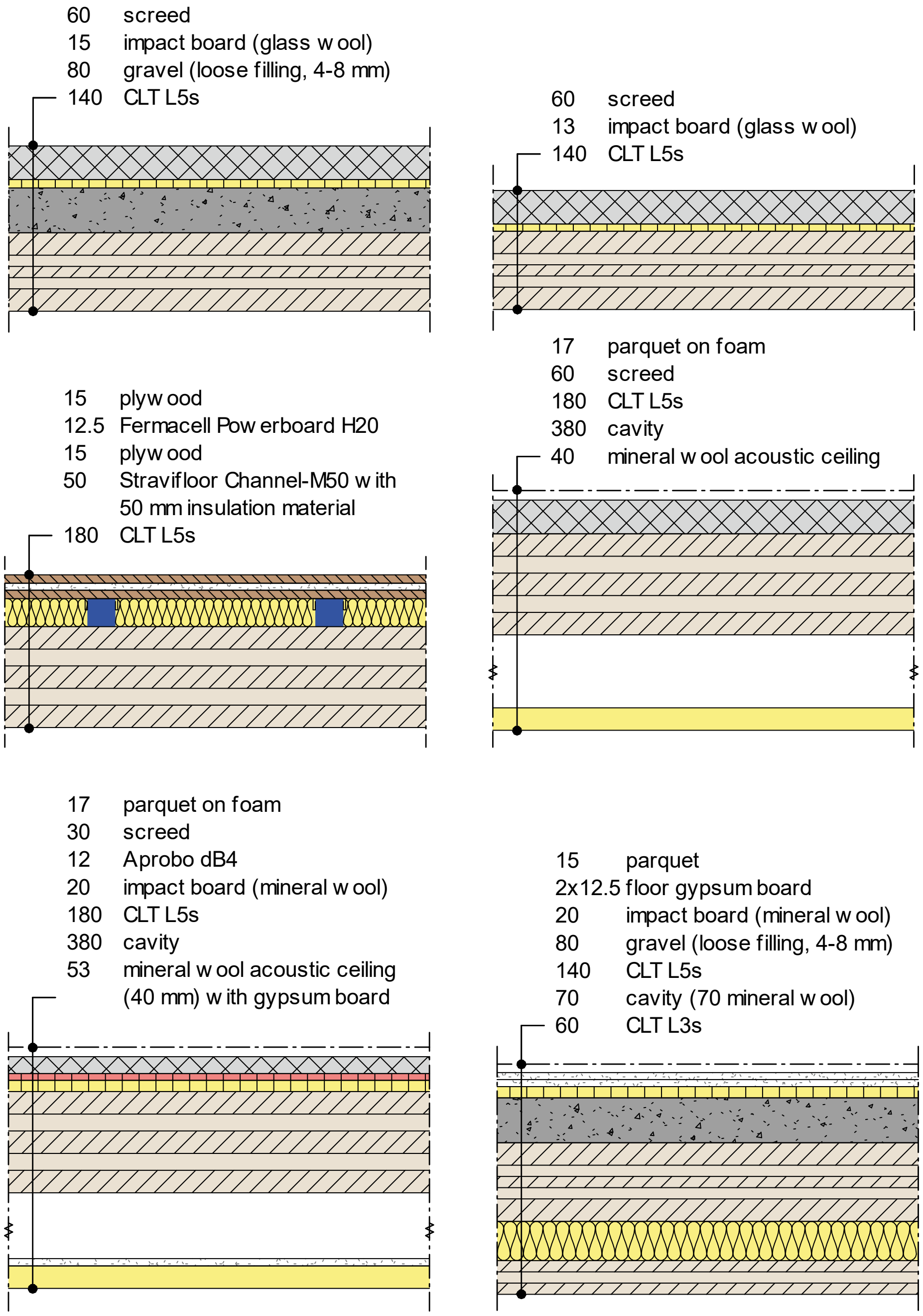

Figure 4: Floor configurations 2 to 7 with 60 CLT L3s, 140 CLT L5s or 180 CLT L5s.

The calculated single numbers for airborne and impact sound and corresponding adaptation terms (airborne: C and $C_{50\text{-}3150}$; impact: C_I and $C_{I,50\text{-}2500}$) are displayed in Table 2 and Table 3 below.

Table 2: Calculated values R_w (C, $C_{50\text{-}3150}$) for the different floors in Figure 4. INSUL 10 and Calculatis are based on Stora Enso panels.

	Lab	**Acoulatis**	**INSUL 10**	**Calculatis**
		R_w (C, $C_{50\text{-}3150}$)		
CLT 140 L5s	36 (-1,-1)	35 (-1,-1)	36 (-1,-1)	35 (-1,-1)
Calc. 02	68 (-2,-6)	66 (-2,-5)	51 (-1,-2) [4]	67 (-4,-5)
Calc. 03	52 (-2,-2)	51 (-4,-4)	47 (-1,-1) [3]	45 (-3,-3)
Calc. 04	63 (-2,-6)	62 (-4,-8)	48 (-2,-3) [2]	-- [1]
Calc. 05	51 (-1,-1)	53 (-1,-2)	52 (-2,2) [5]	-- [1]
Calc. 06	62 (-2,-5)	61 (-5,-6)	59 (-1,-1) [3,5]	-- [1]
Calc. 07	74 (-5,-11) [6]	73 (-6,-9)	77 (-1,-10) [3,4]	-- [1]

1. Raised floors, concrete directly on CLT and double CLT floors are not available in Calculatis.
2. The raised floor is modeled as a Stravifloor w/ HR50.
3. Impact boards are not available in INSUL, insulated panel is used instead.
4. The gravel is not available in INSUL and is instead modelled as a sand/cement render.
5. Acoustic ceiling chosen as an insulated panel.
6. Field measurement calibrated to lab measurement.

Table 3: Calculated values $L_{n,w}$ (C_I, $C_{I,50\text{-}2500}$) for the different floors in Figure 4. INSUL 10 and Calculatis are based on Stora Enso panels.

	Lab	**Acoulatis**	**INSUL 10**	**Calculatis**
		$L_{n,w}$ (C_I, $C_{I,50\text{-}2500}$)		
CLT 140 L5s	88 (-5,-5)	87 (-4,-4)	84 (-7,-7)	87 (-4,-4)
Calc. 02	53 (-3,1)	52 (0,3)	81 (-11,-11) [4]	52 (0,2)
Calc. 03	70 (-2,-1)	70 (-1,0)	86 (-12,-12) [3]	76 (0,0)
Calc. 04	54 (0,2)	54 (0,3)	66 (0,1) [2]	-- [1]
Calc. 05	60 (0,0)	62 (0,0)	64 (-1,1) [5]	-- [1]
Calc. 06	47 (1,7)	48 (2,5)	59 (0,3) [3,5]	-- [1]
Calc. 07	45 (1,9) [6]	47 (1,7)	33 (-1,1) [3,4]	-- [1]

1. Raised floors, concrete directly on CLT and double CLT floors are not available in Calculatis.
2. The raised floor is modeled as a Stravifloor w/ HR50.
3. Impact boards are not available in INSUL, insulated panel is used instead.
4. The gravel is not available in INSUL and is instead modelled as a sand/cement render.
5. Acoustic ceiling chosen as an insulated panel.
6. Field measurement calibrated to lab measurement.

3. ANALYSIS

CLT structures require several different layers attached to the panels in one way or another to fulfil high requirements, like for residential units, whether it is a floor or wall configuration. This fact makes it more difficult to create a model covering all options compared to homogeneous concrete structures. However, by using measured values from laboratories as a basis for predictions combined with general basic equations, models can be developed as the market develops and are constantly revised for better fittings. The three programs analyzed in this short investigation aim to cover some typical wall and floor structures based on CLT from different countries. INSUL 10 is the most extensive program, covering CLT, concrete, and traditional lightweight walls. The other two programs cover so far only CLT walls and floors, which is good since these structures need specific engineering models.

The accuracy of sound reduction single numbers for the walls included in this paper (pre-assuming that the lab values are correct) is shown in Figure 5 below and for the floors in Figure 6 below.

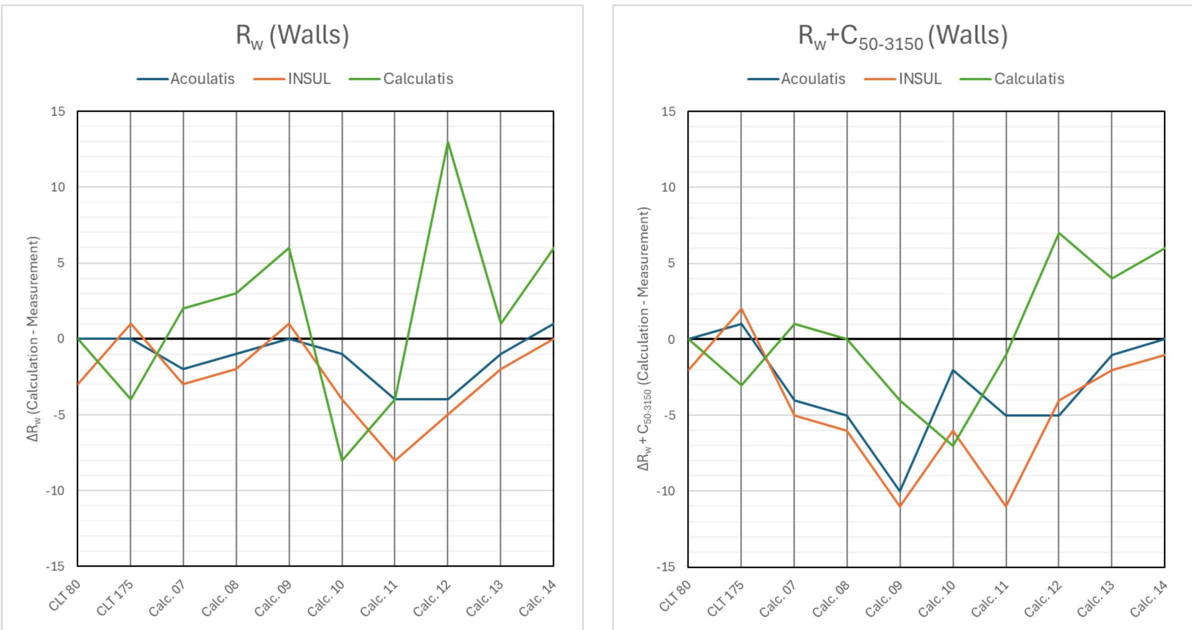

Figure 5: Deviation of calculated sound reduction single number for the three different programs, from corresponding laboratory measurement value for walls.

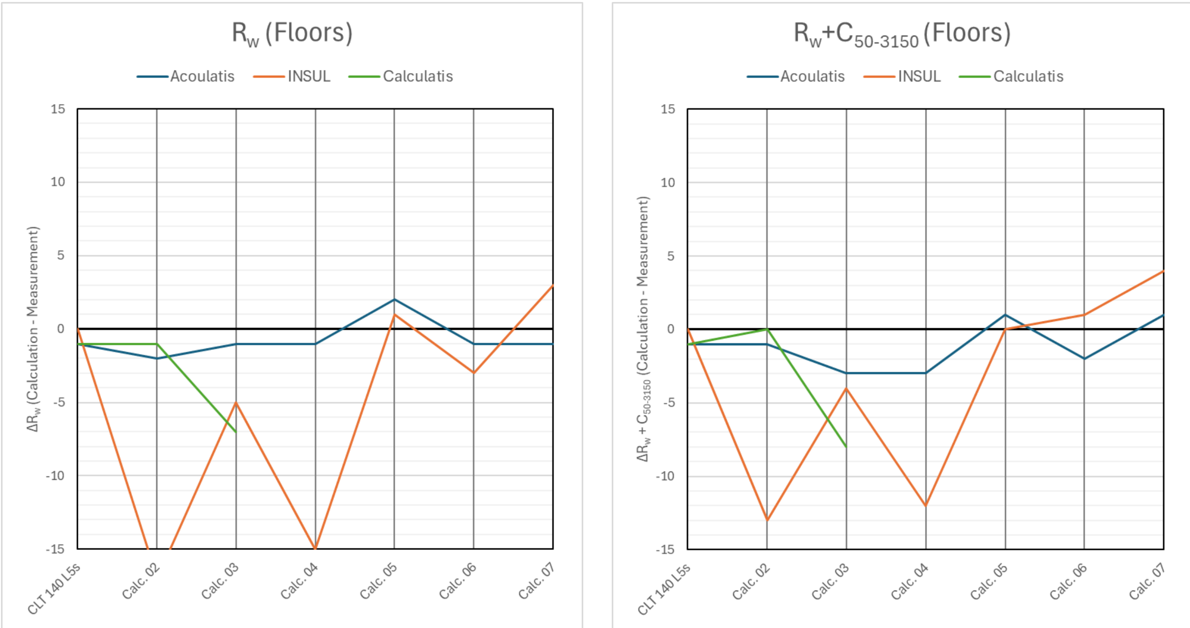

Figure 6: Deviation of calculated sound reduction single number for the three different programs, from corresponding laboratory measurement value for floors. No deviation in the curve means that the floor structure cannot easily be modelled.

The accuracy of impact sound level single numbers for the floors included in this paper (pre-assuming that the lab values are correct) is shown in Figure 7 below.

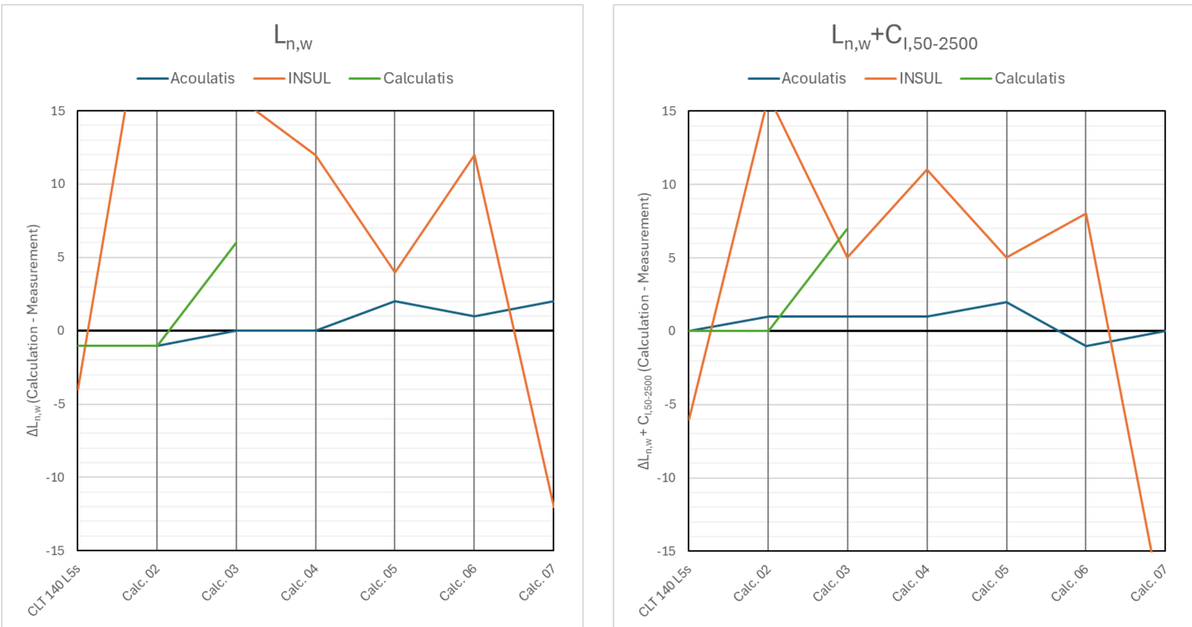

Figure 7: Deviation of calculated impact sound level single numbers for the three different programs, from corresponding laboratory measurement value for floors. No deviation in the curve means that the floor structure cannot easily be modelled.

4. DISCUSSION

The usage of engineering acoustic calculation tools must increase to provide more precise results regarding expected sound insulation and optimization of building partitions in daily acoustic building design. Still, acousticians often use general margins when designing buildings, especially when it comes to wood structures. Apart from building up floors and walls correctly, we also need to use available tools following ISO 12354, but that part is outside the scope of this paper.

The results presented in this paper are not intended to dictate which software is the safest or the best. Instead, they serve as a collaborative comparison, offering insights into the expected performance of various wall and floor configurations using CLT as a structural base. The more assistance we can gather, the more accurate our predictions become. Each program has its unique approach, with its own strengths and shortcomings, leaving the final decision in the hands of the users.

What is important for program developers to consider is that new products and, hence, possible configurations continue to enter the market, and the programs need to be continually updated and maintained. If not, they will lose attractivity in the long run.

REFERENCES

1. Sonusoft. Acoulatis – The acoustic prediction model for future buildings. https://www.sonusoft.com/acoulatis
2. INSUL. Predicting sound insulation. https://www.insul.co.nz/
3. Stora Enso. Calculatis. https://calculatis.storaenso.com/
4. ISO 12354-1. Building acoustics - Estimation of acoustic performance of buildings from the performance of elements. Part 1: Airborne sound insulation between rooms. International Organization for Standardization: Geneva, Switzerland, 2017.
5. ISO 12354-2. Building acoustics - Estimation of acoustic performance of buildings from the performance of elements. Part 2: Impact sound insulation between rooms. International Organization for Standardization: Geneva, Switzerland, 2017.
6. ISO 16283-1. Acoustics - Field measurement of sound insulation in buildings and of building elements. Part 1: Airborne sound insulation. International Organization for Standardization: Geneva, Switzerland, 2014.
7. ISO 16283-2. Acoustics - Field measurement of sound insulation in buildings and of building elements. Part 2: Impact sound insulation. International Organization for Standardization: Geneva, Switzerland, 2020.
8. ISO 10848-1. Acoustics - Laboratory and field measurement of flanking transmission for airborne, impact and building service equipment sound between adjoining rooms. Part 1: Frame document, 2017.