DETAILED ANALYSIS OF DIFFERENT SOFTWARE FOR SOUND INSULATION CALCULATIONS OF VARIOUS STRUCTURES

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ABSTRACT

Easily accessible engineering software to calculate the airborne and impact sound insulation of structural components are a shortage, which hinders the development of new efficient building systems and the inclusion of new environmentally friendly building materials. There are some good possibilities today to calculate field values using commercial programs following the series ISO 12354. However, these standards need to be fed with lab measurements or calculations of each product combination, and all possible product combinations can never be measured. Therefore, calculation tools for various floor and wall configurations are the key for the future development of new building systems and the verification of new materials in the structural components. Few software are available to calculate sound insulation for walls and floors in buildings. Stora Enso offers the CLT software "Calculatis", Marshall Day Acoustics provides "INSUL 10" and the company Sonusoft provides the software "Acoulatis". The three software have slightly different approaches, and so is their capability to calculate various wall and floor structures for CLT. In this paper, a detailed comparative analysis between the software is carried out, based on CLT combinations. The results presented also include comparisons to measured lab values in third octaves, single numbers, and spectrum adaptation terms.

Keywords: *sound insulation, building acoustic predictions, impact sound, airborne sound, calculations, software.*

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1. INTRODUCTION

To promote a sustainable development of future buildings with acoustically optimized building components (such as floor structures and wall structures), various calculation tools must become available to acousticians globally, but also used! To some extent acousticians are lacking helpful engineering prediction tools, especially when it comes to wooden buildings. However, acousticians show a tendency to avoid calculations and base the acoustic design in buildings by using comparable available measured data and local national tools. That is a big problem for the industry in general since this approach limits the possible material combinations when designing the building components and in addition, it creates non-scientific and unnecessary high margins to the actual 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. One software is limited to CLT structures, and two are more comprehensive.

- Acoulatis – CLT and concrete structures, and lightweight frame walls. Online software for purchase, accessible via web browsers [1].
- INSUL 10 – CLT structures and layups with other materials. 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 aimed to calculate laboratory values, mentioned above.

2. METHOD

Some typical floor and wall buildups commonly used in the European market have been arbitrarily chosen to calculate and evaluate with the different software mentioned in section 1. The calculations are then compared with laboratory values if available. We did not have laboratory values for the exact buildup of some instances and for those, we just compare the calculated values or in some cases the values were recalculated 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 software. However, some material data cannot be varied in all software (for example the dynamic stiffness in INSUL and the elasticity modules in Calculatis).

2.1 Calculated wall configurations

Firstly, three bare CLT walls were calculated to compare the basic model in detail, see Figure 1. The CLT walls have a mean density of approximately 470 kg/m^3.

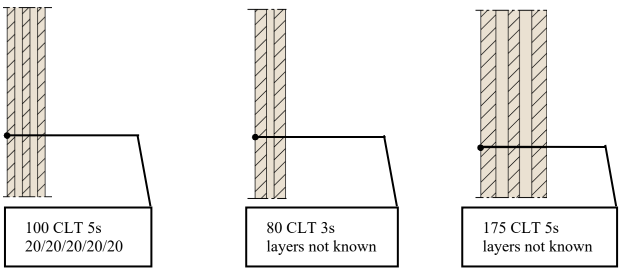


Figure 1. Bare CLT walls compared (calculation 01, 02 and 03).

Additionally, some typical "European" wall configurations are selected for modelling. They are primarily selected since data from lab measurements were accessible, which is considered valuable for the comparison. However, few walls are still selected since they represent a common configuration, but no measurements from lab are available to our knowledge. All wall configurations are shown in Figures 2, 3 and 4. The walls are then modelled in the three software and the results are compared and analyzed in third octaves from 50-5000 Hz (see section 3.1). The following wall combinations are included (apart from the bare CLT walls):

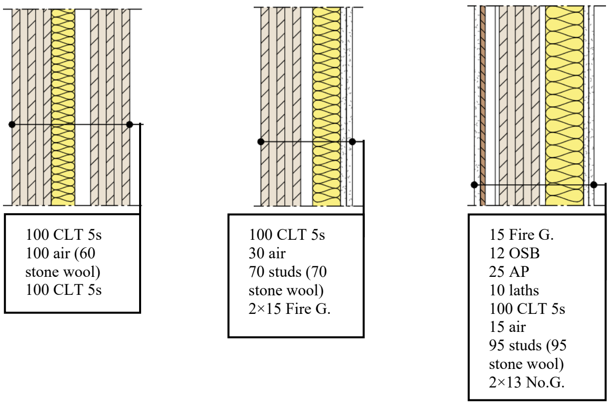


Figure 2. Wall configurations 04 to 06 with 100 CLT C5s (calculation 04, 05 and 06). Fire G. = fire gypsum; AP = acoustic profile; No.G. = Normal Gypsum

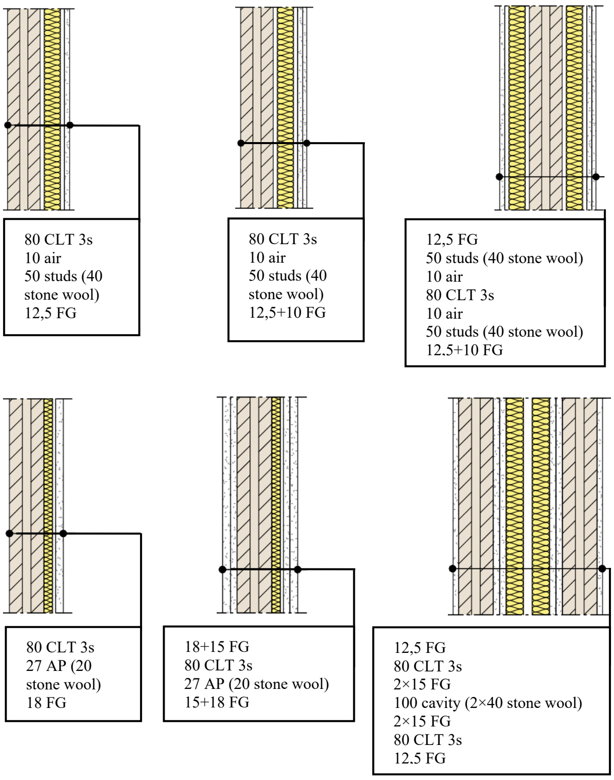


Figure 3. Wall configurations 07 to 12 with 80 CLT C3s (calculation no 07 to 12). FG. = Fibre gypsum; AP = acoustic profile.

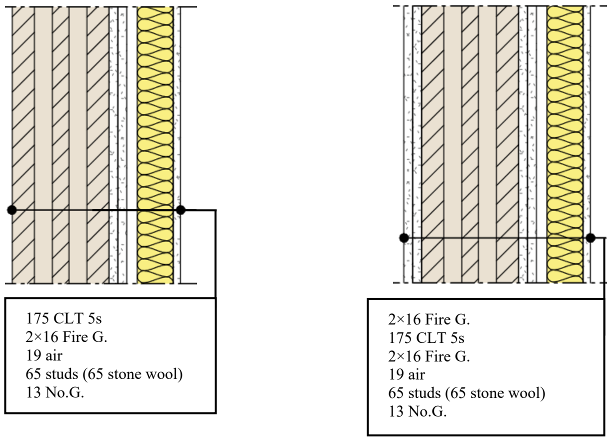


Figure 4. Wall configurations 13 and 14 with 175 CLT C5s (calculation 13 and 14). Fire G. = Fire gypsum; No.G. = Normal Gypsum

2.2 Calculated floor configurations

For the floor structures, calculations were carried out with some different thicknesses of the CLT plates and common material combinations (CLT 140, 180 and one example from a floor buildup typically used in volume elements). However, the possible combinations are close to infinity, implying that a rather small number of available floor constructions have been selected. Nevertheless, they represent some typical floor combinations, frequently used in Europe even if the manufacturers can vary from what is displayed in Figures 5 to 8.

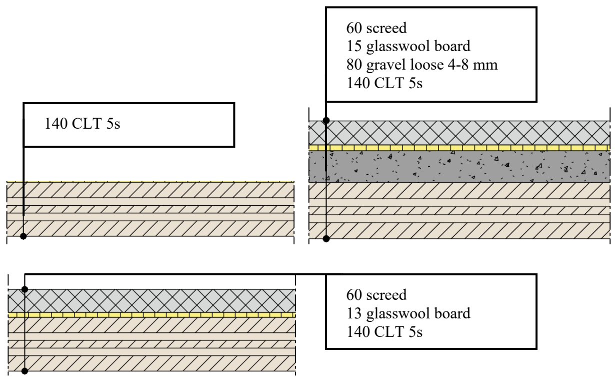


Figure 5. Floor configurations 01 to 03 with 140 CLT L5s (calculation 01 to 03).

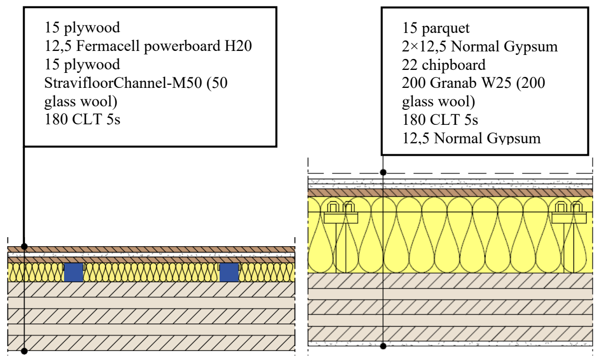


Figure 6. Floor configurations 04 to 05 with raised floor on 180 CLT L5s (calculation 04 to 05).

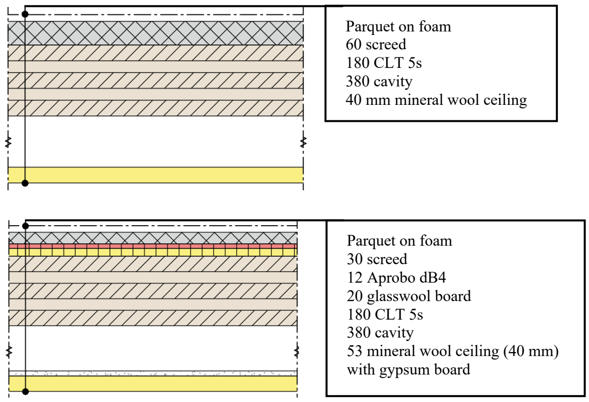


Figure 7. Floor configurations 06 to 07 with screed on 180 CLT L5s (calculation 06 to 07).

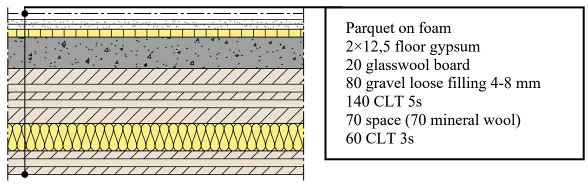


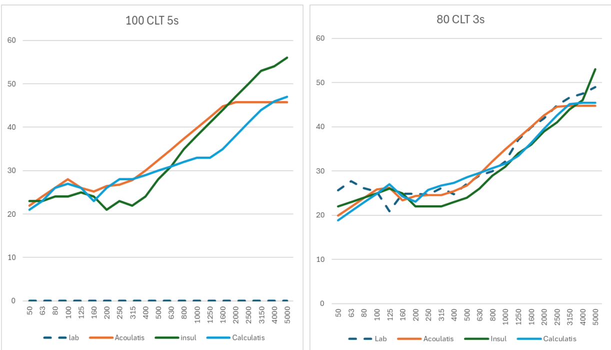
Figure 8. Floor configuration 08 (typical CLT volume elements, calculation no 08).

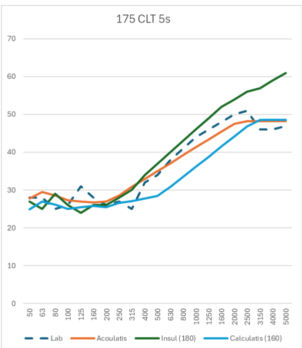
3. RESULTS

In this section, the results from all the different wall and floor configurations are shown. The results are shown in the same order as displayed in section 2.

3.1 Results from wall calculations

Below are the calculated results and they follow the same order as in section 2.1. In Figures 9 to 13, the results are shown in third octaves and the corresponding single number values are shown in Table 1 to Table 5 immediately after the corresponding figure with third octave band levels.





The calculated values for 175 CLT 5s is approximated in Calculatis and INSUL accordingly:

- Calculatis 160 CLT 5s
- INSUL 180 CLT 5s

This is because the maximum available wall structure thickness in Calculatis is 160 mm, and the 175 mm thickness is not available/cannot be modelled in INSUL.

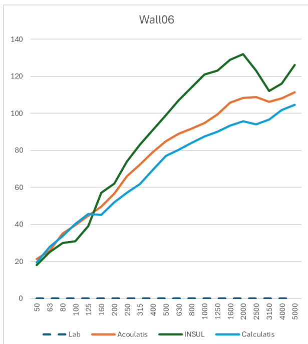
Figure 9. Bare CLT walls, calculated and measured values in 1/3rd octave bands.

Table 1. Corresponding single number values for Figure 9.

	Lab	Acoulatis	INSUL 10	Calculatis
	R_w (C, $C_{50\text{-}3150}$)			
100 C5s	--	37 (-1,-1)	33 (-1,-1)	34 (-1,-1)
80 C3s	33 (-1,-1)	33 (-1,-1)	30 (0,0)	33 (-1,-1)
175 C5s	39 (-2,-2)	39 (-1,-1)	40 (-1,-1)	35 (-1,-1)

The CLT models in INSUL 10 and Calculatis differ, since identical panels from Stora Enso exhibit different results for the 80 and 100 mm CLT plates depending on software. In reality, the panels are identical and therefore the results should be identical. For the 175 mm CLT, the differences are partly explained by the fact that 175 CLT cannot be modelled exactly in Calculatis and INSUL. The selections are fixed to specific panels. Therefore, the thickness of the CLT slab must be approximated to a thickness as close as possible to 175, that is 180 mm in INSUL and 160 mm in Calculatis.

Figure 10 shows the results from calculations of three common dwelling partition wall combinations in Scandinavia, with buildup according to Figure 2.



For wall 4 to 6, no lab data are available. The results shown are therefore just a comparison between the three software. The walls are chosen since they are common in the Scandinavian countries.

They have all been proved to fulfill $D_{nT,w}+C_{50\text{-}3150} \geq 52$ dB in finished buildings.

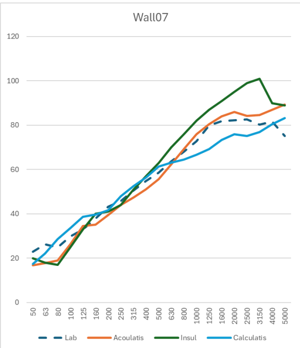
Figure 10. Three different wall configurations calculated, as described in Figure 2. No corresponding lab measurement data is available.

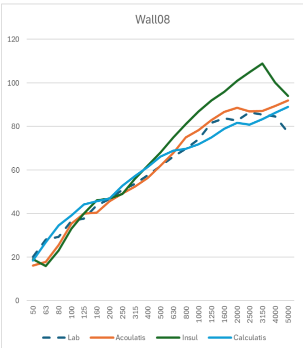
Table 2. Corresponding single number values for Figure 10.

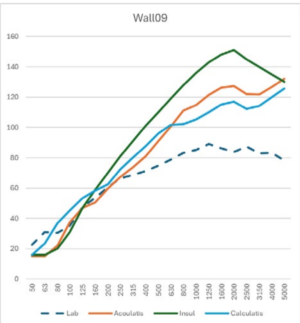
	Lab	Acoulatis	INSUL 10	Calculatis
	R_w (C, $C_{50\text{-}3150}$)			
Calc. 04	--	65 (-2,-4)	65 (-4,-7)	64 (-3,-5)
Calc. 05	--	66 (-3,-10)	67 (-3,-13)	68 (-3,-7)
Calc. 06	--	70 (-6,-19)	72(-12,-19)	67 (-3,-9)

All three software can model the walls in Figure 10 without specific adaptations or additional assumptions. Still the results differ and INSUL generally result in higher values in high frequencies and slightly lower values in low frequencies, ending up in larger negative values for the *C*-corrections compared to the other two software.

Figures 11 and 12 show the results from calculations of wall 07 to wall 09 (Figure 11) and wall 10 to wall 12 (Figure 12). Their buildups are shown in Figure 3 and CLT 80 3s is the base element. They might represent partitions for some high protection office spaces or in some countries for dwellings (wall 09 and wall 12).







For wall 09, the lab measurement is suspected to be affected by background noise and limitations in the laboratory, so the measurement data is likely not reliable in high frequencies.

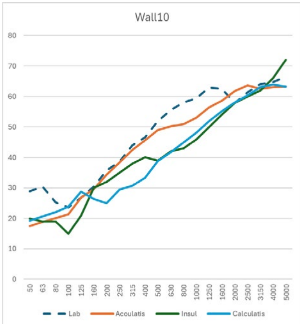
Figure 11. Three different wall configurations calculated, described in Figure 3.

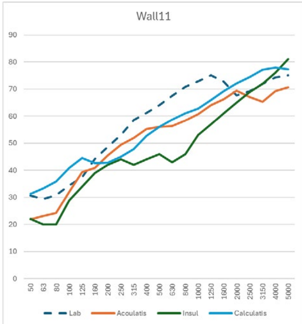
Table 3. Corresponding single number values for Figure 11.

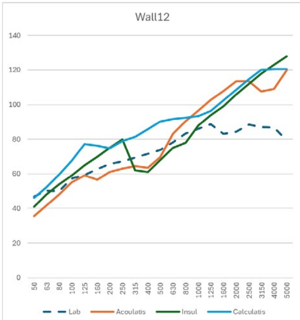
	Lab	Acoulatis	INSUL 10	Calculatis
	R_w (C, $C_{50\text{-}3150}$)			
Calc. 07	56 (-3,-5)	54 (-3,-7)	55 (-3,-9)	58 (-2,-6)
Calc. 08	61 (-2,-6)	60 (-2,-10)	61 (-2,-12)	64 (-3,-9)
Calc. 09	71 (-8,-13)	71 (-6,-23)	72(-12,-24)	77 (-5,-23)

There is generally a good agreement between the software calculations and corresponding laboratory data, except for wall 09, that has extremely good sound insulation in high frequencies compared to the laboratory measurement. For this wall, the calculated values should be more reliable than the laboratory measurement due to max values that can possibly be measured in a lab.

In Figure 12, the results for walls 10 to 12 are shown.







For wall 12, the lab measurement is suspected to be affected by background noise, hence it is not reliable in high frequencies.

Again, when high frequency levels are very high, the lab values show big errors.

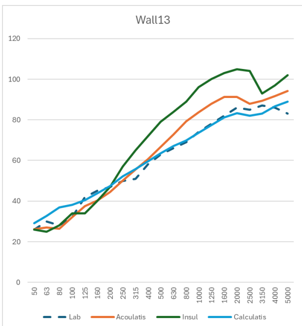
The model in Calculatis is approximated since it is not possible to attach any panels inside a cavity.

Figure 12. Three different wall configurations calculated, described in Figure 3.

Table 4. Corresponding single number values for Figure 12.

	Lab	Acoulatis	INSUL 10	Calculatis
	R_w (C, $C_{50\text{-}3150}$)			
Calc. 10	49 (-2,-3)	48 (-3,-4)	43 (-3,-3)	41 (-1,-2)
Calc. 11	62 (-3,-5)	58 (-2,-6)	50 (-1,-3)	58 (-1,-2)
Calc. 12	78 (-1,-3)	74 (-2,-4) 5	75 (-2,-3)	91 (-2,-9)

Finally, in Figure 13 the results from two walls based on 175 CLT 5s are shown with buildups as described in Figure 4.



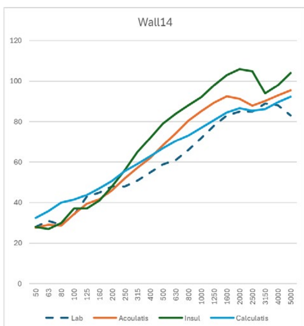


Figure 13. Two different wall configurations calculated, described in Figure 4.

Table 5. Corresponding single number values for Figure 13.

	Lab	Acoulatis	INSUL 10	Calculatis
	R_w (C, $C_{50\text{-}3150}$)			
Calc. 13	61 (-3,-6)	60 (-3,-6)	61 (-4,-7)	62 (-2,-3)
Calc. 14	60 (-2,-4)	61 (-3,-5)	63 (-4,-7)	66 (-3,-4)

These configurations are rather similar, the difference is that calculation 13 emanates from visible wood on one side while calculation 14 is supplied with two extra layers of plasterboards directly attached to the CLT on the opposite side of the cavity. The results indicate that the low frequency performance improves with the extra layers, however the weighted sound reduction index is not really affected. Calculatis shows bigger differences since plasterboards inside the cavity cannot be included in the model.

3.2 Results from floor calculations

Below are the calculated results shown for airborne and impact sound insulation, following the same order as in section 2.2. In Figures 14 to 16, third octaves values are shown and in addition, the corresponding single numbers are shown in tables immediately after the figure with third octave band levels.
INSUL cannot include gravel in its floor configurations and thus, it was modelled as cement / render. Furthermore, INSUL does not include impact boards on CLT for impact noise. Therefore, insulated panels were used instead for the impact sound calculations. The approximations are shown for floors 02 and 03 in Figure 14.

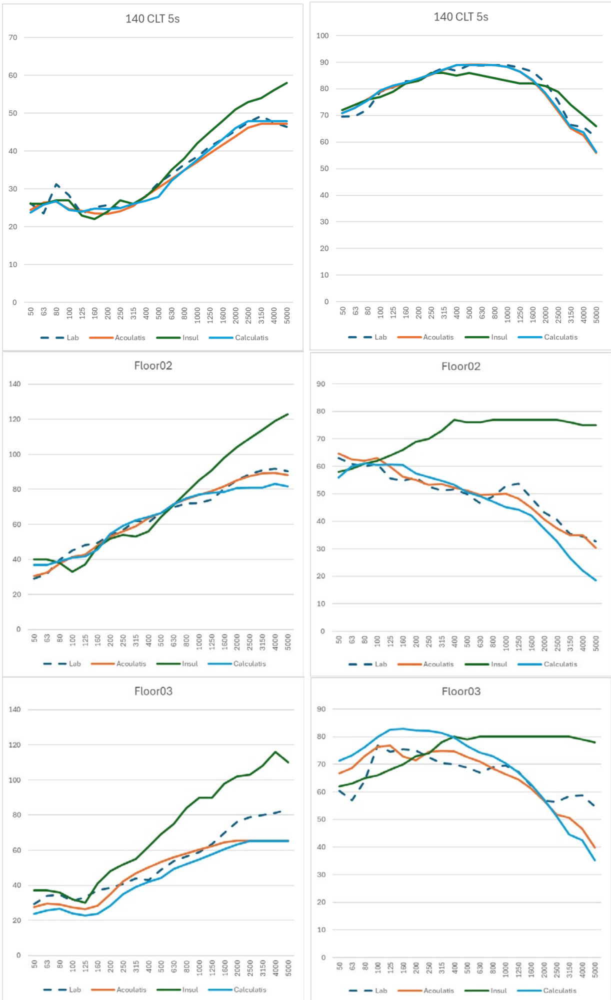


Figure 14. Three different floor configurations calculated, described in Figure 5.

Table 6. Corresponding single number values for airborne sound reduction related to Figure 14.

	Lab	Acoulatis	INSUL 10	Calculatis
	R_w (C, $C_{50\text{-}3150}$)			
CLT 140 5s	36 (-1,-1)	35 (-1,-1)	36 (-1,-1)	35 (-1,-1)
Calc. 02	68 (-2,-6)	66 (-2,-5)	62 (-1,-4)	67 (-4,-5)
Calc. 03	52 (-2,-2)	51 (-4,-4)	59 (-,-)	45 (-3,-3)

Table 7. Corresponding single number values for impact sound levels related to Figure 14.

	Lab	Acoulatis	INSUL 10	Calculatis
	$L_{n,w}$ (C_I, $C_{I,50\text{-}2500}$)			
CLT 140 5s	88 (-5,-5)	87 (-4,-4)	84 (-7,-7)	87 (-4,-4)
Calc. 02	53 (-3,1)	52 (0,3)	81(-11,-11)	52 (0,2)
Calc. 03	70 (-2,-1)	70 (-1,0)	86(-12,-12)	76 (0,0)

In Figure 15, results from calculations of two different combinations of raised floors are shown and compared to the lab values.

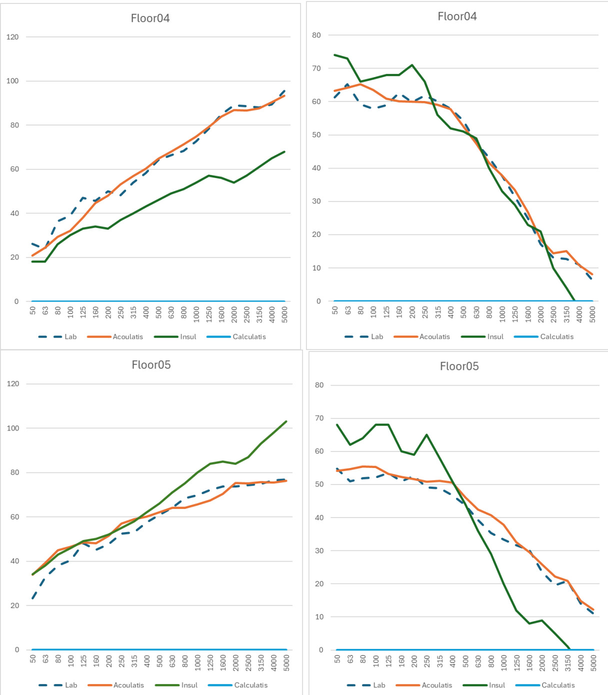


Figure 15. Two different raised floor configurations calculated, described in Figure 6.

Table 8. Corresponding single number values for airborne sound reduction related to Figure 15.

	Lab	Acoulatis	INSUL 10	Calculatis
	R_w (C, $C_{50\text{-}3150}$)			
Calc. 04	63 (-2,-6)	62 (-4,-8)	49 (-2,-3)	--
Calc. 05	63 (-2,-5)	65 (-1,-2)	67 (-1,-3)	--

Table 9. Corresponding single number values for impact sound levels related to Figure 15.

	Lab	Acoulatis	INSUL 10	Calculatis
	$L_{n,w}$ (C_I, $C_{I,50\text{-}2500}$)			
Calc. 04	54 (0,2)	54 (0,3)	66 (0,1)	--
Calc. 05	45 (0,2)	46 (0,2)	56 (1,4)	--

There are no results to present for Calculatis since raised floors cannot be modelled in that software. For INSUL, the floor in calc. 4 is replaced by Stravifloor w/HR50 and in calc. 5 with Mason EAFM Mount (explaining the deviation) since there are only a limited number of raised floors available in INSUL.

In Figure 16, results from calculations of two different combinations with screed and suspended absorbing ceilings are shown and compared to the lab values.

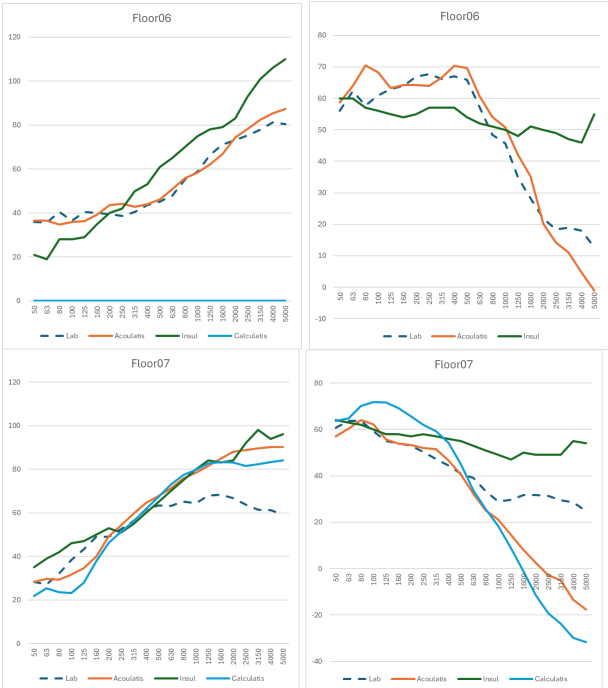


Figure 16. Two different screed floor configurations (including ceilings) calculated, described in Figure 7.

Table 10. Corresponding single number values for airborne sound reduction related to Figure 16.

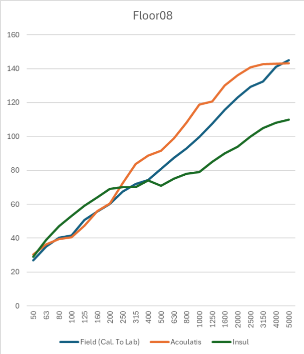
	Lab	Acoulatis	INSUL 10	Calculatis
	R_w (C, $C_{50\text{-}3150}$)			
Calc. 06	51 (-1,-1)	53 (-1,-2)	54 (-2,-5)	--
Calc. 07	62 (-2,-5)	61 (-5,-6)	66 (-1,-3)	56 (-7,-8)

Table 11. Corresponding single number values for impact sound levels related to Figure 16.

	Lab	Acoulatis	INSUL 10	Calculatis
	$L_{n,w}$ (C_I, $C_{I,50\text{-}2500}$)			
Calc. 06	54 (0,2)	54 (0,3)	56 (-5,-3)	--
Calc. 07	47 (1,7)	48 (2,5)	56 (-4,0)	60 (2,3)

Calculatis has no option to model screed directly on the CLT slab and the results are therefore missing for Floor 06. For Floor 07 the ceiling is approximated with a 13 mm normal gypsum board in INSUL and Calculatis since they don't have that product available, contradictory to Acoulatis. The impact board is modelled as one single 30 mm impact board (dynamic stiffness 10 MN/m^3). For

INSUL the impact board is simulated by an insulated panel, as is the ceiling.



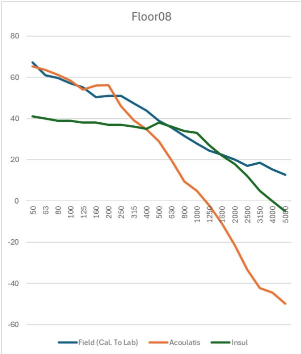


Figure 17. One type of volume element floor calculated, as described in Figure 8.

Table 12. Corresponding single number values for airborne sound reduction related to Figure 17.

	Field (re-calc.to lab)	Acoulatis	INSUL 10	Calculatis
	R_w (C, $C_{50\text{-}3150}$)			
Calc. 08	74 (-5,-11)	73 (-6,-9)	77 (-1,-10)	--

Table 13. Corresponding single number values for impact sound levels connected to Figure 17.

	Field (re-calc.to lab)	Acoulatis	INSUL 10	Calculatis
	$L_{n,w}$ (C_I, $C_{I,50\text{-}2500}$)			
Calc. 08	45 (1,9)	47 (1,7)	33 (-1,1)	--

Calculatis cannot model double CLT floors, that is why it is not included in the comparison. Furthermore the "lab value" is recalculated based on field measurements, hence not measured in lab. For the INSUL values, the impact board and the gravel are approximated by an insulated panel and sand/cement render respectively.

4. DISCUSSION AND CONCLUSION

Developing engineering software for building acoustic calculations demands a high degree of flexibility to accommodate the wide variety of floor and wall constructions encountered for future sustainable buildings. Seamless integration of new products must be possible as they become available. In parallel, developers should continuously seek and incorporate new data into the calculation model. Regular updates are essential, otherwise, the credibility and relevance of the software can quickly diminish. Engineering-based calculation models are fundamental to the future of acoustic design. Without reliable calculation tools, acousticians must rely on standard assemblies or informed guesses, which limit innovation and the ability to design novel solutions tailored to specific projects. Measurements remain crucial and calculation models must be validated against them. However, it is not feasible to measure every possible combination. Therefore, well-calibrated and frequently updated software models are a more practical and scalable solution. This paper highlights that many material options and construction variants for CLT are still missing from existing engineering software tools, like INSUL and Calculatis. As a result, modelling certain combinations may involve a high degree of uncertainty, underscoring the need for continuous development and data integration. Furthermore, for CLT structures, this paper shows that Acoulatis predicts with the highest accuracy for all wall and floor variants combined, of course pre assuming that we can rely on the measured values.

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