# DESIGN IMPLICATIONS FOR IMPACT SOUND INSULATION IN TIMBER FLOORS: EXPERIMENTAL RESULTS ON CLT ASSEMBLIES

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## Abstract

Sound insulation in timber construction remains one of the main challenges for the wider adoption of lightweight building systems, particularly Cross-Laminated Timber (CLT) floors. This paper presents the results of a recent laboratory measurement campaign focused on the acoustic performance of floating floor systems incorporating resilient materials installed under screed on CLT slabs. Measurements were carried out under controlled laboratory conditions, in the absence of flanking transmissions, in order to assess the intrinsic performance of the tested assemblies. The results are discussed in comparison with previous experimental campaigns on similar configurations, as well as with more recent data available in the scientific literature, highlighting both consistencies and discrepancies. A further objective of the study is to compare the measured impact sound insulation performance with the requirements set by major European acoustic regulations, evaluating the compliance of the investigated solutions across different national frameworks. The work will be the basis to extend the knowledge on materials and isolation systems for future comparison on heavyweight slabs, enabling a direct comparison of performance as a function of the structural floor, considering mass and stiffness of the supporting structure, as well as the role of the physical and mechanical properties of resilient materials. The outcomes provide useful insights for the acoustic design and optimization of high-performance timber buildings.

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## 1. Introduction

The CLT technology has developed much in the last thirty years and is now a mature construction method in the market, especially in Europe. The acoustic performance of wooden buildings made of CLT elements can reach interesting levels of insulation globally. However, impact sound insulation of CLT floors is still a challenge today. Structural decoupling helps limiting the structure-born transmission of vibration through joints, but the horizontal floor structures need performing materials and efficient compositions, to get the highest levels of insulation and meet the regulatory requirements, that are evolving continuously to improve people's comfort expectations. In this study, a new set of acoustic tests has been conducted in laboratory, according to ISO 10140 and ISO 717, to evaluate the improvement of impact and airborne sound insulation on a reference CLT floor, using independent technical solutions, easily replicable in site, adopting high performing recycled materials as resilient layers, analyzing suspended ceilings, dry and wet screeds and levelling layers in the assemblies.

## 2. Tested floors

The structural floor is a 160 mm CLT slab. Three types of overstructures have been investigated:
Type A: a wooden joists floor made of 5 cm timber battens installed at 60 cm inter-distance, with a double 12 mm OSB boards layer as top surface. The gap between the timber battens is filled with sand; the whole structure is separated from the CLT floor through a hard resilient rubber layer, 10 mm thick.
Type B: the same timber joists structure, with a fibrous infill (recycled polyester) instead of sand. The polyester

fiber panels have a density of 40 kg/m³ and an air flow resistivity of 4500 Pa/ms².

Type C: a levelling screed made of EPS/cement, with a thickness of 10 cm and a density higher than 900 kg/m³.

On these three types of overstructures, both dry and wet floating screed setups have been tested, including the following resilient materials:

Material 1: recycled rubber mat, thickness 10 mm, with a dynamic stiffness of 6 MN/m³;

Material 2: Rubber bearings with a polyester infill, thickness 25 mm, with a dynamic stiffness between 6 and 10 MN/m³;

Material 3: Composite panel made of a high density polyester fiber mat covered by an integrated rigid walkable rubber layer, total thickness 28 mm, dynamic stiffness 10 MN/m³.

A suspended ceiling has been investigated as complementary technology. The chosen ceiling solution had been already tested on massive slabs during recent testing campaigns with excellent results [1]. The ceiling is made of a single metal frame structure leaving a void of 20 cm, partly filled with recycled polyester fiber panels. The void is closed below by special boards made of gypsum and a laminated rubber layer in 20 mm. In the following picture, a schematic representation of the tested elements is provided.

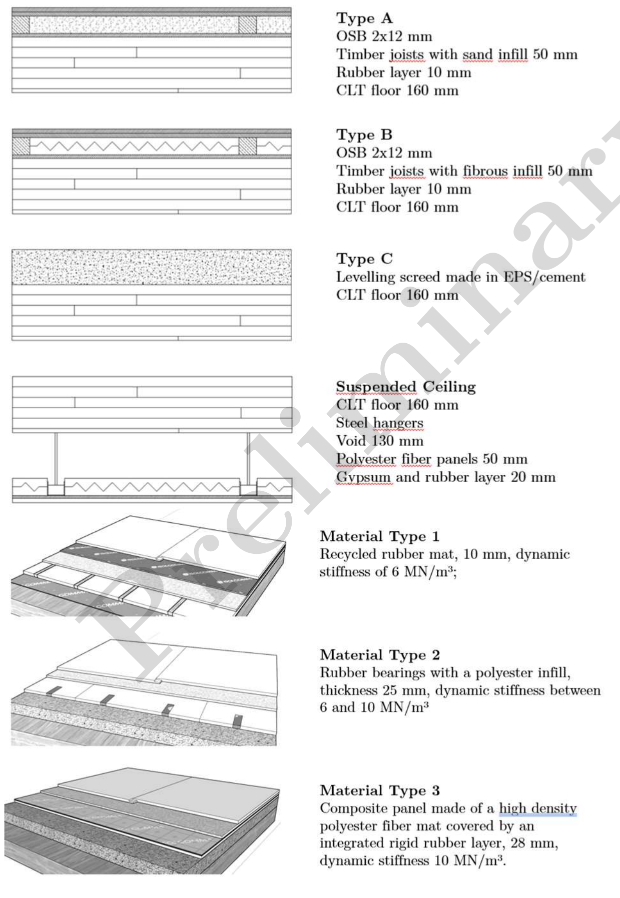



**Figure 1**. Floor types with tested overstructures and ceiling, representation of the types of materials.

## 3. Main results

The results of the studies have been grouped for a better reading and presented in the following paragraphs, expressed as single number rating according to ISO 717, and considering additionally also the behavior at lower frequencies, in general critical for wooden structures.

### 3.1 Overstructures

The three different types of tested overstructures show an interesting improvement of the floor performance. The normalized impact sound level decreases up to 28 dB when expressed as single number rating ($L_{n,w}$), while airborne sound insulation improves up to 25 dB ($R_w$).

**Table 1.** Acoustic performance of the CLT floor when tested with an overstructure, without a floating screed. A, B, C refers to the overstructures described in the previous paragraph, in particular A refers to a timber battens with sand closed by 2 OSB boards on a rubber protection layer; B is equivalent to the previous, but with a polyester fiber panel instead of sand, C refers to a EPS/cement levelling screed. Values expressed in dB.

| Floor Type | $L_{n,w}$ | $L_{I,50}$ | $R_w$ | $R_{A,50}$ |
|---|---|---|---|---|
| CLT | 84 | 81 | 35 | 34 |
| CLT + A | 63 | 63 | 53 | 51 |
| CLT + B | 56 | 59 | 60 | 57 |
| CLT + C | 77 | 69 | 46 | 46 |

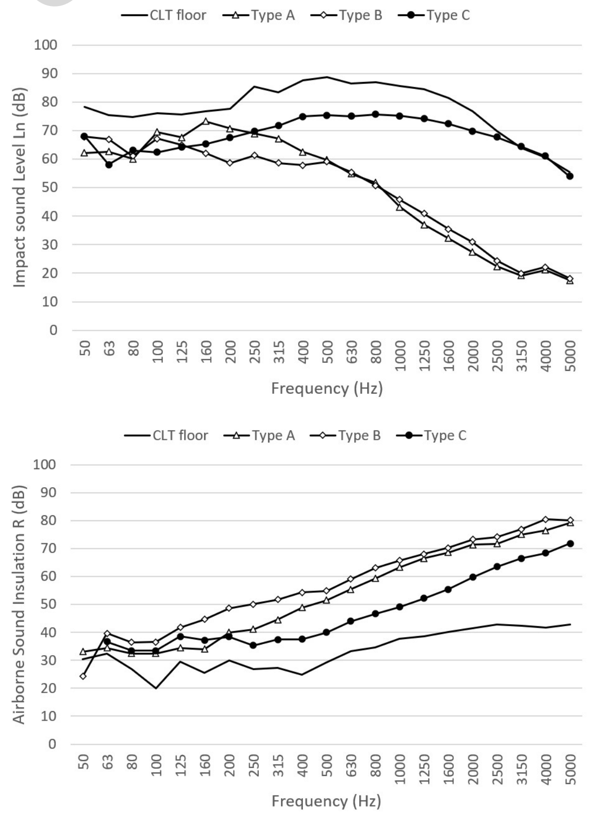



**Figure 2**. Impact and airborne sound insulation of the overstructures.

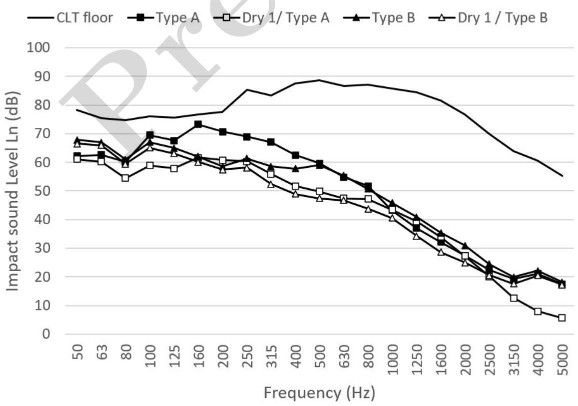
These figures underline an important effect for the use of a rigid resilient layer as a separation between structural floor and infill or levelling layer above. (A) and (B) show a floating floor-like behavior, with a sharp attenuation above 250 Hz, linearly increasing, while (C) influences the impact noise performance shifting the noise levels down 10-15 dB, as already assessed in previous studies [2]. Considering that the three layers have different values of mass, estimated for (A) 90 kg/m², (B) 16 kg/m² and (C) 100 kg/ m², this first comparison shows that while mass helps the total insulation, it's also true that an engineered lightweight timber structure with cavity absorption material can perform similarly, with one sixth of the mass compared to the other types. Limiting the load on top of the floor will be beneficial for the design of the whole wooden building design and construction.

### 3.2 Dry screeds and wet screeds

On the tested systems, the advantage gained with the timber structures seem to disappear once a dry floating screed is applied on top.
Adding a dry floating screed will improve impact sound insulation up to an $L_{n,w}$ of 52-53 dB, independently from the type of infill between the joists (sand or fibrous infill). It's important to notice that $L_{I,50}$ starts to deviate (2 to 3 dB) from $L_{n,w}$, compared to the basic structure, as a consequence of the higher attenuation in the middle-high frequency range, compared to the lower frequencies.
Airborne sound insulation is not varying much among different configurations and seems reaching a structural limit around the value of $R_w$ 60 dB.

**Table 2.** Acoustic performance including dry screeds on top of the timber framed overstructures (A,B refer to the overstructure; 1 refers to the material type, as descried in the previous paragraph). Values expressed in dB.

| Floor Type | $L_{n,w}$ | $L_{I,50}$ | $R_w$ | $R_{A,50}$ |
|---|---|---|---|---|
| CLT | 84 | 81 | 35 | 34 |
| CLT+A | 63 | 63 | 53 | 51 |
| CLT+A+1(dry) | 52 | 54 | 59 | 57 |
| CLT+B | 56 | 59 | 60 | 57 |
| CLT+B+1(dry) | 53 | 57 | 59 | 56 |



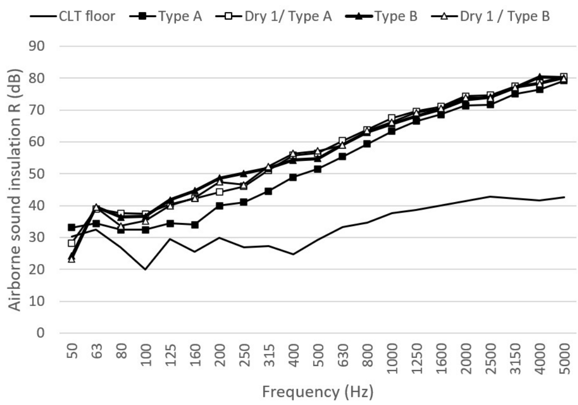




**Figure 3**. Impact and airborne sound insulation of dry assemblies (no ceiling).

While it's not common to find wet screeds on top of timber framed overstructures, floor compositions based on EPS/cement levelling screeds (Type C) can fit quite often a sand cement top screed with a resilient layer in between. This configuration has been tested as well, compared with a dry assembly in the same conditions.
With the adoption of a floating screed, the single number rating reaches interesting results, compatible with most minimum requirements in Europe. However, the deviation between the performance assessed in the range 100-3150 Hz and the extended range down to 50 Hz starts to be relevant, with the performance aligned for all systems to 54-55 dB ($L_{I,50}$). Airborne sound insulation shows a similar behavior, with all spectra almost overlapped.
Both dry and wet screeding technologies work well for the impact insulation purpose. Apparently, in those countries where only a standard frequency range evaluation is demanded, a dry application can push the performance up to 5 dB higher, However, when a low frequency evaluation is also needed, the two systems can be considered equivalent.

**Table 3.** Acoustic performance including dry and wet screeds on top of the levelling EPS/cement screed (C refers to the levelling screed; 2,3 refer to the material type). Values expressed in dB.

| Floor Type | $L_{n,w}$ | $L_{I,50}$ | $R_w$ | $R_{A,50}$ |
|---|---|---|---|---|
| CLT | 84 | 81 | 35 | 34 |
| CLT+C+2(dry) | 47 | 54 | 60 | 56 |
| CLT+C+2(wet) | 52 | 54 | 62 | 59 |
| CLT+C+3(dry) | 46 | 54 | 60 | 56 |
| CLT+C+3(wet) | 48 | 55 | 60 | 57 |

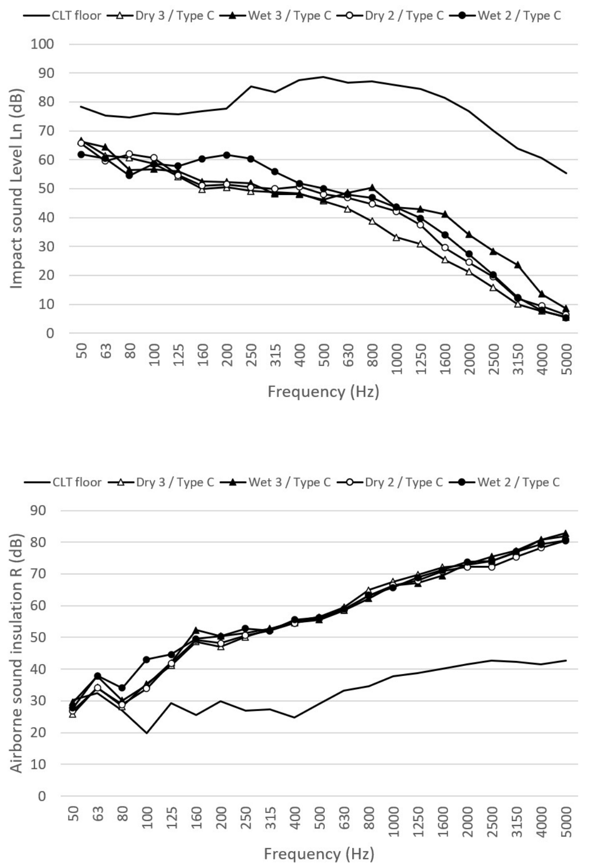



**Figure 4**. Impact and airborne sound insulation of dry and wet assemblies on levelling screed made of EPS/cement (no ceiling).

### 3.3 Suspended ceilings

The use of suspended ceilings on CLT constructions is a commonly discussed topic, since it's a key technique to sensibly improve impact sound insulation on lightweight structures, but most of the times not accepted by designers, to preserve the architectural appearance of the assembly. However, the use of special engineered materials on ceilings, including gypsum boards laminated with high density and elastic layers and fibrous polymeric panels, can become an easy solution for both a new design or a renovation project.

**Table 4.** Acoustic performance of CLT assemblies including a suspended ceiling (B,C refer to overstructure type; 1,2,3 refer to the material). Values expressed in dB.

| Floor Type | $L_{n,w}$ | $L_{I,50}$ | $R_w$ | $R_{A,50}$ |
|---|---|---|---|---|
| CLT | 84 | 81 | 35 | 34 |
| Ceiling+B+1(dry) | 40 | 53 | 64 | 60 |
| Ceiling+C+2(dry) | 37 | 51 | 64 | 60 |
| Ceiling+C+3(wet) | 36 | 50 | 65 | 61 |
| Ceiling+C | 51 | 53 | 61 | 58 |

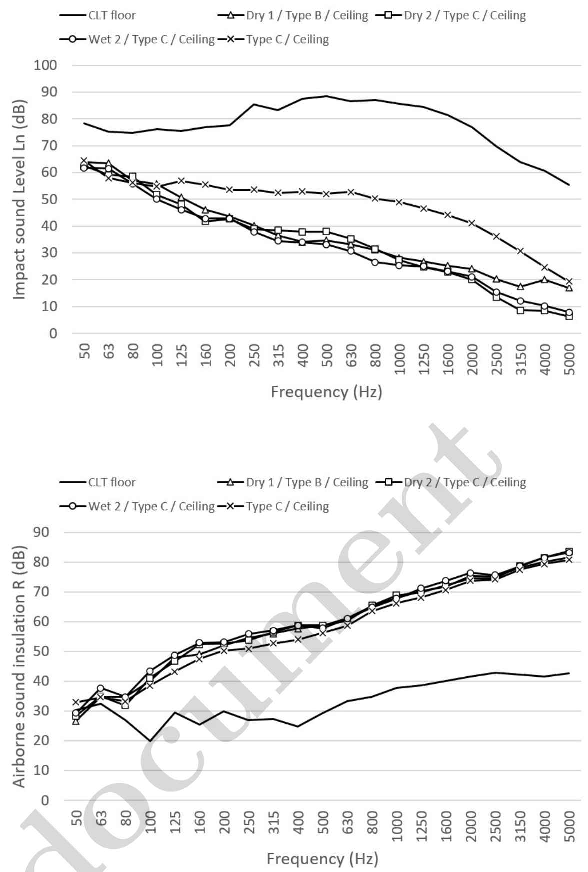



**Figure 5**. Impact and airborne sound insulation of solutions with ceilings.

The results highlight how a well designed suspended ceiling can contribute to reach any target coming from national regulations, with laboratory values of $L_{n,w}$ sensibly lower than 40 dB and additional low frequency evaluation around 50 dB. The spectra in figure 5 clearly put in evidence the specific contribution of both the ceiling and the floating floors, that cut the transmitted noise in the whole frequency range, especially starting from 100 Hz and above. As already discussed in previous studies, these contributions of ceiling and floating screed can be combined separately with a good precision and approximation, when evaluating the floor insulation according to EN 12354 standards; under this point of view, this study will help improving the precision of preliminary calculations and design.

### 3.4 Impact sound improvement on CLT and concrete slab

For comparison purpose, one of the assemblies has been tested on the reference concrete slab, in the same exact installation conditions.

The results of this test show a substantial analogy of the behavior on the two floors. This outcome was partially unexpected, since in past investigations a clearly different performance was noticed for same floating floors applied on structural floors with different mass and rigidity [3], [4]. This topic will be studied further with more data and case studies.

**Table 5.** Impact sound attenuation ΔLw for the same assembly, made of a timber battens structure with polyester fiber panels between, a double layer of OSB boards and a dry floating screed on a 10 mm rubber resilient layer, tested on a CLT floor and a reference concrete slab. For the CLT, the difference between bare and insulated floor has been considered.

| Floor Type | $\Delta L_w$ |
|---|---|
| CLT | 31 dB |
| Concrete slab | 34 dB |

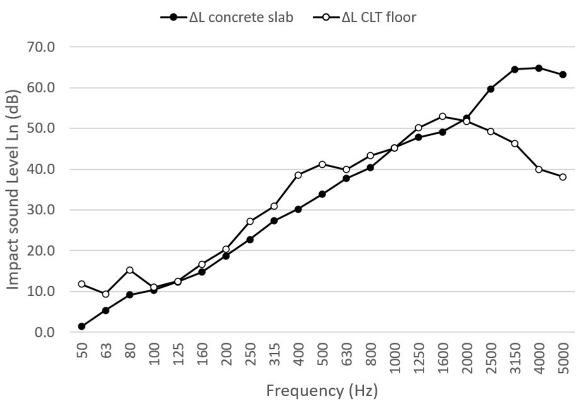



**Figure 6**. Comparison of impact sound attenuation measured on a reference concrete slab and a CLT floor on the same floor composition.

## 4. Conclusions

The study, started as an industrial investigation on updated technical solutions for CLT floors' insulation, has pointed out how traditional techniques can be used as simple and safe site practices, to reach the target insulation values. Especially, the dry assemblies based on timber joists, fibers and loose sand are efficient and cheap solutions to boost the floor performance, especially when coupled with a top floating screed, for full performance. The role of the suspended ceiling has also been investigated further: this solution does not meet always the architectural design criteria in the projects, but is definitely a safe method to obtain a full acoustic result on both heavy and lightweight structures. As a final remark, this study will be developed further, trying to collect more comparative data on differences between same insulation layers applied on CLT and massive slabs, to assess the applicability of existing experimental calculation methods of impact sound improvement of materials and floating systems.

## References

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