



Cross-laminated timber system (CLT): laboratory and in situ measurements of airborne and impact sound insulation

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Abstract

CLT panels are well suited for the construction of walls, floors and roofs thanks to their structural properties. They are used as prefabricated building elements which can accelerate building phases. In situ and laboratory measurements are the best methodology that allows investigating the real acoustic behaviour of the CLT system, considering both the flanking transmissions and the connection between the single elements. Indeed, the acoustic prediction of the acoustic performance of prefabricated construction systems like CLT using standardized methods is not entirely accurate.

Keywords: CLT, timber, sound insulation, impact noise.

1 Introduction

Cross-laminated timber (CLT) is defined as a prefabricated solid engineered wood product, made of at least three orthogonally bonded layers of kiln-dried lumber boards bonded with structural adhesives, and pressed to form a solid, straight and rectangular panel intended for roof, floor, or wall applications.

This new generation of engineered wood product was developed initially in Europe. It was introduced in the early 1990s in Austria and Germany and it has been gaining popularity in residential and non-residential applications. In the mid-1990s, Austria undertook an industry-academia joint research effort that resulted in the development of modern CLT [1]. The construction in CLT increased significantly in the early 2000s, partially driven by the green building movement but also due to better efficiencies, product approvals, and improved marketing and distribution channels. In recent years, CLT panels have been introduced as an emerging building system in the North American Market as a new wood construction technology.

The type of the wood used in CLT depends on the region it is manufactured, but softwood spruce is the main species used. The thickness of CLT panels is from 80 and 400 mm, depending on the structural requirements. CLT panels offer design flexibility and low environmental impacts.

The acoustic prediction of the acoustic performance of prefabricated construction systems like CLT using standardized methods (ISO 15712 - EN 12354 series) is not entirely accurate. The greatest difference to concrete and masonry buildings are the greater damping of the CLT and their junction details with rather point than line connections. At present, some studies concerning the applications



of the models listed above have been carried out [2], [3], [4], [5], [6], [7] but in situ and laboratory measurements are the best methodology that allows investigating the real acoustic behaviour of the CLT system, taking into account flanking transmissions and connections between the single elements.

In the present paper, the results of the tests conducted within the research [8] are collected, and are implemented with new arguments based on new laboratory tests of different CLT solutions.

2 In situ measurement campaign

The in situ acoustic insulation tests have been performed between dwellings in a multi-family house located in the North Area of Milan. The building chosen is a three-story construction with a total of 8 different dwellings. The walls, the floors and the roofs were entirely built using CLT system. The structural part of the separating floors is made of 144 mm thick CLT panels, but in order to investigate the acoustic behaviour of different solutions, some of the layers that complete the floor stratigraphy are different from one floor to another. Six impact sound insulation tests in accordance with EN ISO 140-7:1998 [9] and rated in accordance with EN ISO 717-2: 2013 [10].

The focus was mainly on separating floor, especially the contribution given by the introduction of stonewool absorbing material within the cavity between the screed and the ceiling. Moreover, the contribution of different screed and under-screed elements has been assessed. But also the airborne sound insulation was measured. Two airborne sound insulation tests were conducted in accordance with EN ISO 16283-1:2014 [11] and rated in accordance with EN ISO 717-1:2013 [12].

2.1 Description of tested constructions

2.1.1 Separation floors

S1:



Figure 1. Separating filoor 51

Two different solutions have been tested: with and without stonewool placed in the ceiling cavity. **S2:**



Figure 2. Separating floor S2



Also in this case, with wood fiber panel above the screed, two different tests have been performed. **S3: S3**



Figure 3. Separating floor S3

The S3 solution is made using cemented-based products, instead of dry materials. In addition, the S3 construction has been analysed with wooden and ceramic floor as finishing layer.

2.1.2 Partition walls





Figure 4. Partition wall W1

The partition wall W1 was performed with a CLT panel of 95 mm with dry lining system of gypsum plasterboard in both sides.

The junction between floors and walls has been made as show the following Figure.



Figure 5. Junction detail between floor and wall



2.2 Test results

2.2.1 Separation floors

The measured impact noise levels of all above mentioned constructions with different solutions and characteristics are listed up in Table 1:

Separating Floor	Stonewool in the ceiling cavity	Type of flooring	Type of screed	Type of infill layer	Under screed damping material	Impact sound insulation L' _{nw} (dB)
S 1	No	Wooden	Gypsum fiberboard	Marble	Polyester Stonewool	45 (1) dB
S1	Yes	Wooden	Gypsum fibreboard	Marble	Polyester Stonewool	42 (-1) dB
S2	No	Wooden	Gypsum fibreboard	Marble	Polyester Wood fiber	51 (1) dB
S2	Yes	Wooden	Gypsum fibreboard	Marble	Polyester Wood fiber	46 (2) dB
S3	Yes	Wooden	Cement	Lightweight	Polyester	50 (2) dB
S3	Yes	Ceramic	Cement	Lightweight	Polyester	53 (2) dB

Table 1: Test results of separating floors solutions

The result of the airborne sound insulation of the separating floor S3 is reported in Table 2.

Separating Floor	Stonewool in the ceiling cavity	Type of flooring	Type of screed	Type of infill layer	Under screed damping material	Airborne sound insulation R' _w (dB)
S3	Yes	Ceramic	Cement	Lightweight	Polyester	64 (-4;-10) dB

Table 2: Test result of separating floor S3





Figure 6 compares the measured impact noise levels as a function of frequency:

Figure 6. Comparison in terms of impact noise of the different tested solutions.

2.2.2 Partition wall

The result of the airborne sound insulation test of the partition wall W1 is listed up in the following table (Table 3):

Partition	CLT	Type of	Type of	Type of	Airborne sound insulation
wall	System	lining	structure	absorber	$R'_{w}(dB)$
W1	Yes	2 x 12,5 mm Plasterboard	Metal	2 x 40 mm Stonewool	64 (-2;-6) dB

Table 3: Test result of partition wall W1





measurement:



3 Laboratory measurements

3.1 Description of tested constructions

The measurements have been performed according to EN ISO 10140-2 [13] and ISO 717-1 [12] and are shown in Figure 9.

The campaign consists of three different configurations:

- CLT wall without any linings.
- CLT wall with double lining: the same configuration as for wall W1 (see Figure 4).
- Ventilated façade system with 75 kg/m³ stone wool panels installed in the air cavity between the external prefabricated compressed mineral wool boards and CLT panels. Internally plasterboard and gypsum fiberboard lining system has been installed. Stone wool panels have been placed between 50 mm metal studs (figure 8).





Figure 8 - Ventilated façade system

3.2 Test results

The measured sound reduction index for the CLT panel without lining is Rw (C; Ctr) = 33 (-1;-4) dB; and for the partition wall (with lining and stonewool) is Rw (C; Ctr) = 75 (-2;-7) dB. The ventilated facade sound reduction index is Rw (C; Ctr) = 68 (-3;-9) dB Results are shown in Figure 9.



Figure 9 – Laboratory measurement: sound reduction index as a function of frequency.



4 Discussion

4.1 Separating floors

Results show the increase in terms of acoustic performance given by the use of stonewool within the ceiling cavity: a general improvement around 3-5 dB has been assessed.

As expected, the lower the performance of the overlying layers, the greater the contribution given by the insertion of stone wool in the cavity.

Absorbing material placed in the cavity has the further advantage of increasing the performance of airborne sound insulation, limiting the flanking transmission between rooms located on the same floor that can pass across the CLT panels.

Following the results reported from Table 1, dry floating screeds in conjunction with a high density filling layer (marble granulate) give the better performance compared to traditional solutions. As shown in Figure 6, the marble granulate weight has a positive impact on the performance in the low frequency range.

Dry screeds and sand-cement screeds show different damping effect, as also reported in standards ISO 15712 and EN 12354 series "Building Acoustics – Estimation of acoustic performance of buildings from the performance of elements" where two distinct formulas are applied for estimating the impact noise reduction for dry or cement-based screed.

Table 1 underlines that the installation of materials with low dynamic stiffness values obtain higher impact noise insulation values compared to stiffer materials: the benefit obtained using polyester + stonewool instead of polyester + wood fiber is around 4-6 dB.

Discontinuous walls across stories and resilient element in the walls-to-floor connection help prevent flanking. As an additional result of uncoupling construction elements, the installation errors are minimized compared to traditional construction.

S3 floor has a mass around 280 kg/m³, which is half the average mass of a traditional separating floor (550-600 kg/m³). However, S3 reaches a good level of airborne sound insulation thanks to the ceiling system with stonewool absorbing material inside.

4.2 Partition wall

Normally the sound insulation level for a three layer bare CLT wall (95 mm \sim 115 mm) is around 32-34 dB in terms of STC [14]. Moreover, the test reported in Figure 9 carried out 33 dB in terms of Rw for a 95 mm – 5 layers CLT wall. As a consequence, the use of wall lining systems is the proper choice for significantly improves the sound insulation level of CLT partition wall.

Figure 7 and Figure 9 shows that thanks to a proper design of the cavity width filled with stonewool, as well as the use of finishing slabs with an adequate surface mass, the resonance frequency of the system does not affect the level of sound insulation of the complete wall. The metal frame must be totally decoupled from the bare CLT wall in order to maximize the acoustic benefit.

For better understanding the real acoustic benefit of the CLT solution, a comparison with a traditional one is hereby presented.

Figure 10 shows a traditional partition wall largely used in Italy: double leaf cavity wall composed by three plaster layers and perforated clay blocks (density between 600 kg/m³ and 800 kg/m³). The cavity is filled with 60 mm mineral wool.

In Figure 10 and Table 4 the in situ performance and characteristics of the two partition wall is reported.





Figure 10. Traditional partition wall.

	Thickness (mm)	Total weight (kg/m ²)	Results R' _w (dB)
CLT	295	100	64 (-2;-6)
Traditional	300	205	52 (-1;-4)



Figure 10. Comparison of the sound reduction index for traditional and CLT party wall.

Both solutions fulfil the usual national requirements for dwellings ($R'_w \ge 50 \text{ dB}$), but CLT technology provides an improvement in terms of R'_w equal to 12 dB. Despite of the lower weight of the CLT



solution, even in the low frequencies range the sound insulation level is always higher than the masonry one.

A comparison between the laboratory and the in situ measurement of the partition wall shows that, thanks to the junction configuration between floors and walls reported in Figure 5, flanking transmission are reduced. A resilient element between the junctions has a big impact in the vibration reduction Kij.

5 Conclusions

The comparison between the different floors solutions shows that dry screed, in combination with resilient material like mineral wool, together with suspended ceiling with fibrous absorbing material placed in the cavity, provides the best performance in terms of impact noise reduction among the analysed. The study records improvement of around 3-5 dB by using stonewool within the ceiling cavity.

Airborne sound insulation level in the low frequency bands is a critical point for light constructive systems. Laboratory and in-situ measurement shows that the acoustic performance of CLT panels together with wall lining systems is at least 12 dB higher compared to traditional type of construction, even in the low frequency range. In laboratory the difference is obviously even stronger. Comparing in situ and laboratory measurements is clear that junctions with resilient elements improve the Kij vibration reduction indices and guarantee a general low level of flanking transmissions.

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