FLANKING TRANSMISSION IN CLT BUILDING ELEMENTS: EFFECT OF MOUNTING CONDITIONS ON SOUND REDUCTION INDEX

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One of the main limitations of the laboratory measures of sound reduction index of building elements according to the standards of the ISO 10140 series is the difficulty to make “non-flat” samples in the test opening to simulate the actual “T” or “X” connections, typical of separating building structures, in order to test simultaneously both sound and vibration reduction indexes. Due to the particular dimensional and geometric characteristics of the Acoustic Laboratory (LabAcus) at University of Padova, a special setup was arranged in the opening between the two adjacent reverberation rooms for the measurement of sound insulation. A T-junction was made applying a vertical CLT element to a full size CLT vertical wall installed in the test opening. Measurements of sound reduction index and vibration reduction index were carried out at the same time on the same sample, changing the mounting conditions (interposition of an elastic interlayer, variation in type and number of fixing elements, etc.).

Keywords: sound reduction, vibration reduction, clt

1. Introduction

During a research on the optimization of the sound reduction performances of CLT building elements [1, 2], a measurement campaign of vibration reduction index was carried out on a special setup. In order to be able to simultaneously perform sound reduction index and vibration reduction index measurements according to the procedures of the respective standards [3–11], a special arrangement for a T-junction of bare Cross Laminated Timber building element was made-up in the test opening of the Acoustic Laboratory (LabAcus) at University of Padova. With the same setup it is possible to compare results obtained from different measurement techniques for the evaluation of transmission loss, such as by means of mobility measurements, as described in [12, 13].

In this work, part of the measurements carried out jointly by the University of Padova and University of Bologna are shown and commented.
2. Laboratory set-up

Among the peculiarities of the transmission suite of the Acoustic Laboratory at University of Padova there is the 1 m deep mounting frame with the lower part at the same level of the floors of transmitting and receiving room. Furthermore, the transmitting room is easily accessible from the outside with construction machinery. It’s therefore easy to install large monolithic prefabricated elements.

The vertical CLT building element analysed in this study consist of a single-panel (3-ply, fir wood) of dimensions 3600×2800 mm, nominal thickness 100 mm, density 470 kg/m³, installed in the concrete frame of the opening of the transmission suite of the laboratory by means of supporting brackets and sealed around the edges with elastic acrylic resin (Fig. 1).

Subsequently, after a first round of sound reduction and structural reverberation measurements, a second panel of 2000 mm length and 2800 mm height was placed at 90° with respect to the first, on the transmitting room side, at a distance of 2005 mm from the left edge of the test frame. In this way it was possible to measure the influence of the junction to the sound reduction index performances of the wall and the vibration reduction index for different types of connection systems.

The length of the element perpendicular to the base wall is slightly less than that prescribed by the measurement of the vibration reduction index but is the maximum allowed for a measurement set-up that allows to verify that the diffused field conditions are still respected as required by the standards for the laboratory evaluation of sound reduction index.

3. Verification of the sound field in the transmitting room

In order to verify the compliance of the sound field to the relevant standards, following the introduction of the CLT “T” element protruding into the transmitting room for a length of 1670 mm, the perpendicular wall was preliminarily installed so that there was no point of contact with the base wall (Fig. 2). In this way it is possible to exclude any mechanical interaction between the two elements and effects on sound radiation in the receiving room due to the different vibration behaviour of the entire “T-shaped” element. The sound reduction index was subsequently measured in 11 different configurations of the source/microphone positions, including the reference one, usually adopted for this type of laboratory measurements.

Comparing the reference configuration (reference source/microphone positions and CLT base wall only) with the new configurations (reference source/microphone positions plus ten alternative combinations and CLT wall with the detached T-junction of the protruding element), the one that gave the lower deviations on sound reduction index measurements was the reference configuration (Fig. 3).
It is therefore possible to compare the base wall and the jointed wall using the same source/microphone configuration for measuring the sound pressure level in the transmitting room.

Figure 2: The protruding element detached from the CLT base wall during the verification of the sound field in the transmitting room.

Figure 3: Comparison between sound reduction index measurements with different configurations source/microphone position for the base CLT wall (CLT100, Ref. Mic. Config.) and the CLT wall with the detached T-junction of the protruding element (CLT100+T//D, Ref. Mic. Config. plus ten alternative configurations).

4. **Comparison between sound reduction index and vibration measurements**

4.1 **Sound reduction index measurements**

Several measurements were carried out on the examined CLT wall. Among these, some concerned the effect on sound reduction index of the different connection techniques between panels. As reference for the comparison, the values of sound reduction index of the CLT base wall and of the T-shaped wall
with the perpendicular element detached were assumed. The configuration of the two reference walls and of the five connection systems of the T-shaped CLT element are described below:

- **CLT100**: reference base wall made up of a single CLT panel (3-ply, fir wood), 100 mm thick, density 470 kg/m³; perimeter sealed with acrylic sealant; $R_w (C; C_{tr}) = 32 (-1; -4)$ dB.

- **CLT100+T//D**: reference T-shaped wall made up as the previous, with an additional CLT panel, with the same characteristics as the base wall, installed perpendicularly to form a T-junction with the base wall on the transmitting room side, without any direct contact with the test wall itself (mechanically detached); $R_w (C; C_{tr}) = 31 (0; -3)$ dB.

- **CLT100+T_CONN_1**: as the previous, with the T-junction fixed by countersunk carpenter screws 8x240 mm, 400 mm pitch, set at an angle of 30°−35°; $R_w (C; C_{tr}) = 31 (-1; -4)$ dB.

- **CLT100+T_CONN_2**: as the previous, with carbon steel angle brackets, pitch 600 mm, fixed with 30 round head screws and a 6 mm thick polyurethane resilient layer interposed between the CLT panels; $R_w (C; C_{tr}) = 31 (-1; -4)$ dB.

- **CLT100+T_CONN_3**: same as CLT100+T//D with the T-junction fixed by carbon steel angle brackets, pitch 600 mm, fixed with 30 round head screws; $R_w (C; C_{tr}) = 31 (-1; -4)$ dB.

- **CLT100+T_CONN_4**: same as CLT100+T//D with the T-junction fixed by full thread screws with cylindrical head 7x260 mm, pitch 400 mm, set at an angle of 45° and carbon steel angle bracket, pitch 600 mm, fixed with 30 round head screws; $R_w (C; C_{tr}) = 31 (-1; -4)$ dB.

- **CLT100+T_CONN_5**: same as CLT100+T//D with the T-junction fixed by full thread screws with cylindrical head 7x260 mm, pitch 400 mm, set at an angle of 45°; $R_w (C; C_{tr}) = 31 (-1; -4)$ dB.

The results of the measurements are shown in Fig. 4.

Figure 4: Sound reduction index of the reference walls (solid lines) and T-shaped walls with five different connection configurations (dashed lines).

It can be seen the greater differences in sound reduction index occur at low frequency, below 315 Hz. In particular, at 100 Hz and 125 Hz there is a noticeable decrease in performance due to the connection of the perpendicular panel, both with and without interposed resilient material. Above 400 Hz
the fixing contribution is not significant if compared with the behaviour of the reference walls. The trend in frequency values is consistent with that expected for CLT elements with this mass per unit area [1].

4.2 Vibration reduction index and structural reverberation time measurements

As far as the vibration measurements are concerned, structural reverberation time and vibration reduction index measurements were performed using an instrumented hammer. The measurement method used is described in the previous works of the authors [2, 14, 17].

Figure 5: Diagram of the excitation (×) and acceleration measurement points (⊕) on the T-shaped wall (dimensions in cm). The perpendicular element of the T-junction is on the transmitting room side.

The comparisons between the structural reverberation time values $T_{10}$, measured in the CD-EF panel, are shown in figure 6.

Figure 6: Reverberation time of the radiating panel (path CD-EF).

The structural reverberation time of the CD-EF panel does not change above 400 Hz, with and without the T-junction. However, the resilient interlayer reduces the stiffness of the junction because it has eliminated the linear connection between the AB and CD-EF panels.
The values of $K_{ij}$ of the T-junction, agreed to the literature [14–16] and ISO standards [8–11], are shown in Figure 7, grouped according to the propagation path.

From the analysis of the results, the angle brackets (“CONN_2”, “CONN_3” and “CONN_4”) increase the lateral transmission if compared with the junction with screws only (“CONN_1” and “CONN_5”). As highlighted in other works [14, 17], the type of screws modifies the effects of the lateral transmission, that are reduced with the full thread screws. Fully threaded screws tend not to bring in contact the walls notwithstanding the use of tensioners, while partially threaded screws bring panels to a closer contact.

For all the measured configurations, the lateral transmission depends non-linearly on the frequency. Although the number of angle brackets and fixing systems between “CONN_1” and “CONN_2” increases, the $K_{ij}$ values do not increase due to the polyurethane resilient interlayer [2].

![Figure 7: Vibration reduction index (from 100 Hz to 3150 Hz) for the two paths of propagation in the T-junction.](image)

5. Conclusions

In this work an innovative set-up, which allowed to perform simultaneously acoustic and vibration measurements on a complex T-shaped sample, was presented.

The research confirmed the results of previous work on lateral transmission in CLT panels. In particular, measured $K_{ij}$ values depends non-linearly on the frequency and strongly depend on the type of fixing systems: the application of the angle brackets increases the lateral transmission even by 5 dB.

On the other hand, this variation is not reflected on the values of the single-number quantities for airborne sound insulation, as the major differences appear below 400 Hz. However, the implications of this loss of low frequency performance can be very significant for the estimation of acoustic performance of buildings from the performance of elements according to ISO standards [18, 19].

The input data for the standardized calculation models are based on the characteristics of acoustic insulation building elements measured in the laboratory on vertical or horizontal building elements without joints. The insertion of an element connected to the base wall leads to a decrease in performance at low frequencies, particularly evident below 160 Hz. This decrease is not due to the different
structural reverberation time of the base wall but it is more probably connected to an increase in the resonance frequency due to the greater rigidity of the system.

The risk of underestimating the performance of acoustic insulation in situ is particularly evident if it is considered that most of the thermal insulation technologies combined with the CLT construction system do not contribute to improve adequately low-frequency sound insulation [20, 21]. Moreover, the construction practices favour the application of redundant connections, often justified by particular construction needs and not explicitly foreseen in the building acoustic design stage [22].

REFERENCES


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