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ON THE LABORATORY STUDY OF JUNCTION IN FLANKING TRANSMISSION IN TIMBER BUILDINGS

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ABSTRACT

ISO 12354 standards describe a calculation model to estimate the sound insulation between adjacent rooms in buildings, and the method also evaluates the performance of timber structures. The standard proposes two types of cross-laminated timber junctions, while the joining technologies are many more. Over the years, many measurement campaigns have been carried out to evaluate the flanking transmission according to the ISO 10848 standard. This study talks about the results and the comparison with a model for lateral transmission measures from experience gained since 2015. Various connection systems such as plates, screws and resilient interlayers have been tested to match the mechanical properties with the acoustic properties of different resilient strips.

Keywords: *flanking transmission - ISO 10848 standard - resilient interlayer*

1. INTRODUCTION

In the last 10 years, the study of noise propagation in timber structures and flanking transmission has been a constant activity in research centres [1-4]. The first examples of prediction model formulae for flanking transmission were presented in 2015 by Guigot-Villot [5], and Annex F of ISO 12354 Part 1 is based on them. At the same time, several manufacturers of fixing systems, in collaboration with research Institutes and Universities, have tested different configurations of junctions based on their fixing systems, from the simplest using only screws to the most complex through the insertion of specially shaped plates with resilient materials. From these studies, it has emerged that timber structures differ from brick or cement structures, although both are type A. The type of fastening system constitutes an additional variable: it determines the value of the index of flanking transmission, especially if it is analysed in frequency.

The authors' activity in the timber sector started in 2015 and continues today. The first studies aimed to understand the phenomenon of flanking transmission in timber structures and study and evaluate their variables.

The "Flanksound project" [6] mainly tested connections between walls. The research continued by analysing the dependency of the vibration reduction index K_{ij} on the presence of resilient strips and vertical structures, such as the central node made by the floors and walls.

In recent years, resilient interlayers are increasing their presence in buildings to reduce flanking transmission. Consequently, the demand to characterize and compare the different types of products placed on the market has increased. Resilient interlayers are used between structural elements, typically between floor and wall, and they become part of the structure. For this reason, acoustic performance, static stability, and durability over time shall be investigated. From a static point of view, it is essential to test the material's compressive behaviour by determining elastic modulus, compressive creep, compressive stress, deformation, and compression set. The structural junction configurations shown below result from optimising acoustic performance combined with structural performance and the choice of resilient materials.

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2. MODEL FOR FLANKING TRANSMISSION ON CLT

As mentioned earlier, CLT junctions can be of various typologies that are difficult to compare.

To standardize the method of measuring K_{ij}, according to ISO10848, a full-scale model was created that allows different construction solutions to be tested on the same junction. This model can be configured as a vertical X-junction (Fig. 1) or a vertical T-junction (Fig. 2) formed by CLT panels (five layers) of equal thickness (10cm) and, therefore, with the same mass per unit area m'. Various fastening systems, such as screws, plates and resilient strips, can be applied to this junction. This, therefore, enables the basic configuration without any fasteners and the various fastening configurations to be compared. As a source, it was decided to use a system that excites the entire surface rather than using point sources. To do this, three vibroacoustic transducers for low and three for high frequencies were placed in each panel, thus achieving homogeneous excitation of the entire surface.

The measurement equipment comprises a computer that generates pink noise, a sound card, an amplifier, a signal switcher for panel selection, and vibroacoustic transducers. The response of the structure is then recorded by accelerometers placed on the surface of the panels (through a magnet on screwed washers) that send the signal to an acquisition card that then returns to the computer.

An essential problem with resilient strips is that they must be measured in their normal load of effective use. There are resilient strips suitable for use on the top floor, whose load is only one floor and strips used on the first floor that has to take the weight of all the floors above. Therefore, a method was found that reproduces the weight of the conditions of use through tensioned load-bearing bands. This method prevents the system from being constrained at the top, similar to the case with a hydraulic press.

3. CHARACTERIZATION OF FLEXIBLE INTERLAYER

EPDM (ethylene propylene diene rubber), monolithic polyurethane, or similar materials are most used as flexible interlayers to reduce flanking transmission in CLT constructions. The difficulty in characterizing these resilient strips is that there still needs to be a unified standard. For this reason, an EAD DP 21-04-2232-0502 was created, allowing these materials to be characterized from a mechanical and acoustic point of view.

The mechanical properties allow both to verify that the material is suitable from a static point of view for the structure in which it is inserted and to check that the acoustic behaviour is maintained.

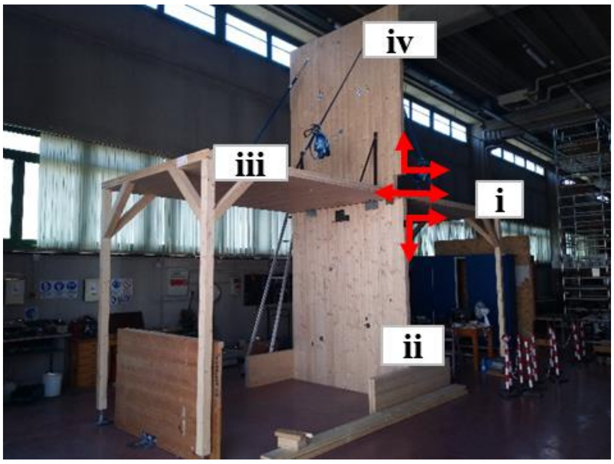

Figure 1. Mock-up of vertical X-junction for experimental measurements of flanking transmission in CLT junctions.

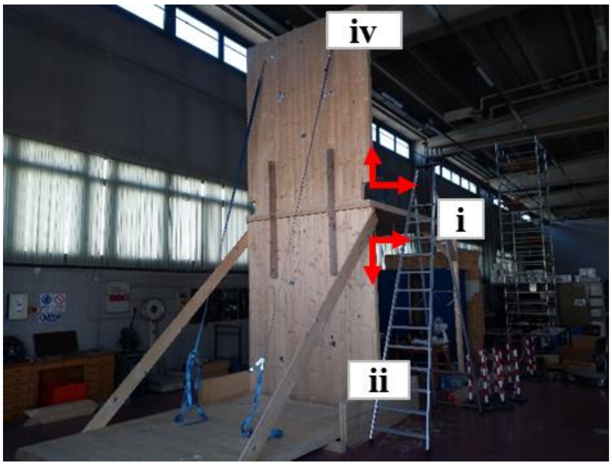

Figure 2. Mock-up of vertical T-junction for experimental measurements of flanking transmission in CLT junctions.

The tests carried out were a reaction to fire, compressive creep, compression set, compressive stress and deformation, dynamic elastic modulus and damping factor, flanking transmission, and a compressive modulus.

According to ISO 8013, the compressive creep test allows the effects of compressive viscous sliding to be evaluated over the long term to know how mechanical and acoustic characteristics will change over time.

According to ISO 1856, the compression set test consists of applying a heavy load to the specimen for a long time and then measuring how much of its initial thickness it recuperates after a recovery time. This lets us consider whether the material will change its thickness after high stresses. A decrease in thickness changes its mechanical and acoustic properties because a crushed specimen will not have the same elastic response as an intact specimen.

The compressive stress and deformation test, according to ISO 844, measures how much load must be applied to the material in order to deform it by 1mm, 2mm and 3mm, which is very useful from a static point of view for tolerance management during the design phase.

Tests of dynamic elastic modulus and damping factor, according to ISO 4664-1, are conducted through DMA (dynamic mechanical analysis) in dynamic conditions using load fluctuations at certain frequencies. Through the measurement of dynamic elastic modulus and dissipative modulus, it is also possible to gain a good understanding of the material in its viscous behaviour and elastic behaviour.

The flanking transmission was measured according to ISO 10848.

According to ISO 844, the compressive modulus test provides an understanding of the material's behaviour in its elastic range, representing its normal use condition.

A unified characterization of these materials also makes it possible to compare them with each other and thus choose the best product for its use.

4. RESULTS

The mounting conditions for the junction of the full-scale model realized analyzed in this paper for the basic configuration are 2 angle brackets (146x55x77x2.5 mm, full pattern with 31 screws 5x50 mm, step 1760mm) and 6 partially threaded screws (8x240mm, step 440mm). The other configurations have the same fastening system as the basic configuration with the flexible interlayer only above (*ab*), above and below (*ab+be*) or only below (*be*). The two flexible interlayers presented in this paper have a shore of 35 (x35) and a shore of 50 (x50).

The vertical T-compressed configuration is loaded in order to compress the resilient interlayer by 10%, equivalent to its condition of normal use.

The values stated in the ETA refer to the transmission path characterized by the presence of the resilient interlayer for which measurements need to be made with and without them. For each path shall be defined the vibration reduction index with resilient interlayer in frequency (K_{ij}) and correction of the $\overline{K_{ij}}$ in the presence of elastic interlayers in the junction (Δ_l) (1).

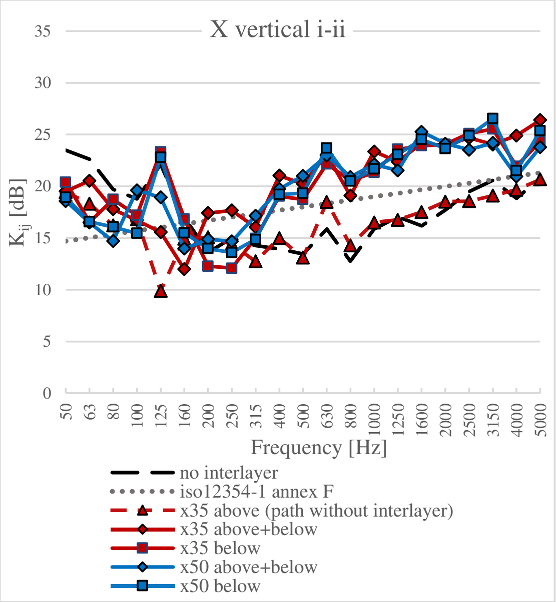

Figure 3. Experimental measurement of vibration reduction index K_{ij} of a vertical X-junction in the path between panel "i" and panel "ii" with and without resilient interlayer.

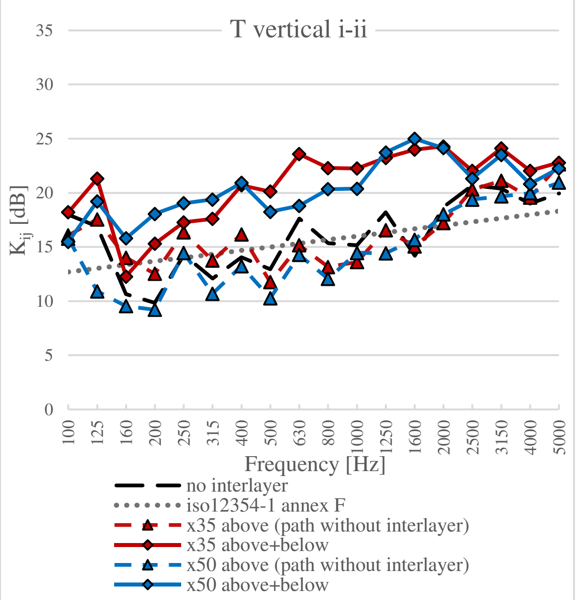

Figure 4. Experimental measurement of vibration reduction index K_{ij} of a vertical T-junction in the path between panel "i" and panel "ii" with and without resilient interlayer.

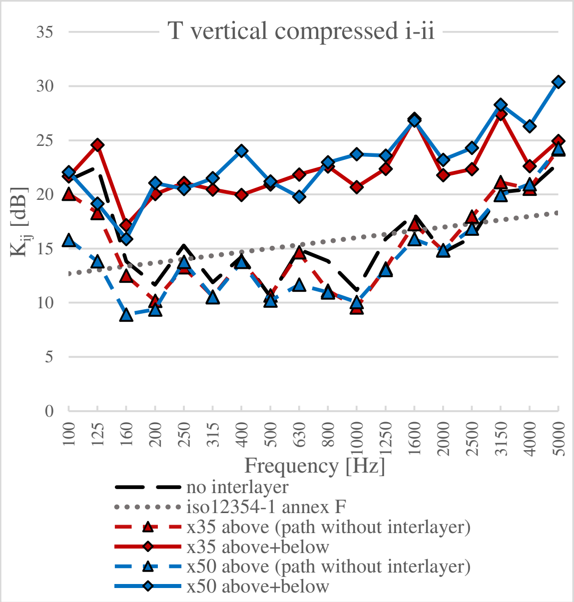

Figure 5. Experimental measurement of vibration reduction index K_{ij} of a vertical T-junction-compressed in the path between panel "i" and panel "ii" with and without resilient interlayer.

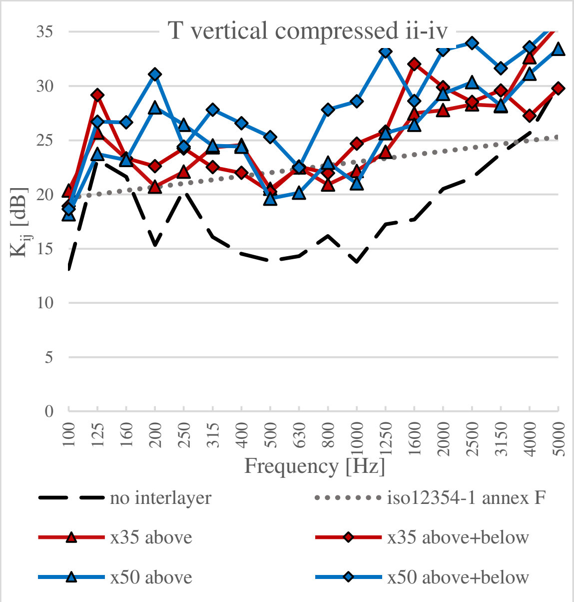

Figure 6. Experimental measurement of vibration reduction index K_{ij} of a vertical T-junction-compressed in the path between panel "ii" and panel "iv" with and without resilient interlayer.

Δ_l for a specific path is calculated as the difference between $\overline{K_{ij}}$ of the same path with and without resilient interlayer. $\overline{K_{ij}}$ is the arithmetic average of K_{ij} within the frequency range 125 Hz to 2000 Hz (one-third octave bands) according to point 10 of the EN ISO 10848-1. Table 1 shows the results.

$$\Delta_l = \overline{Kij_{with}} - \overline{Kij_{without}} \qquad (1)$$

Table 1. Δ_l value of vibration reduction index K_{ij} averaged between 125Hz to 2000Hz.

	i-ii			i-iv			ii-iv		
	X	T	Tc	X	T	Tc	X	T	Tc
x35 *ab*	-0.7	0.2	-1.4	2.2	3.5	6.8	1.8	2.5	6.2
x35 *ab+be*	3.8	5.7	7.1	2.9	3.5	6.1	5.4	6.4	7.4
x35 *be*	3.5	-	-	-	-	-	4.6	-	-
x50 *ab*	-	-1.7	-2.4	-	6.8	7.6	-	5.1	7.0
x50 *ab+be*	3.9	5.6	7.3	3.2	6.4	6.6	5.8	8.9	10.6
x50 *be*	3.8	-	-	0.5	-	-	4.0	-	-

5. DISCUSSION

The figures (Fig. 3-6) show the values of the vibration reduction index K_{ij} of different flanking transmission paths, particularly the corner paths. In addition, the correspondence with the prediction formula contained in Annex F of EN ISO 12354-1 is also checked.

In all cases, it is evident from the comparison that where the timber panels are directly in contact with each other and connected with plates and screws, the measured values (dash line) are lower than those derived from the prediction formula (dot line). This also occurs in all paths where the resilient material is not present. When resilient material is inserted in a flanking transmission path, the values improve by 5-10 dB per frequency (solid line with triangle mark vs solid line with rhombus mark). As indicated in Annex E for heavy building structures, when a resilient material is installed, the paths where it is present increase index K_{ij} values. In contrast, the others worsen due to the different distribution of transmitted energy between structures (dash line vs solid line with triangle mark).

The measurements also show that for suspended panels, the reduced presence of constraints at the edges of the panels also leads to some resonance phenomena, especially when there is no resilient material to dampen these resonances.

6. CONCLUSIONS

From the analysis of the measurement results, it can be stated that the predictive formulae can be used to assess the behaviour of the junctions in the CLT-based construction systems without specific information on the fastening systems. Still, the presence of fixing systems changes these values depending on the path and the type of junction. In addition, the resilient layers improve the reduction index, but no predictive formulas exist to estimate such improvements, as in Annex E.

Finally, for the CLT structures, it may be necessary to better define the facing for the installation of the mock-up in order to avoid the effects of the resonances of the structures due to the free edges.

This mock-up makes possible the comparison of different mounting systems with stable boundary conditions, thus enabling a better understanding of the behaviour of individual elements as they are added or removed from measure to measure. Through the realised mockup, measurements can continue to be taken to form an increasingly robust database of measurements. These measurements will allow more robust predictive formulae to be developed, which will then be validated by as many case studies as possible of real construction site cases where special ad hoc solutions are often used. The goal is the integration of predictive formulae for CLT junctions, even for groups of assembly systems, with the implementation of resilient materials.

7. REFERENCES

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