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CROSS LAMINATED TIMBER ABSORBENT

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Abstract

Wall and ceiling systems fabricated as cross laminated timber (CLT) is gaining popularity in Europe. When designing a sports arena or a multipurpose hall you look for just such a light weight building element with appropriate load bearing and aesthetic qualities. These easy adaptive elements also liberate the designer in building future green buildings. The use of traditional acoustic panelling might be inconsistent with the wish to expose wooden building parts, and since modern architecture prefer clean surfaces and tidy interiors, the application could be limited due to lack of natural acoustic absorption. On the contrary, need for inherent acoustic absorption of the element has evolved a design challenge.

This paper presents a solution on refining a standard CLT element to become a Helmholtz resonator, primarily to reduce the room reverberation time at the lower frequency range. From ancient times – long before Helmholtz - the volume resonator is known. The existence of natural slits between boards of the fabricated element sat us on the path. If these slits could be connected to an appropriate volume, the basic parts of a volume resonator were at hand. This volume was furnished by removing every second centre cross-boards of the CLT, and widened the slits by sawing open slits through the surface boarding. The resonator damping component became mineral wool infill.

The paper includes the classical theory for the resonator design, the acoustic laboratory full scale measurement results and a reverberation time evaluation of the new library hall under construction with the actual CLT elements installed as exposed load bearing roof and walls. The most cost effective use of CLT has so far proven to be load bearing floor and roof constructions with a ceiling as an exposed CLT elements. The laboratory results are used to evaluate the effect of inherent acoustic absorption and to define the need for future development work.

Keywords

Cross Laminated Timber element, CLT, Acoustic absorbent, Helmholtz resonator, hall absorption

1. Introduction

Solid wood and heavy timber constructions are not associated with sound absorption capabilities – they could rather be classified similar to brickwork. Cross laminated timber (CLT), assembled by gluing together cross laid timber boards – lamellas – makes a solid wood element. Figure 1 shows a CLT build-up by 33 x 94 mm^2 lamellas. CLT provides both structural strength with shell and plate action, and an attractive wooden surface for interior exposure.

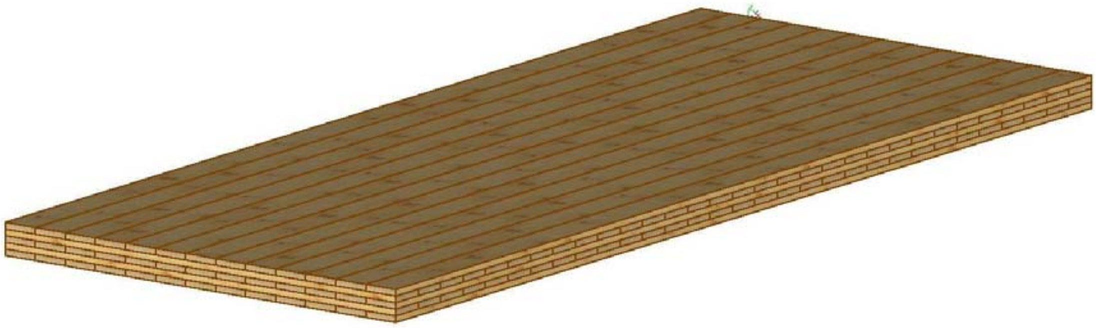

Figure 1 - Cross laminated timber element with five layers.

CLT is mainly used as a support element, but partition elements may combine properties of structural strength, fire resistance, durability and acoustic absorption. In the interest of architects CLT should preferably be visually exposed and uphold all the mentioned functionalities. However, when considering large timber constructions absorption of sound waves has become a fairly new field within building physics.

The architectural demand for exposure of the CLT surfaces while achieving sound absorption across the same surfaces has made acoustic designers into speculators. Since no porous material is at hand the volume resonator had to be the key. This classical principle had already been introduced within the pending design movement - *Norwegian wood* – but temporarily put on ice.

The mature idea of integrating volume resonator capabilities into the CLT element became suddenly close at hand when a contractor realised that a beautiful CLT ceiling of a library hall of approximate 7000 m^3 had to be concealed by absorptive lining to fulfil functional requirements. By demanding CLT elements with acoustic absorption properties the major norwegian CLT manufacturer took the challenge to investigate an adaptation to the production line.

Every second cross laid lamella could be exchanged by a void of 200mm width while still keeping an acceptable shear force capability within the CLT. Figure 2 shows the acoustic element fabricated with such voids. When moulding the element, surface slits were cut into the voids. The air mass of the slit neck couples to the air spring of the void and a Helmholtz type volume resonator is a reality. In the production the void was created by exchanging lamellas with lightweight mineral wool which becomes the damping element of the resonator

Figure 2 - Assembling of the acoustic CLT element (not showing the void infill)

The need for acoustic damping in dwellings depends on user preferences. Piping and ducting is often hidden within dropped ceilings. However, architects like to design rational, but refined and artistic solutions. One way of rational designing is by including more functionality into one building element. Some ventilation and piping might be visible below the ceiling, which anyhow simplifies the maintenance.

Some engineered solid wood corresponding to CLT does have sound absorbing properties, i.e. Lignatur, but the authors have not found referenced any producers using the Helmholtz resonator.

The project tried to optimize the industrial process, keep a solid wood surface and provide acoustic absorption. The resonance frequency is designed towards the lower voice frequencies (base tones) to compensate for the lack of room absorption of furniture and coverings.

2. Method

2.1 Helmholtz resonator

The Helmholtz resonator is a resonance absorbent where the air mass in a slit or hole and the stiffness of a connected air volume make an oscillator. Maximum sound absorption is achieved at the resonance frequency. In architectural acoustics this principle has been used to create appropriate acoustic conditions, especially in the low frequency range, dependent on the use of interior areas.

The resonance frequency is found in cylindrical and rectangular slits by the formula:

$$f_H = \frac{v}{2\pi}\sqrt{\frac{A}{V_0 L}} \tag{1}$$

Where f_H resonance frequency (Hz)
v speed of sound (m/s)
A cross-sectional area of the slit (m^2)
V_0 static volume of the corresponding void (m^3)
L effective depth of the slit (m)

The acoustic absorption is measured in 1/3 octave bands from 100 – 5000 Hz in accordance with [2].

2.2 Laboratory test

The development of the acoustic element has been done through three phases. The first test element had 8 slits to the void between the cross-boards, sawed with regular centre distances and tested with empty voids. The second test element was sawed with 12 slits with irregularly spaced slit centre distances and furnished with fibre cloth inside. The third test element was similar to the second, but with industrial processing adapted to the production at Molven Massivtre AS and furnished with mineral wool infill. Table 1 shows the setup of the test elements.

Table 1 – Characteristics of test elements

Filling	Slits in CLT of 1200 mm width #	Slit perforation %	Void in mid layer %	Test area m^2
Empty	8	4	50	12.7
Fibre cloth	12	6	67	11.5
Mineral wool	12	6	67	11.5

The acoustic elements were tested in a reverberation room at SINTEF Building and Infrastructure, see Fig. 3. Three elements were laid on the floor and the edge covered with boards and carefully taped in all joints, in order to refine the measurement to solely apply to the slit area of the tested elements. Standard element width is 1200 mm. The first test elements had lengths of 3400 mm, the next test elements were 3200 mm long. All element was of 100 mm thickness. Ref. [2] defines the test area to be 10-12 m^2, however the small excedance of the first test elements make no significant failure.

Figure 3 - Test elements on floor in reverberation room.

2.3 Building test

The test in the library hall cannot be done till the room is fully closed. This will happen in the autumn of 2011.

3. Test results

The results show spectral signatures of a Helmholtz resonator which corresponds to the theoretical assessment.

3.1 Laboratory measurements

Fig. 4 displays the test results form the reverberation room where the variations clearly show the improvement when including the mineral wool into the void. The element used in the library hall is the variant with mineral wool innfill of the void.

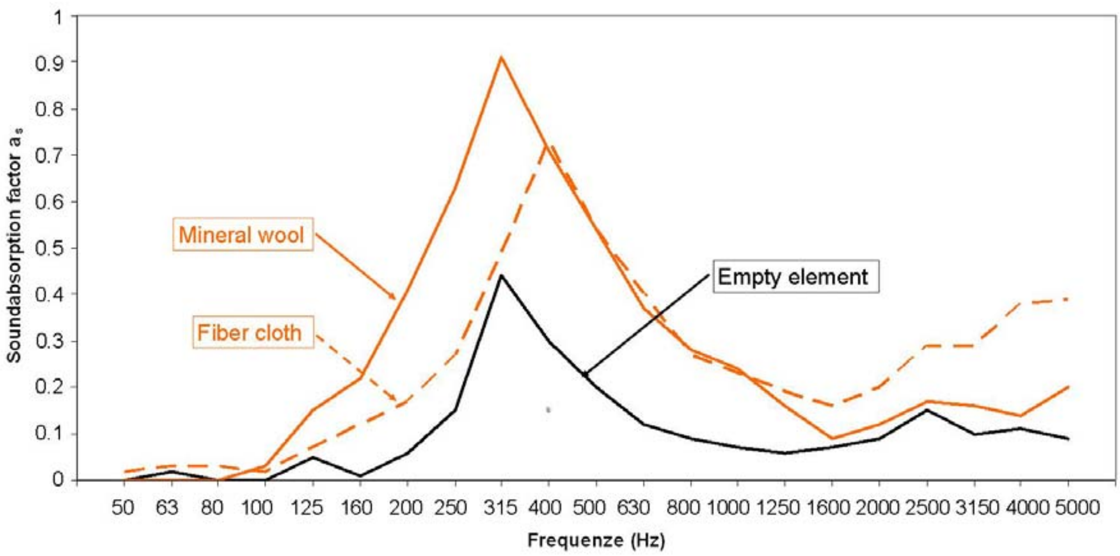

Figure 4 - Sound absorption re frequencies for the test elements.

3.2 Calculated reverberation time of the library hall

Fig 5 show a stylistic drawing (seen from below) of ceiling and walls surfaces of the library hall. The 1150 m^2 ceiling and the (pink) wall partitions consist of the mentioned absorbing CLT elements with mineral wool infill.

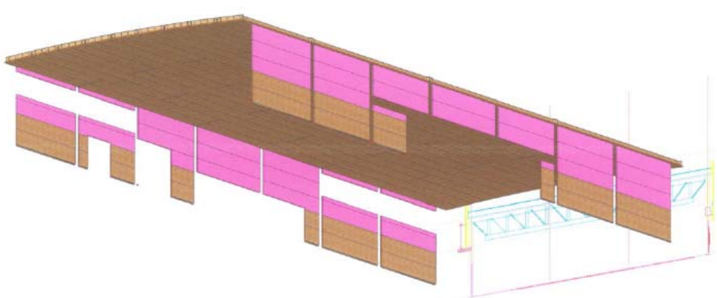

Figure 5 – Library hall

In the calculation of the hall reverberation time also all furniture is taken into account. Fig. 6 show the calculated reverberation time (blue curve) based on diffuse sound field Sabine calculations. The results are shown to be within the Norwegian standard requirements (red curve).

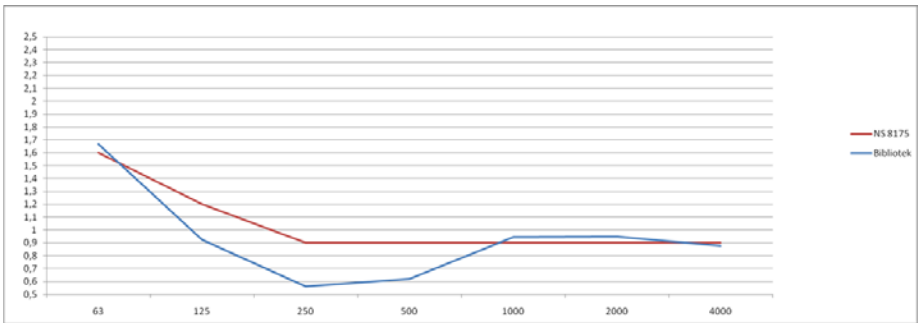

Figure 6 – Calculated reverberation time (in seconds) of the library hall

3.3 Other considerations

Shear tests are made for ordinary and acoustic CLT elements. Even full scale shear testing of the built-in elements is planned for.

The ceiling is air tight with vapour sheeting above the CLT elements to avoid moisture transportation into the roof cavity insulated with mineral wool.

Fire resistance in the ceiling is of vital importance. The acoustic element has not endured a fire test. However, including mineral wool is advantageous because oxygen transport is limited from any fire.

4. Conclusions

A test element with integrated acoustic absorption was developed and found to be a sufficient sound absorbent for the actual application of the library hall and similar public areas. An acoustic foil may exchange the mineral wool in the void, but this alternative must be done in according with regulations for fire protection.

The development of CLT is still in its childhood. Further development work is needed on several fields of building physics.

5. Acknowledgements

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References

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[2] EN ISO 354 (ISO 354:2003) Acoustics - Measurement of sound absorption in a reverberation room (ISO 354:2003)

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