AIRBORNE SOUND TRANSMISSION IN CROSS-LAMINATED TIMBER BUILDINGS: THE INFLUENCE OF BUILDING HEIGHT

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1 Introduction

Buildings with cross-laminated timber (CLT) has gained growing popularity in several countries. In addition, buildings constructed with CLT are increasing in building height, which increases the load on the junctions and structural building elements lower down in the buildings. These increasing loads could have an impact on the elasticity of junctions and thus affect the sound transmission between apartments on different stories as suggested by Ref. [1]. Moreover, Ref. [2] focused on airborne sound transmission measurements in a lightweight wooden frame building and found that the sound insulation was better higher up in the building. However, it was suggested that the results were due to a mismatch between load and elastic strip stiffness, rather than the load itself. Ref. [3] measured in a real CLT building and found that the vibration reduction index reduces with increased load for the path wall to wall. The authors of Ref. [1] investigated vibrations induced by a tapping machine in a multi-family wooden frame building and concluded that junctions attenuated vibrations better higher up in the building.

Previous studies, mentioned above, have investigated how the number of stories, or the load, affects the sound insulation or the vibration reduction index between apartments or different building elements. However, the actual difference in airborne sound insulation with increasing load is not thoroughly investigated in previous research. The purpose of this paper is to show the effect of the building height, and thereby the load, on the vertical airborne sound insulation between apartments on different stories in different CLT buildings which is a summary of Ref. [4].

2 Method

2.1 Project description

Airborne sound insulation measurements took place in three different projects at different locations in Sweden before people had moved in which are described as projects A, B, and C. The same floor plan is used over the different stories per building in the evaluations. Moreover, vertical measurements were conducted and compared between the same type of rooms over the different stories to minimize the number of affecting parameters. To sum up, the surface dividing area, the volume and the construction elements were the same and the rooms had no furniture in them. Thus, the main parameter that is different between measurements over different stories is the load on the junctions and the stiffness of the resilient interlayers dependent on the load.

Measurements in project A took place in two separate buildings, building 1 with twelve stories, and building 2 with ten stories. The building system in project A is built up with CLT, a suspended gypsum ceiling, concrete above an impact sound insulation board and 6 mm resilient interlayers in the junctions in building 2 but none in building 1. The difference in number of stories was in project A: six in building 1 and five in building 2. Project B consist of 6 stories and measurements were conducted between stories 2–3 and 4–5. The building system in project B is built up with CLT, a suspended gypsum ceiling, a raised resilient floor and 25 mm resilient interlayers in the junctions. Project C is constructed with eight stories and measurements were conducted between stories 3–4 and 7–8. The building system in project C is built up with volume modules of CLT, with a raised resilient floor and resilient interlayers between the volume modules.

2.2 Evaluation description

Evaluation of the measurements are done separately for each building by subtracting the differences in vertical airborne sound insulation between low and high stories accordingly: $D_{nT,high} - D_{nT,low}$. Identical floor plans are used where measurements took place in each building. Thus, the only main difference in the evaluation is the load on the junction. Moreover, for Project A – Building 2, Project B and Project C, the stiffness of the resilient interlayers is different depending on the load on the junctions.

3 Results

Over the three different projects, with in total four buildings, 58 vertical airborne sound insulation measurements were conducted. Each project consisted of varying junctions, different dividing elements and a varying total number of stories. The result from the projects and buildings are displayed in Fig. 1 were the mean values over the frequency range for each project is compared and evaluated. Measurement data show that there is an overall positive difference in vertical airborne sound insulation between high and low stories. This result indicate that the vertical airborne sound insulation decreases lower down in the building with increasing load on the junctions. However, the results are spread with several decibels over the frequency range, and there is no clear correlation between the reduction in sound insulation and the different buildings.

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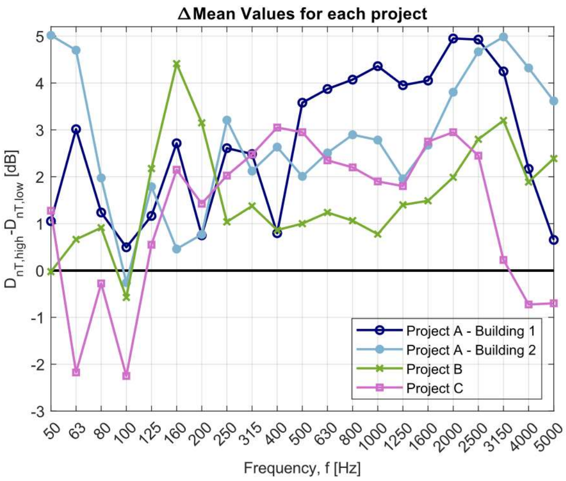

Figure 1: Mean values of the difference in vertical airborne sound insulation between high and low stories for each building and project.

4 Discussion

The number of stories in each project differs where measurements took place, from two to six stories depending on the project and the building. The result in Fig. 1 is therefore divided with the difference in the number of stories for each measurement in each building and the result is presented in Fig. 2. This approach results in a good agreement between the difference in vertical airborne sound insulation per story for each building for frequencies between 250 and 2000 Hz with a linear correlation. The improvement in sound insulation higher up in the building is vaguely apparent in low frequencies which is likely caused by the effect of the direct sound transmission. Yet, the improvement is clearly apparent in mid-frequencies, which is typically around the critical frequency region of CLT panels. Above 2000 Hz, the mean values are spread and reduced which is likely due to the background noise. The black dashed line is a mean value curve for the data in Fig. 2. However, the mean value curve is modified to not include values between 125 and 200 Hz from project B since it is suggested in Ref. [4] that it is related to the specific design system of the project.

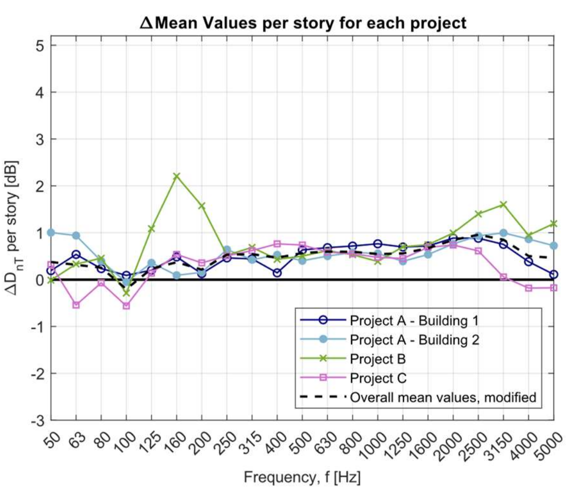

Figure 2: Mean values of the difference in vertical airborne sound insulation between high and low stories, per story, for each building and project with a mean value curve modified between 125 and 200 Hz.

This measurement data indicates that the stiffness of the resilient interlayers has less effect on the difference in vertical airborne sound transmission between stories at high and low levels in buildings. The result also shows that the primary dependent factor for the difference is the load, with or without resilient interlayers, in cross-laminated timber junctions.

The difference in the result is related to the difference in load on the junctions and the flanking sound transmission. If flanking paths are suppressed to greater extent in a building, the same result is not expected to be visible. Moreover, flanking sound transmission is typically more dependent in wooden buildings compared to concrete buildings. Consequently, the same result presented here cannot be expected in a concrete building, and specifically in a building with low-flanking sound transmission. To evaluate the result further, vibration reduction index measurements are required.

5 Conclusion

Measurements from several projects with various building systems suggests that increasing load on junctions results in a worse vertical airborne sound insulation (lower down in the buildings). Measurements also indicate that the effect is similar regardless of the presence of resilient interlayers in the junctions. With or without resilient interlayers, increasing load results in a higher sound transmission between apartments and, therefore, lower sound insulation.

The result further suggest that the vertical airborne sound insulation have a mean difference per story over the measured frequency range of 0.5 dB. Although 0.5 dB is a low number, a 6-story difference in a CLT building is expected to have a mean difference of 3 dB and the effect is expected to increase further with more stories. Therefore, with increasing building height in high-rise CLT buildings, the load on the junction should be considered and specifically at lower levels to choose the right treatments and to ensure good sound insulation performance.

References

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