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Nail Laminated Timber for Mass Timber Residential Constructions

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Mass timber constructions are gaining popularity in Canada as more provinces have allowed the construction of timber buildings of several stories. One of the mass timber elements in use in mass timber constructions is the Nail Laminated Timber (NLT or Nail-lam) element which is constructed by fastening individual dimension lumber, stacked on edge, into a single structural element. An advantage of NLT elements is that they can be constructed on site. Although NLT elements have been in use for decades, little is known about the transmission loss of the elements. The National Research Council of Canada undertook a study of the acoustic properties of the NLT elements including the transmission loss and the radiation efficiency of the elements with and without linings.

1 Introduction

Nail laminated timber (NLT) elements have been gaining popularity as part of mass timber constructions in Canada. NLT floors and walls, an example of which is shown in Figure 1 are fabricated by stacking on edge, boards that are 2x4 (38 mm x 89 mm), 2x6 (38 mm x 140 mm), 2x8 (38 mm x 184 mm), 2x10 (38 mm x 235 mm) or 2x12 (38 mm x 286 mm) and then fastening them with 2 to 4 rows of 83 mm collated nails spaced 406 mm on center. Combinations of boards with different thickness (2x4 and 2x8 for example) can be used to create fluted surfaces.

Figure 1: NLT installed in the laboratory and a schematic of the NLT construction. The bright spots in the photo are reflective tape which was used for the measurements of the surface velocity with the laser vibrometer.

Once the NLTs are fabricated, shear elements of 19 mm plywood or oriented strand board (OSB) are typically fastened to the elements using nails spaced 305 mm on center. An advantage of NLT elements over cross laminated timber (CLT) elements is that they can be built on site to create monolithic slab panels that support a range of design needs including curves and cantilevers.

Although the NLT elements have been in use for decades, there is a lack of published transmission loss data for bare NLT elements or NLT elements with linings that builders or architects can use. Therefore, as a stakeholder in this project, the Canadian Wood Council requested that the acoustic testing of NLT elements be a top priority. The results collected to date for the NLT testing are shown in this paper with a brief analysis of the data. Further testing and analysis as well as comparisons between NLT and DLT (doweled laminated timber) and CLT (cross laminated timber elements) will be part of the broader outcomes of the study.

2 NLT elements and linings evaluated

The NLT elements evaluated for this study included five thicknesses:

- 2x4 89 mm thick with a mass per unit area of 39.5 kg/m^2
- 2x6 140 mm thick with a mass per unit area of 65.8 kg/m^2
- 2x8 184 mm thick with a mass per unit area of 81.6 kg/m^2
- 2x10 235 mm thick with a mass per unit area of 89.5 kg/m^2
- 2x12 286 mm thick with a mass per unit area of 136.8 kg/m^2

The linings installed on the NLTs are shown in Table 1.

Table 1: Linings evaluated as part of the study.

Lining	Side 1	Side 2
1	19 mm Plywood	Bare
2	19 mm OSB	Bare
3	Two layers of 12.7 mm thick fire-rated gypsum board screwed to 38 x 38 mm wood furring (spaced 400 mm on center and mechanically attached to 19 mm plywood which was attached to the face of the NLT with 38 mm thick glass fiber batts filling the spaces between the gypsum board and the plywood	Bare
4	Two layers of 12.7 mm thick fire-rated gypsum board screwed to 64 x 38 mm wood studs (spaced 600 mm on center and spaced 13 mm from the plywood which was fixed to the face of the NLT) with 64 mm thick glass fiber batts filling the spaces between the gypsum board and the NLT	Bare
5	Two layers of 12.7 mm thick fire-rated gypsum board screwed to 38 x 38 mm wood furring (spaced 400 mm on center and mechanically attached to the face of the NLT with 38 mm thick glass fiber batts filling the spaces between the gypsum board and the plywood	19 mm Plywood
6	Two layers of 12.7 mm thick fire-rated gypsum board screwed to 64 x 38 mm wood studs (spaced 600 mm on center and spaced 13 mm from the face of the NLT) with 64 mm thick glass fiber batts filling the spaces between the gypsum board and the NLT	19 mm Plywood
7	Parge	Bare
8	Parge	19 mm Plywood

The linings chosen for the study were identical to those which were evaluated on CLT elements as described in the research report, RR-335: Apparent sound insulation in cross-laminated timber buildings [1]. The commonality between the linings evaluated would allow for the similarities between NLTs and CLTs to be assessed.

3 Measurements

3.1 Transmission loss, ΔTL and Δ*STC*

The transmission loss of each of the NLT elements with and without linings was measured in the direct wall transmission loss laboratory at the National Research Council. The change in the transmission loss when each of the linings was applied was determined using the procedure outlined in detail in Section 2.1 of RR 335. For each of the NLT elements, the transmission loss of the base wall without sound leaks was determined from the transmission loss measured with parge on one side of the element. The layer of parge suppressed the sound leaks through the gaps between the individual beams of the NLT element. The suppression of leakage was important to not only determining the change in the transmission loss (ΔTL) due to the lining, but also for the future calculation of flanking transmission through the NLT elements. The term "Base" NLT is used throughout the remainder of this paper to denote a NLT element without a lining but without any reduction of the direct sound transmission loss due to leakage. The term "Bare" NLT will be used to denote a NLT element which does include a reduction of the direct sound transmission loss due to leakage.

3.2 Additional measurements

In addition to the transmission loss measurements, the resonant and total radiation efficiencies were measured for each of the linings. The loss factors of the NLT elements with and without linings were also evaluated. Lastly, the wave numbers were determined in the directions parallel and perpendicular to the orientation of the individual boards of the NLT elements. The results of the additional measurements will be included in the publically available final report for the project.

4 Results

4.1 Transmission loss

The transmission loss of the bare NLT elements are compared in Figure 2.

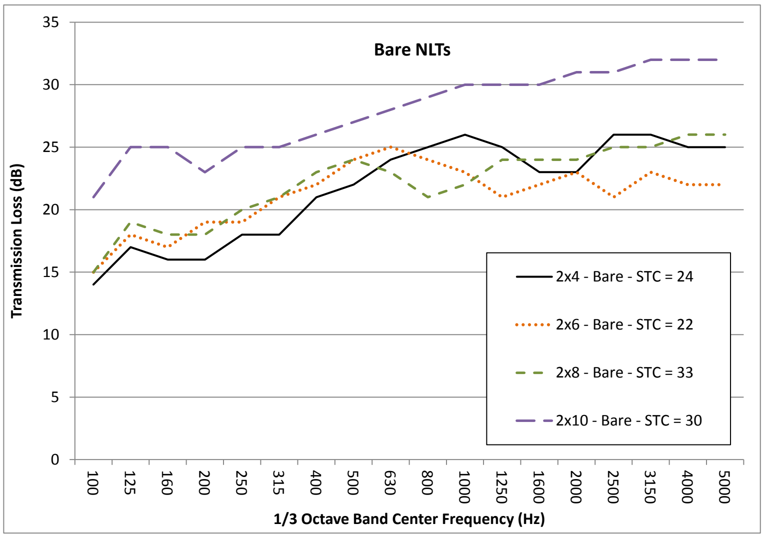

Figure 2: Comparison between the transmission loss values of the bare NLT elements which is the "Bare" case.

Note that the measurements on the 2x12 NLT were not complete at the time this paper was written. The transmission loss measurements included the effect of significant sound leakage through the gaps between individual boards of the NLT elements. For example, the 2x6 NLT that was tested exhibited more sound leakage than the 2x4 NLT, resulting in a lower single number rating. The effect of the sound leakage can be observed by comparing the transmission loss values of the bare NLTs shown in Figure 2 with the transmission loss values of the base NLTs shown in Figure 3.

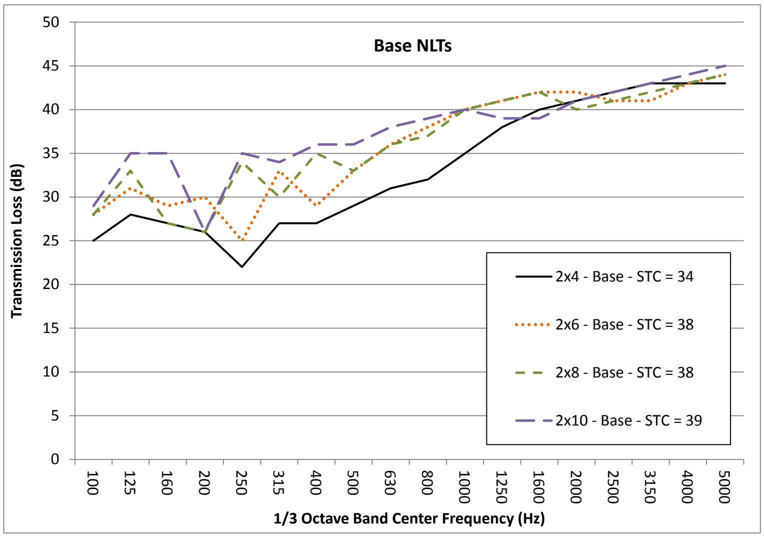

Figure 3: Comparison between the transmission loss values of the NLT elements with parge which is the "Base" case.

The parge on one side of the base NLTs reduced the sound leakage, especially at the higher frequencies while causing negligible change to the loss factor of the NLT elements. While the 2x12 NLT shown in Figure 2 had a higher transmission loss over the frequency range, the differences between the transmission losses of the different thicknesses of the NLT was reduced when sound leakage was minimized by the parge. The thicker NLT base elements had a higher single number rating as would be expected.

4.2 The effect of linings

The transmission loss values for each of the NLT elements with the linings attached are shown in Figure 4 to Figure 7.

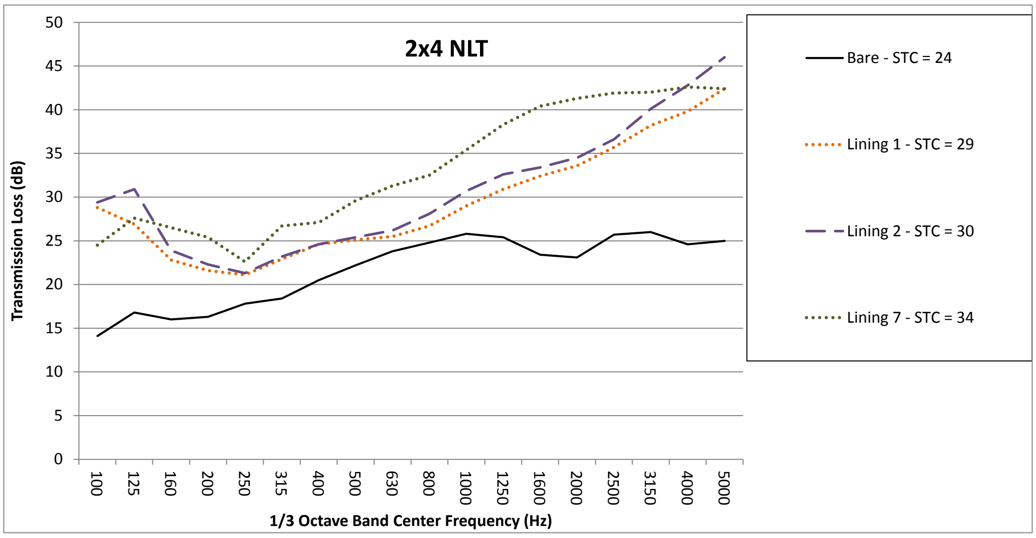

Figure 4: The transmission loss values for the 2x4 NLT with and without linings.

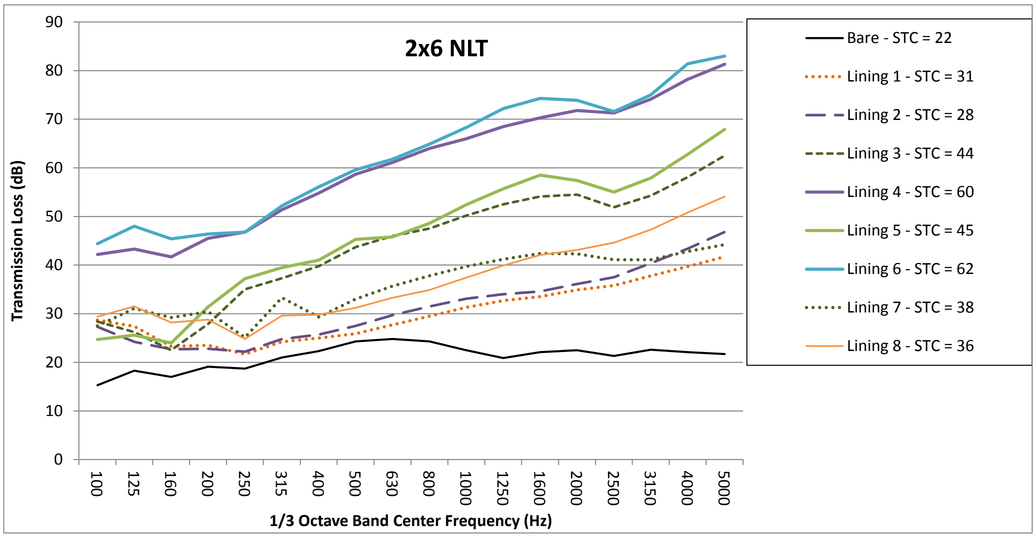

Figure 5: The transmission loss values for the 2x6 NLT with and without linings.

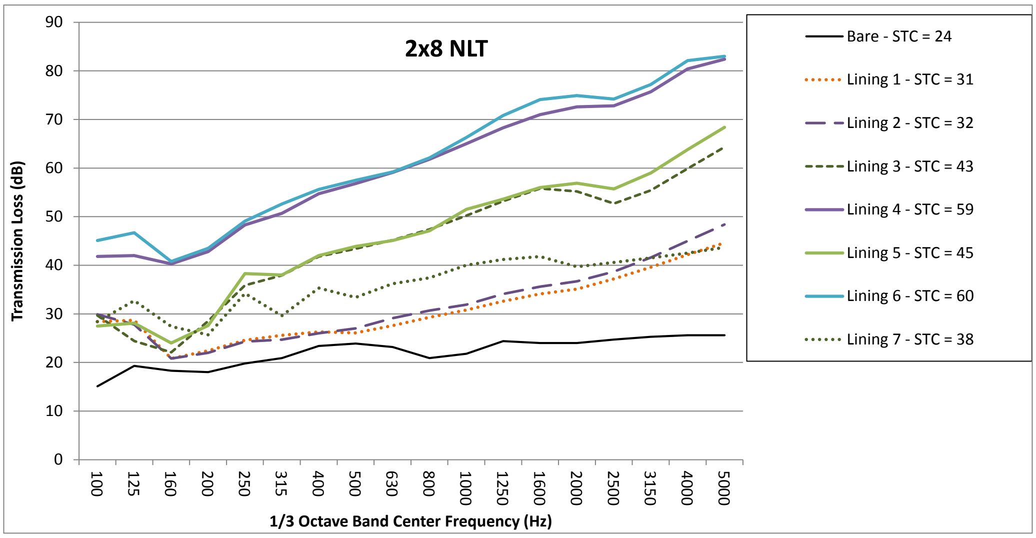

Figure 6: The transmission loss values for the 2x8 NLT with and without linings.

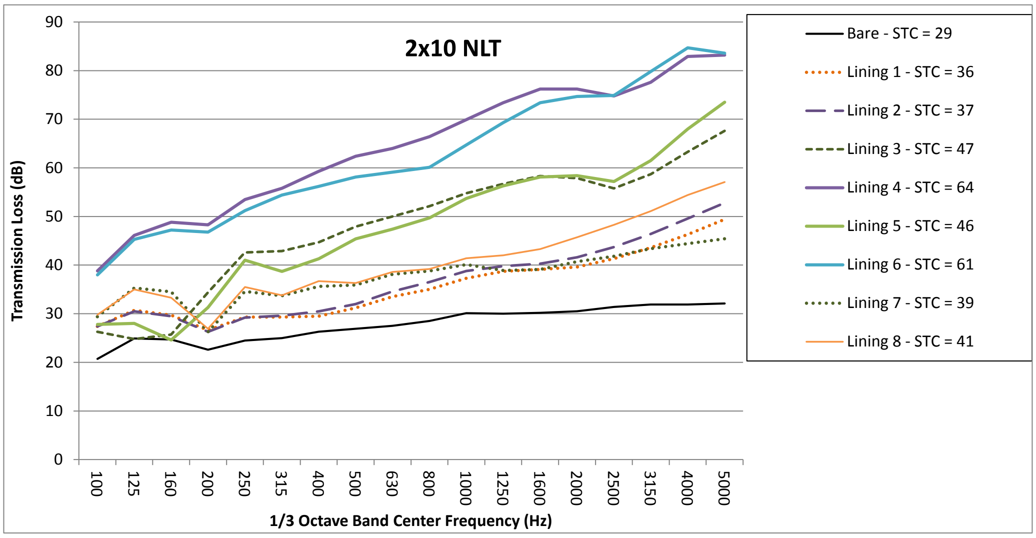

Figure 7: The transmission loss values for the 2x10 NLT with and without linings.

The figures show that the addition of the linings improves the transmission loss of the NLTs, but not enough to meet the minimum requirement of the current Ontario Building Code which is currently a STC rating greater or equal to 50. Of the linings evaluated to date, only Lining 4 and Lining 6 resulted in an STC rating that met the minimum requirements of the current Ontario Building Code.

5 Discussion

The data for the NLTs which has been measured and analyzed to date shows that the NLT elements are prone to lower transmission loss due to sound leaks. The addition of a shear element of OSB or plywood reduces the effect of the leakage, but the increase in the transmission loss is not enough to meet the minimum acoustic requirements of the current Ontario Building Code. Of the linings evaluated to date, only Lining 4 and Lining 6 increased the transmission loss enough to meet the code requirements.

The future analysis of the loss factor, wavenumber and radiation efficiency data will give further insight about improving the transmission loss of the NLT elements. It is expected that the improvements due to linings used on NLT elements will be similar to those for linings installed on CLT elements which also show signs of sound leakage. If the improvements due to linings are similar enough, it will allow the ΔTL and ΔSTC for linings to be shared between the NLT and CLT elements which will be advantageous.

6 Summary

Preliminary results for NLT elements of different thicknesses both with and without linings have been shown. Further testing and analysis is scheduled to give more insight into the behavior of the NLTs elements to allow comparisons with both CLT elements and DLT elements.

Acknowledgements

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References

[1] Hoeller C, Mahn J, Quirt D, Schoenwald S, Zeitler B. Apparent Sound Insulation in Cross-Laminated Timber Buildings. Ottawa, Canada: National Research Council Canada; 2017. http://doi.org/10.4224/23002009