Post-fabrication Preservative Treatment of CLT

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ABSTRACT

Cross laminated timber is becoming a popular manufactured building material that offers a safe and environmentally friendly alternative in large building applications that were previously limited to concrete and steel. Preservatives are often applied to wood products to protect them from decay and extend their service life. However, CLT panels are typically not treated due, in part, to a lack of efficient and effective methods for treating large panels and a lack of information on what impact the treatment process has on the panels' mechanical properties. In this work, a variety of CLT panels were obtained from different manufacturers and constructed with different species and layup options to evaluate the double-vacuum preservative treatment method, which has the potential to accommodate large panels. Small samples were cut, edge-sealed, and double vacuum-treated with a borate preservative solution. Samples were then tested in rolling shear following standard procedures. Preservative retention, penetration, and dimensional changes varied among each species and consisted of retentions above, near, and below standard values presented for solid sawn lumber. The double vacuum treatment method effectively penetrates around laminations but negatively impacts the mechanical properties. The reduction in mechanical properties could be acceptable in some cases, depending on wood species and their treatability, and therefore warrants more research to optimize the double vacuum method. This work will help to provide higher-durability CLT panels, and thus increase the potential applications and service life of this exciting new technology.

INTRODUCTION

Cross-laminated timber (CLT) is emerging as an environmentally friendly alternative to concrete and steel in large buildings. CLT is among the mass timber family of products (with glulam, large timbers, etc.) that can provide flexibility in construction, rapid construction, and good fire and seismic performance. As with all building materials, CLT is liable to wetting during construction and in-service, which increases susceptibility to biological degradation. However, panels are currently not treated with preservatives; the strategy for durability consists only in keeping the wood dry. CLT treatment options are needed to address the inevitable need for supplemental protection(Wang, Stirling et al. 2018).

Treatment of CLT panels is challenged by their large size; traditional pressure treatment is not possible for many panels that are too large to fit in a treatment cylinder. One potential option is to treat by double vacuum in a vacuum bag. However, the potential to penetrate CLT via vacuum treatment is unknown, as is the potential impacts on the panels' mechanical properties.

Borates are a good potential preservative for CLT panels, given that most CLT will be used in interior applications and mostly protected from wetting; they are odorless, colorless, inexpensive, diffusible, and protect against a wide range of insects and fungi (Williams 1996).

The objectives of this initial study were to determine if double vacuum treatment, post-fabrication, of commercially produced CLT can achieve useful levels of borate preservative penetration and retention, and if the treatment impacts panel mechanical properties.

MATERIALS AND METHODS

Commercially produced CLT panels were obtained and consist of a range of species and layup variations. The panels evaluated in this test include Douglas-fir (*Pseudotsuga menziesii)* from the United States, spruce (*Picea* spp.) from Austria, and radiata pine (*Pinus radiata)* from Chile. All the panels were approximately 102 mm (4 in.) thick. The Douglas-fir and pine panels were each three lamellae thick; the spruce panels were made of five lamellae.

Treatment:

10 samples with dimensions of 229 mm x ~ 102 mm (panel thickness) x 305 mm (9 in. x 4 in. x 12 in.) were cut from the panels. Each sample was edge sealed using a neoprene coating. The initial weight and dimensions of the samples was recorded.

Samples were double vacuum treated with 8% DOT (Bora-care with Mold Care, Nisus Corporation) in a small pressure/vacuum vessel as follows:

1. 30-minute vacuum (~22 inHg) in an empty vessel.
2. Introduce the ambient laboratory temperature treating solution using the residual vacuum. The solution completely submerged the samples, which were weighted down to prevent floating.
3. Allowed to soak in the solution for 30 minutes.
4. Vessels emptied using gravity.
5. 30-minute final vacuum. This second vacuum (hence the term “double vacuum”) serves to remove excess treating solution.

Post-treatment, the samples were wiped with paper towels and immediately weighed and measured to assess solution uptake and dimensional change. The treating solution was sampled and analyzed for borate content. Preservative retention was calculated as the product of solution uptake and preservative concentration. Dimensional change was calculated as volumetric swelling.

Samples were cut in half (along the 12 in. axis) and sprayed with curcumin reagent to indicate the presence of borate inside the samples (Smith and Williams 1969). The samples were then conditioned to weight equilibrium at 20°C and 65% relative humidity (~12%MC) prior to mechanical testing.

Mechanical Testing:

Treated samples of each panel type (n=20, two from each of the 10 treated samples that were subsequently cut in half) were tested in rolling shear in accordance with EN 789. An equal number of untreated controls cut from the same parent panels were also tested. The nominal sample size was 95 mm x 102 mm x 305 mm (3 ¾ in. x 4 in. x 12 in.).

Samples were placed in a direct shear rig and tested using a uniaxial testing machine (UTM), where applied load and crosshead displacement was recorded. Two linear variable differential transformers (LVDTs) were secured to opposite sides of the panel using aluminum brackets and hanger bolts to measure relative displacement of the outermost plies for which the grain is parallel to the direction of applied load. Once the sample was plumbed and LVDTs were in place, the test was run until a decisive rolling shear or glue bond failure occurred. The load was applied in displacement control at a rate of approximately 2.54mm/min (0.1 in/min).

RESULTS AND DISCUSSION

Solution uptake varied greatly among the panel types (Table 1) and corresponded to preservative retention and volumetric swelling. The greatest uptake was in a panel made of a treatable species (radiata pine) that was not edge glued. The spruce panel was five-ply vs. the three-ply of the other panels and the spruce panel samples achieved higher retention than the Douglas-fir, despite both spruce and Douglas-fir being refractory species. It is likely that species, laminate thickness, and whether the lamella were edge glued are factors relevant to solution uptake, but the relative impacts of these variables cannot be distinguished based on these data.

Table 1. Preservative uptake of CLT samples.

Manufacturer	Species	Edge-glued?	Volumetric swelling (%)	Preservative solution uptake (kg/m^3)	Retention (SBX as B_2O_3, kg/m^3)
A	Douglas-fir	Yes	0.402	8.7	0.2
B	Spruce	Yes	1.14	52.7	2.5
C	Radiata pine	No	4.19	263.1	9.1

There is no standard for CLT preservative treatment but the following standards for sawn lumber suggest that double vacuum treatment could provide practically important levels of preservative retention:

- AWPA UC2 is SBX as B_2O_3 = 2.7 kg/m^3
- New Zealand Standard NZS3640 ~ 0.6 kg/m^3

High uptake levels (retention) coincided with good penetration (Figure 1). The solution appeared to preferentially penetrate the bond-lines and preexisting cracks, particularly in the panels made with refractory species (Douglas-fir and spruce).

The treatment reduced the average rolling shear stress of the CLT samples (Figure 2). Variability was high within the treatment groups and it is unclear whether the treatment effects measured here would be practically limiting; however, it may be that the treatment parameters could be adjusted to reduce the negative effects on mechanical properties.

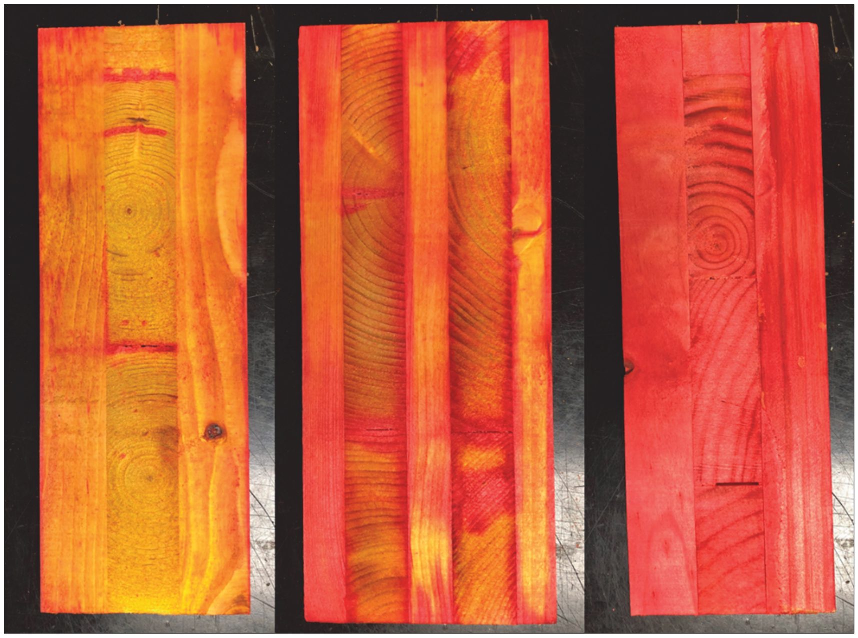

Figure 1. Typical penetration of borate into treated CLT samples. Red color indicates the presence of boron. L-R: Douglas-fir, spruce, and radiata pine. All samples were edge-glued prior to treatment and cut open after treatment. The cut faces are shown.

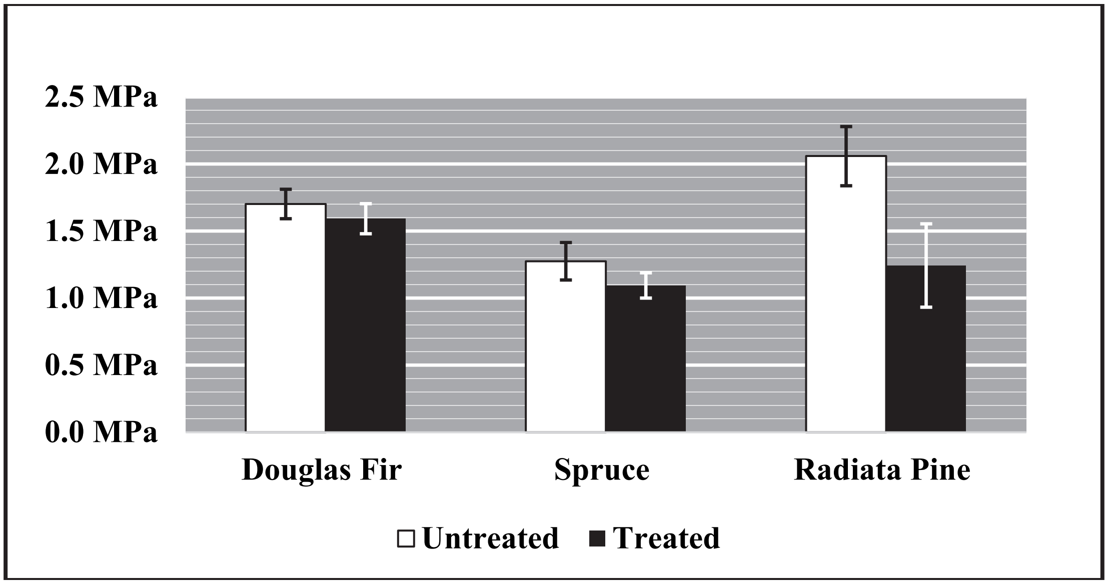

Figure 2. Rolling Shear Average Values. Error Bars are 95% Confidence Intervals of the Mean.

CONCLUSIONS

An initial test of double vacuum borate treatment of CLT samples achieved a wide range of solution uptakes. Preservative retention in some cases was well above standards for solid sawn lumber. Solution uptake was related to preservative retention, penetration, and volumetric shrinkage. The treatment reduced the rolling shear strength, and the degree of impact was correlated to the solution uptake.

Further work is recommended to optimize the treatment process variables and to confirm that the treatment results in the anticipated durability improvements.

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