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Evaluation of vacuum borate treated spruce or pine cross laminated timber (CLT) in an above ground protected test in southern Mississippi

Mark E Mankowski[1], Adam Taylor[2] and Grant T Kirker[3]

[1] Durability and Wood Protection
USDA-FS Forest Products Laboratory
Starkville, MS 39759, USA

[2] Professor & Wood Products Extension Specialist
University of Tennessee
Knoxville TN 37996

[3] Durability and Wood Protection
USDA-FS Forest Products Laboratory
Madison, WI 53726, USA

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IRG SECRETARIAT
Drottning Kristinas v. 61B
SE-114 28 Stockholm
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Evaluation of vacuum borate treated spruce or pine cross laminated timber (CLT) in an above ground protected test in southern Mississippi

Mark E Mankowski[1], Adam Taylor[2], Grant T Kirker[3]

[1] Durability and Wood Protection, USDA-FS Forest Products Laboratory, Starkville, MS 39759, USA, mark.e.mankowski@usda.gov

[2] Wood Products Extension, University of Tennessee, Knoxville TN 37996, USA, mtaylo29@utk.edu

[3] Durability and Wood Protection, USDA-FS Forest Products Laboratory, Madison, WI 53726, USA, grant.kirker@usda.gov

ABSTRACT

Cross laminated timber (CLT) has become a popular wood composite in large building applications that were previously limited to concrete and steel. To extend service and prevent biological attack, chemical protectants are often applied to wood. Cross laminated timber panels are not typically treated, in part due to a lack of data on efficient and effective methods for treating large panels. There are also limited long term field data regarding the exposure of CLT to biological attack. In this study, commercially prepared CLT panels consisting of either 5-ply Norway spruce or 3-ply southern pine were obtained and treated via a double-vacuum preservative treatment with borates and placed in an above ground covered field test. Samples measuring230mm x 300mm x 100 mm were cut, edge-sealed, and double vacuum-treated with a with a 10% disodium octaborate tetrahydrate (DOT)/glycol solution. Target loadings were a low (~1kg/m^3 SBX) and high (~2.5 kg/m^3) borate retention. There were also untreated samples of either wood species employed in the test. All treatments employed 10 samples for a total of 60 samples in test. Samples were placed in an above ground AWPA E21-18 covered field test in Saucier, Mississippi in 2023. One-year ratings and moisture contents indicated an increase in sample moisture content and negligible biological attack. The presence of termites was noted on feeder stakes in the test subplots, but termite attack on samples had not occurred at this point. As this is the first year of a long-term test, further evaluations will continue.

Keywords: Mass timber , borate, double vacuum, AWPA E21, field test.

1. INTRODUCTION

Mass timber, particularly cross-laminated timber (CLT,) is increasingly used in construction situations that in the past were restricted to steel and concrete. Since wood building materials are subject to biodegradation due to unintended wetting, treating mass timber elements like CLT is important. Secondly, testing treated CLT elements in field conditions is also important. Currently CLT is not treated with preservatives and long-term durability strategies only employ keeping the wood dry. Treatment options for mass timber products including CLT are needed to address the inevitable need for supplemental protection (Wang et al. 2018).

A challenge of treatment for CLT panels is their large size. Traditional pressure treatment may not be possible if panels are too large to fit in a treatment cylinder (Taylor et al. 2022). Taylor et al. (2022) successfully treated large CLT panels with borates via a double vacuum process and had relatively negligible impact on panel mechanical properties. This type of treatment could allow large panels to be treated in a large plastic bag. Borates are a good potential preservative for CLT panels, given that most CLT will be used in interior applications where it is mostly protected from continuous wetting; they are odorless, colorless, inexpensive, diffusible and protect against a wide range of insects and fungi (Williams 1996). However, little information exists on the exposure of borate vacuum treated CLT panels to field conditions in high biodeterioration regions.

The objective of this study was to assess double vacuum borate treated CLT elements in an above-ground protected field test in a high deterioration zone in the United States. We set up an AWPA E21-18 (AWPA 2019) above-ground test with borate treated and untreated pine and spruce CLT in southern Mississippi. This report gives information on the test setup and first year moisture content and biological rating data.

2. MATERIALS AND METHODS

2.1 Sample Treatment

Commercially prepared CLT panels made from either Norway spruce (*Picea abies* (L.) Karst or southern pine (*Pinus* spp.) were purchased for the testing. Spruce samples were 5-ply and were purchased from Binderholz (Fugen, Austria). Pine samples were 3-ply and were purchased from SmartLam (Dothan, AL, USA). Sixty samples with approximate dimensions of 230 mm x 300 mm x 100 mm (panel thickness) were cut from the panels. Each sample was completely edge sealed with neoprene coating (1300L, 3M, St. Paul MN), leaving only the panel faces exposed. The initial mass and dimensions of the samples were recorded.

Samples were vacuum treated with ~10% disodium octaborate tetrahydrate (DOT)/Glycol solution (Bora-care, Nisus Corporation) in a small, rigid pressure/vacuum vessel using the following sequence (see table for specific parameters):

1. Initial vacuum was applied to the CLT samples in an empty vessel (30 minutes; 100-760 torr)
2. The treating solution, at ambient laboratory temperature, was introduced using the residual vacuum (the solution completely submerged the samples, which were weighted down to prevent floating)
3. Samples were allowed to soak in the solution under ambient pressure (1 – 5 minutes)
4. Vessel was emptied using gravity
5. Final vacuum was applied to remove excess treating solution (30 minutes)

Treatment parameters were adjusted to obtain samples with low (~1kg/m^3 SBX) and high (~2.5 kg/m^3) borate retention. Untreated controls were also prepared. 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 by titration (AWPA 2022). Preservative retention was calculated as the product of solution uptake and preservative concentration, expressed as SBX (DOT x 0.67) in kg/m^3. Soak times, pressure and final retention for spruce and pine CLT samples are shown in table 1. Ten samples were used for each of four borate treatments and untreated controls for each species. Different times and vacuum levels were used to achieve the two retention levels. Not all samples were useful – and some that were targeted for one group ended up in the other, depending on retention which could only be measured after treatment.

Table 1: Treatment parameters and retentions for spruce or pine CLT used in an above-ground field test.

Species	Sample #	Soak Time (minutes)	Pressure (torr)	SBX kg/m3
Spruce	1	1	100	2.42
	2	5	100	2.83
	3	1	100	1.97
	4	5	100	2.2
	5	5	100	2.2
	6	5	100	3.18
	7	5	100	2.08
	8	5	100	2.28
	9	5	100	2.53
	10	5	100	2.38
Spruce high retention average				**2.41**
Spruce	11	1	100	1.79
	12	1	100	1.54
	13	1	100	1.78
	14	1	300	0.94
	15	1	300	0.75
	16	1	250	1
	17	1	250	1.65
	18	1	250	1.36
	19	5	100	1.73
	20	5	100	1.46
Spruce low retention average				**1.4**
Pine	1	1	760	0.62
	2	5	500	1.77
	3	1	600	1.25
	4	1	600	1.25
	5	1	600	1.26
	6	1	600	1.25
	7	1	600	1.76
	8	1	600	1.55
	9	1	600	1.17
	10	1	600	1.04
Pine low retention average				**1.29**
Pine	11	3	300	2.51
	12	3	300	2.75
	13	3	300	3.1
	14	3	300	3.81
	15	1	400	2.23
	16	1	400	2.31
	17	1	400	3.84
	18	1	500	2.71
	19	1	600	3.05
	20	5	600	2.16
Pine high retention average				**2.85**

2.2 Field Testing

The test was installed at the Harrison Experimental Forest (HEF) in Saucier, Mississippi. The HEF has an average annual precipitation of 1600 mm. Mean annual minimum and maximum temperatures (Jackson, MS data) are 12°C and 24°C, with no mean monthly temperature below 10°C. The topography is flat with a slope of 5 to 12 percent. The site has a Scheffer Index value of 70 (Morris and Wang 2008). Ground cover is predominately yaupon holly, wiregrass, broom sage with loblolly and long leaf pine. The HEF has a well-documented occurrence of the Eastern subterranean termite, *Reticulitermes flavipes* Kollar.

Samples were installed in an AWPA E21-18 (AWPA 2019) above-ground protected field test. Six samples (one from each treatment and species) were placed on cinder blocks in ten subplots (Fig. 1, left). The cinder blocks measured 394mm x 203mm x 197mm (L x H x W and the CLT samples were placed on the solid face of the cinder block to represent a cement slab. The blocks and samples were placed in two rows of three blocks. Before sample placement, 19mm square pine feeder stakes were tapped into the soil around the cinder blocks to the level of the top of the cinder block. A total of 17 feeder stakes were placed around the six cinder blocks in each subplot. The test samples were placed on the blocks approximately 90mm apart in sets of three. Each set of three samples was approximately 127mm apart.

Figure 1: Placement of CLT test samples on cinder blocks and position of some of the feeder stakes (left). Test plot showing subplot before covering and other test plots with ventilated covers

After placement, the samples were covered with pre-constructed ventilated plywood covers. The covers measured 965mm x 787mm at their base and were 610mm high in front and 571mm high in back creating a sloped roof for rain runoff. The roof of each box measured 1,219mm x 838mm allowing for 127mm of overhang on each side and 25mm overhang at the front and back (Fig.1, right). The covers were constructed from preservative-treated plywood and painted white to minimize heating. The top front and back of each cover had two 50mm diameter ventilation holes and the top two sides had three 50mm ventilation holes. The bottom front and back of each cover had five 25mm diameter ventilation holes. All ventilation holes were covered with aluminum window screen mesh attached with staples on the inside of the cover box.

Samples were evaluated for biological attack after one year using the AWPA E21-18 rating scale for termite attack and the AWPA E18-15 rating scale for decay (AWPA 2017). At this evaluation time, two moisture readings were taken on the surface of each broad face of the sample using a Wagner electrical resistance type moisture meter. The two moisture readings per sample were averaged for the overall set of samples, by wood species and by treatment.

3. RESULTS AND DISCUSSION

Surface moisture contents of all CLT samples after one year averaged 19.4%, (Fig. 2). Average moisture content for all pine and spruce CLT was 17.6 and 21.2%, respectively. Untreated pine and spruce CLT moisture contents were 15.2 and 18.75%, respectively. Borate treated samples of either wood species had higher moisture content after one year. The high borate retention samples of pine and spruce were 21.4 and 22.8%, respectively. Some of the surface moisture contents reached levels close to where biodeterioration could start, but none was observed. Initial moisture contents were not taken for this study, but Mankowski et al. (2022) found the that pine and Douglas-fir CLT had initial moisture contents of 9.0 and 11.5%, respectively.

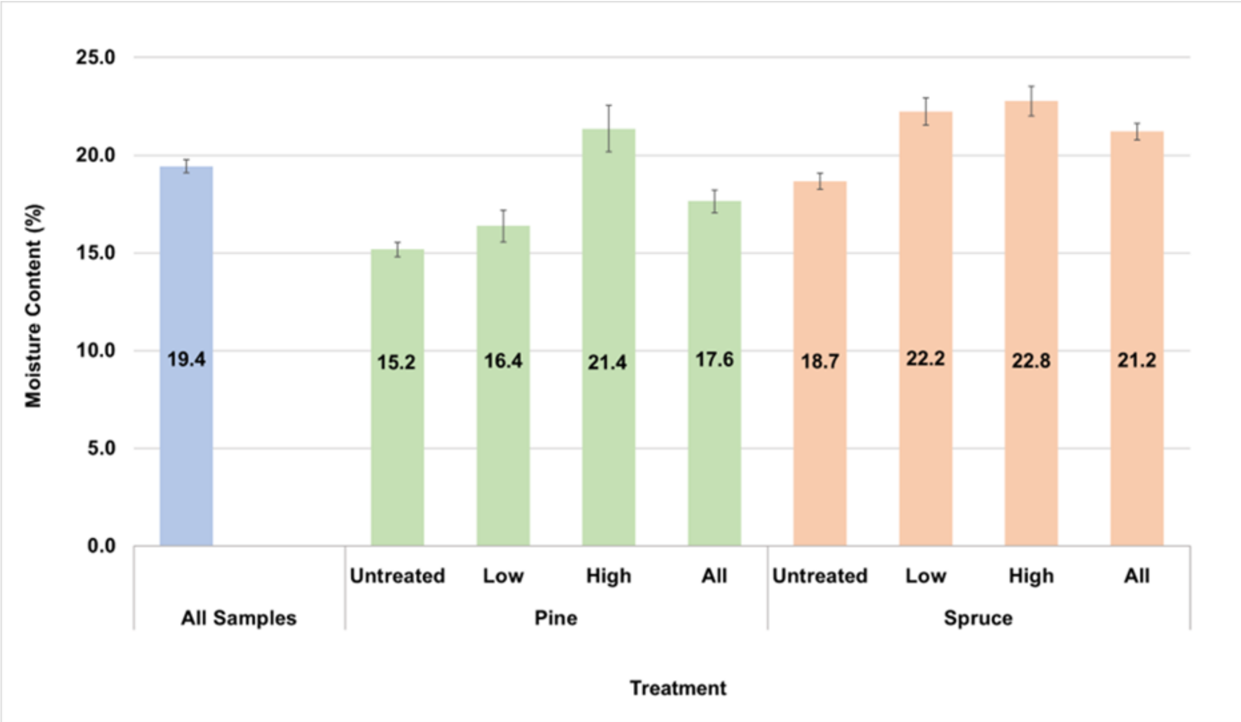

Figure 2: Average surface moisture content after one year in an above-ground covered field test for CLT samples consisting of pine or spruce that were untreated or treated with low and high retentions of disodium octaborate tetrahydrate (DOT). Numbers in bars represent average moisture content. Numbers shown in bars represent the average moisture content.

Table 2 shows the average decay, termite ratings and average moisture contents of the samples for the various treatments. No samples showed any evidence of biodeterioration at one year. This may be attributed to the generally lower moisture content after one year than observed in similar testing (Mankowski et al. 2018, 2020, 2022). Evidence of termite activity was observed on feeder stakes in 9 out of 10 of the test plots. Mud tubes up the feeder stakes and onto some of the cinder blocks near samples was observed, but no termite damage had occurred (Fig. 3).

Table 2: Average decay and termite ratings for spruce and pine CLT placed in the field in a ground proximity test after one year

	Termite	Decay	% MC
Pine CLT			
Untreated	10	10	15.2
Low Boron ~1kg/m3	10	10	16.4
High Boron ~2.5 kg/m3	10	10	21.4
Spruce CLT			
Untreated	10	10	18.7
Low Boron ~1kg/m3	10	10	22.2
High Boron ~2.5 kg/m3	10	10	22.8

Figure 3: Example of termite activity in test subplot. Mud tube observed from feeder stake to test sample

4. CONCLUSIONS

- Near surface moisture contents in mass timber samples exposed in an above ground test were lower in untreated samples than samples treated with ~2.5 kg/m^{3} of SBX.
- Termite attack was observed on feeder stakes in 9 of 10 subplots, but no termite attack or decay was observed on any test samples after one year.

5. ACKNOWLEDGEMENT

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