Potential Impact of Subterranean Termites on Cross-Laminated Timber (CLT) in the Southeastern U.S.

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ABSTRACT

Cross-laminated timber (CLT) is an emerging product in the North American mass timber market. Intended to compete with pre-cast concrete panels for modular construction, these laminated wall and floor-sized panels have been successfully used in European construction markets for the past 20 years. However, introduction of this material to areas of North America that have high pressure from subterranean termite and decay fungi may prove detrimental to the potential market for this product. This paper describes ongoing work seeking to describe interactions between CLT with both native and introduced termite species in the southeastern United States. Early results indicate that this material is susceptible to feeding by termites, is capable of water uptake providing a habitable environment within the material for decay organisms, and may not be easily evaluated by conventional means (i.e. visual rating currently in use versus more advanced X-ray scanning described here).

INTRODUCTION

Cross-laminated timber panels (CLT; X-lam) have sparked great interest within the wood products, architecture, and construction industries in North America. With a history of successful use in several European countries, CLT 'crossed the pond' to Canada in the early 2000's. In 2010, APA – The Engineered Wood Association and FPInnovations (Canada) began developing a standard for manufacturing and use of the product in North America (Yeh et al. 2011). From this work, the CLT Handbook for North America was published in 2013, defining manufacturing specifications, instructions for handling, use of fasteners, and a broad range of other information. More recently, CLT has been included in ANSI/APA Performance Standards (ANSI/APA PRG 320) and approved for inclusion in the 2015 International Building Code (APA 2011; Karacabeyli and Douglas 2013).

Multiple buildings in North America are under construction or have been constructed using CLT as a primary construction material. The University of British Columbia in Vancouver, Canada, constructed the mixed-material CLT and reinforced concrete, 158,000 ft^2 Earth Sciences Building in 2012 (Holt and Wardle 2014). Promega Corporation in Madison, WI, United States, added to their existing facility combining steel, concrete, and CLT in a 52,000 ft^2 reception area (WoodWorks Wood Products Council 2013). In Huntsville, AL, United States, Candlewood Suites completed construction in 2015 on a 92-room hotel designated for temporary military housing at Redstone Arsenal (WoodWorks Wood Products Council 2015). Architects around the U.S. have expressed interest in the use of CLT in urban development, modular housing, and public-use space design.

However, there is little to no published research on the long-term durability of CLT in zones with high decay hazard ratings. Since CLT use in North America is on the rise, and since it is designed to be used in ways that no current mass timber product is being used, as it spreads into areas with high degradation pressures it is vitally important to determine the ability of this mass timber product to resist termite infestation and fungal decay. Mississippi State University (MSU) Department of Sustainable Bioproducts along with USDA Forest Products Laboratory have endeavored to supply this much needed information to manufacturers, construction professionals, and architects across North America.

Climatic conditions for wood degradation are nearly ideal in the southeastern U.S. with Scheffer index values greater than 65 (Carll 2009). Warm yearly average temperatures and number of days with rainfall allow wood decay fungi to spread widely and subterranean termites to feed actively for much of the year. To determine CLT resistance to these pressures, multiple research projects are underway at MSU Sustainable Bioproducts and USDA Forest Products Laboratories. The project described herein seeks to answer the following questions: How do subterranean termites (native subterranean and invasive Formosan termites) interact with CLT? Can we measure invasion damage over time? How does CLT compare to other laminate mass timber products for termite resistance? Ultimately, an amendment to existing AWPA standard test methods may be developed for determining mass timber product susceptibility to termite infestation.

METHODS

The primary question when developing a methodology for testing of CLT was to determine the scale of testing. AWPA E1-15 calls for test pieces with a dimension of 1" x 1" x ¼" (25 mm x 25 mm x 6 mm) (AWPA 2015). To cut a piece of this size from a panel of CLT, however, would only test the wood from which it is made or the adhesive interface between two adjacent pieces within the panel. This information would be useful in some studies, but would not describe the ability of this large-scale product to resist infestation by termite species. It was therefore determined that the product should be tested at its full thickness.

Test pieces of CLT were cut from 3-ply panels, approximately 4" (10.16 cm) in thickness. Cubes of 3-ply CLT, approximately 4" (10.16 cm) in each dimension, were cut for five replicate termite-exposed containers. Additionally, five CLT test pieces were prepared for no-termite control containers to judge moisture absorption within the block. For comparison with the termite-exposed CLT treatment, a positive control using copper azole treated southern yellow pine 4" x 4" (10.16 cm x 10.16 cm) blocks were prepared, along with 1 ½" x 2 5/16" untreated, kiln-dried spruce/pine/fir to mimic the layers of CLT, but without adhesive. All test pieces were conditioned for two weeks in the environmental chamber in which the test would be carried out (77° F; 66% RH; 12% EMC). Test containers were eight liter food-grade clear plastic containers. Screened, heat-sterilized sand was used as the substrate, 1 liter per container (1715 g). Containers with sand were autoclaved less than a week prior to use and sealed until assembly.

Next, the amount of termites per container was determined. AWPA E1-15 calls for 400 individuals, with no more than 10% soldiers to be present inside the container. Volumetrically, the scale of the test piece was increased by a factor of 64. To match that, a total of 25,600 termites would need to be added to each container. Since that would require collection of a termite population of nearly 2,000,000 individuals, it was determined that this scale was simply not feasible.

Native subterranean termites (*Reticulitermes* spp.) were collected from the one log found in the Sam D. Hamilton National Wildlife Refuge, Brooksville, MS, United States, and used within one month of collection. On the day of the test, sterilized containers with sand substrate were labeled according to treatment and moistened with 200 mL of sterile distilled water. One conditioned, weighed test block was added to each of the 20 containers. The average mass of 400 worker termites was determined and then multiplied by a factor of 2.5 to obtain the mass of termites (approximately 1000 termites with less than 10% soldiers), which was added to each of the 15 containers requiring termite exposure. Treatment containers were sealed with a lid that had a hole plugged with sterile cotton for air exchange, weighed, and placed in the environmental chamber in which the blocks had been conditioned (Figure 1).

Visual observations and weights of containers were taken each day for seven days. Weights were stable, changing less than 0.3 g over seven days. After that point, weights were taken once per week. Visual observations were continued on alternating days.

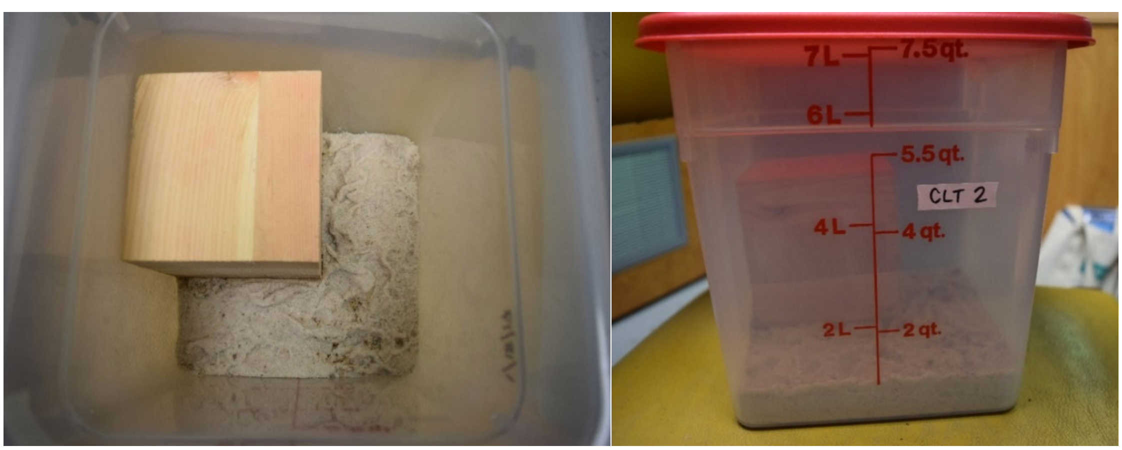

Figure 1. Test containers for subterranean termite testing. Termites introduced into corner diagonally opposite of the test block location.

At four weeks, it was observed that all termites in the copper azole treated pine (CA-P) treatment were deceased. To prevent mold takeover, these treatments were removed, broken down, and the blocks were weighed and visually graded. No signs of mold were observed in other treatments and termites continued to be visually active. At eight weeks, signs of mold were observed in some of the other test containers and this was determined to be an appropriate time to disassemble the remaining test and control containers and evaluate the results.

Disassembly of containers began by removing the test or control block, photographing it, and striking the block with a hammer or large screwdriver to remove as many termites as possible from within. Blocks were then weighed and set aside. Live termites removed from the block were counted as they were aspirated. Sand was removed from each test container and live termites found within were added to the running count. Total live termite counts (Table 1) and presence/absence of mold or fungal growth were recorded. Sand was collected for disposal and blocks were placed back into containers. Blocks representing each type of material were placed on a tray and X-rayed for density changes using an Inspex® wide-format X-ray scanner. Test blocks were re-conditioned for 14 days to a stable weight and processed through the X-ray scanner again. X-ray scans were taken with multiple arrangements of blocks to determine the best exposure for observing potential termite excavation of the materials. Photos were also taken for image comparisons with X-ray scans.

Table 1. Number of live termites recovered at disassembly of test containers.

Treatment_Rep*	Termites added (approximate)	Termites counted at disassembly	Mold/fungal growth detected
CLT_1	1000	342	Y – red/orange/black
CLT_2	1000	783	Y – green/red/orange/black
CLT_3	1000	573	Y – green/black
CLT_4	1000	0	Y – green/red/orange/black
CLT_5	1000	644	Y – red/black
SPF_1	1000	667	Y - black
SPF_2	1000	597	Y – black/green
SPF_3	1000	761	Y – red/black
SPF_4	1000	494	N
SPF_5	1000	629	Y – white fuzzy mold
CA-P_1	1000	0	N
CA-P_2	1000	0	N
CA-P_3	1000	0	N
CA-P_4	1000	0	N
CA-P_5	1000	0	N

* CLT termite-exposed blocks = CLT_1 – CLT_5; spruce/pine/fir no adhesive termite-exposed blocks = SPF_1 – SPF_5; copper azole treated pine termite-exposed blocks = CA-P_1 – CA-P_5. 100% mortality was observed in test containers of CA-P at 4 weeks. Mold/fungal growth indicated with colors observed by visual assessment. No isolation/identification data performed at this time.

RESULTS AND DISCUSSION

All CLT control blocks gained mass over the course of the 8-week test (39.5 g average). This uptake was attributed to the capillary action of water from the sand substrate moving into the blocks over the course of the test, which stained the face exposed to the damp sand on each block (Figure 2). Termite-exposed blocks also increased in mass over the course of the test, aside from copper azole treated pine (CA-P) (Table 2). Weight increase in test blocks may partially be the result of water uptake, but may also be a result of debris left behind during termite excavation. Some, but not all, of this debris may have been removed during disassembly. How much is difficult to determine at this time.

Figure 2. Water staining on exposed (bottom) face of control (no termite) CLT blocks after 8 weeks. Average water uptake of control blocks was 39.5 g.

Table 2. Mass change in termite-exposed and control blocks over the duration of test.

Treatment_Rep*	Pre-test conditioned weight (g)	Post-test conditioned weight (g)	Mass Change (g) (Pre-Post)
CLT_A	542.1	581.8	-39.7
CLT_B	603.3	645.4	-42.1
CLT_C	601.8	644.4	-42.6
CLT_D	576.4	609.8	-33.4
CLT_E	528.9	568.6	-39.7
CLT_1	524.2	567.8	-43.6
CLT_2	547.6	589.6	-42
CLT_3	513.5	545	-31.5
CLT_4	538.3	563.4	-25.1
CLT_5	540.2	560	-19.8
SPF_1	285.7	293.5	-7.8
SPF_2	307.8	316	-8.2
SPF_3	291.5	288.6	2.9
SPF_4	291.9	291.6	0.3
SPF_5	291.8	295	-3.2
CA-P_1	476	394	82
CA-P_2	469.9	384.4	85.5
CA-P_3	520.6	385	135.6
CA-P_4	457.2	371.4	85.8
CA-P_5	512.4	390.6	121.8

*CLT controls = CLT_A – CLT_E; CLT termite-exposed blocks = CLT_1 – CLT_5; spruce/pine/fir no adhesive termite-exposed blocks = SPF_1 – SPF_5; copper azole treated pine termite-exposed blocks = CA-P_1 – CA-P_5

Photographs of test blocks show indications of termite excavations on the exposed surface of CLT and spruce/pine/fir (SPF) blocks (Figure 3). The maximum depth of termite excavations into CLT was measured and found to be 1/8” (3.2 mm). Termites also constructed mud tubes on multiple vertical faces of CLT and SPF test blocks apparently to reach openings into other areas of the wood such as non-glued internal board faces or adhesive overflow channels. Copper azole blocks showed no signs of excavation or construction of mud tubes.

Visual inspection of test and control blocks was performed according to AWPA E1-15. CLT blocks visually rated at 9 – 9.5 while CA-P and Control blocks were rated 10. SPF test blocks were rated at 8 – 9. While this type of evaluation is easily performed, the rating can only evaluate visual surface damage and does not take into account any internal excavations that may be within the mass timber product. If termites enter the material through small openings, such as are found in non-edge glued internal board faces, damage to the interior of the material may carry on for an extended period of time, undetected.

X-rays were taken to compare blocks and images show less dense areas that were suspected to be termite excavations and higher density areas that could be excavations filled with waste and debris (Figure 4). However, when sliced, only some of the samples indicated potential excavations that could be confirmed as having been opened up by termite feeding activity. This may be a result of damage done to the excavated areas while cutting test blocks on a band saw.

Figure 3. Termite excavations on the exposed (bottom) face of spruce/pine/fir and CLT test blocks. Termites and mud tubes intact on test blocks.

Figure 4. X-ray scan analysis. Red arrows on right indicate suspected termite damage areas. Top left = copper azole treated pine; Top right = spruce/pine/fir; Bottom left = CLT exposed to termites; Bottom right = CLT control.

CONCLUSIONS

In summary, the current visual rating scale for termite infestation may not be sufficient to serve as an evaluation standard for cross-laminated timber panels. Further testing of both native subterranean and Formosan termite damage to large sections of the material is needed to determine whether a visual scale will be applicable to the material. Non-destructive evaluation methods such as X-ray appear to have potential, but indicated excavations are difficult to confirm at this time. Further X-ray scan optimization (beam strength, beam width, scan rate, etc.) must be performed to develop an ideal set of conditions under which to evaluate CLT products. Additionally, the application of other non-destructive techniques for evaluation may be preferred, such as CT scanning or near-infrared technologies.

Further comparison tests are ongoing, including water uptake controls for CLT and other tested materials, comparisons between CLT and other laminated mass timber products, and CLT exposure to invasive Formosan termites. Future tests will include AWPA E21-15 full size commodity tests for exposure to both native subterranean and invasive Formosan termites.

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