

Evaluation of a Soil Termiticide or Borate Non-Pressure Treatments for Protecting Douglas-Fir CLT in a Field Test: Two Years Results

Mark E. Mankowski

Thomas G. Shelton

USDA Forest Service, Forest Products Laboratory
Starkville, Mississippi

Grant Kirker

USDA Forest Service, Forest Products Laboratory
Madison, Wisconsin

Jeffrey J. Morrell

Centre for Timber Durability and Design Life, University of the Sunshine Coast
Queensland, Australia

ABSTRACT

Mass timber, which includes cross laminated timber, is becoming increasingly popular as a material choice for mid-level and high-rise construction. Material durability, especially in extreme exterior exposures, is a key concern of developers that has to date not been fully resolved. Data on the effectiveness of currently labeled soil termiticides, as well as spray-on borates applied either post-construction or as a remedial treatment, needs to be generated for cross laminated timber (CLT) structures. Current design standards do allow for preservative treated and naturally durable wood but incorporating treatment options into CLT manufacturing is a considerable challenge that is being addressed, albeit slowly. Soil and perimeter termiticidal treatment is also a necessity for CLT construction, especially if installed in southeastern United States climates, as most species currently used in fabrication of CLT are not naturally termite resistant. In this study, 3-ply 12"x14"x4" Douglas-fir CLT pieces were installed in an above ground protected test at the Harrison Experimental Forest (HEF) (Saucier, Mississippi) in September 2017. Test samples were placed in sets of two on bricks approximately 3-4" above soil and covered with ventilated waterproof covers. A total of 20 test sets (40 total samples) of four different treatments were installed in this test. Soil below five sets of CLT samples was treated with a soil termiticide (fipronil). One sample per set in the other five sets was treated with a spray-on borate (23% DOT) preventative treatment. The remaining ten sets were left as controls with no treatment. Ten control sets were examined for termite attack one year after installation. Five of the attacked sets were treated with the same spray-on borate as a remedial treatment to evaluate its ability to arrest active termite attack. After one and two years, most untreated control replicates were attacked by combinations of decay fungi and termites. Samples treated with borates at test initiation and remedially after one year showed limited decay or termite attack. Remedially treated samples showed no increase in degradation. Soil termiticide treated plots showed no sign of termite attack, but four of the plots had heavy decay compared to non-soil termiticide treated plots.

INTRODUCTION

Initially popular in Central Europe and Scandinavia, mass timber construction is gaining popularity globally (Karacabeyli and Lum 2014; Pei et al. 2016; Singh and Page 2016; Stokes et al. 2017; Wang et al. 2018). The number of buildings constructed within the last five years using mass timber as well as the number of companies producing these products have greatly increased. These structures are already changing global perceptions about wood construction (Mallo and Espinoza 2014). Several low to high-rise buildings have been built using mass timber, including cross-laminated timber, or are in planning as architects and engineers are reevaluating wood construction (Mallo and Espinoza 2015).

Wood has many qualities that make it a preferred construction material over steel or concrete (Robertson et al. 2012). The development of mass timber products has allowed wood to be used in much taller buildings formerly restricted to steel and concrete. The use of mass timber for multi-level construction has increased substantially in recent years due to a general desire to use more environmentally sustainable materials coupled with changes to building codes. Mass timber has excellent seismic (Popovski et al. 2012) and thermal properties (Pei et al. 2012), can allow parts of structures to be prefabricated, and provides increased carbon sequestration making it an attractive construction material (Brandner et al. 2016).

Even though the use of mass timber in construction is becoming increasingly accepted, there is limited information on the durability of this material and the information currently available does not offer realistic methods for limiting the risks of

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deterioration. Currently, most mass timber used in construction is not chemically treated to prevent decay or insect attack, but preliminary laboratory assays do indicate the material is wholly susceptible to termite attack (Wang et al. 2018, Franca et al. 2018). As a building material, wood can degrade, particularly when exposed to elevated moisture levels. Many mass timber structures being built or in planning are in areas with potentially high decay and termite activity and thus prone to biological attack (Wang et al. 2018). In recent laboratory tests exposing CLT to subterranean termites, termites readily attacked CLT material, tunneling along glue lines (Stokes et al. 2017, Franca et al. 2018).

Understanding the conditions that are conducive to deterioration of mass timber elements and identifying methods for preventing this damage will be essential for expanded use of these materials. Even though mass timber will be used out of ground contact where the risk of damage is lower, buildings will be constructed in areas prone to subterranean termite attack. In this paper, we discuss the methodology and two-year results of a five-year field study examining the ability of soil termiticides and spray-on borate treatments to protect cross laminated timber materials in a ground proximity protected test.

MATERIALS AND METHODS

Three ply cross laminated timber (CLT) made from Douglas-fir was provided by D.R. Johnson (Riddle, Oregon). The material varied in width and height with a constant thickness of 4 1/8" (105 mm). Forty samples were cut into approximate 12" x 14" x 4 1/8" (305mm x 355mm x 105 mm) pieces for testing. Samples were conditioned at 75° F and 12% relative humidity for approximately 60 days and weighed before initiation of the field test. Two moisture measurements were made with a Wagner MMC 220 pinless electronic moisture meter (Wagner Meters, Rogue River, Oregon) on the face of each sample after the 60-day equilibration period.

Samples were taken to the Harrison Experimental Forest (HEF) in Saucier, Mississippi where they were installed in a modified AWP A E21 (AWPA 2017) ground proximity protected field test. The modification being that the samples were placed closer to the ground than a typical AWP A E21 test. The test consisted of a large plot measuring 24' x 25' with 25 subplots measuring 30" x 30". A total of 20 subplots were used for the four treatment sets of the study. Five subplots were not used (Figure 1). The 20 subplots were tilled by hand to a 4" depth with a pickaxe and any roots or stones were removed. Each subplot contained two CLT samples set on four bricks on a 30 x 30" cleared square on the ground (Figure 2). The treatments were a soil termiticide only, a preventative borate spray on application at test initiation, a remedial borate spray at one-year post initiation, and an untreated control. The test was set up in a randomized block design with five blocks containing one treatment per block in the total plot (Figure 1). For the remedial treatment, five plots were left undisturbed for one year to allow for termite attack, after which one of each sample pair (in this treatment) was remedially treated with the spray-on borate solution.

For the five soil termiticide treatment plots, a 24" x 24" area of the 30" x 30" subplot was drenched with a 0.125% fipronil [5-amino-3-cyano-1-(2, 6-dichloro-4-trifluoromethylphenyl)-4-fluoromethylsulfinyl pyrazole] solution (per gallon of water). Bricks and CLT samples were placed on the treated area with as little soil disturbance as possible (Figure 2). The borate spray-on (Nisus, Knoxville, TN; 23% sodium octaborate tetrahydrate (DOT)) was applied to one sample in each of five subplots while the other was left untreated. A plastic shield was placed over the adjacent bricks (where the untreated sample would be) before the sample was sprayed to minimize borate contamination in the non-treated CLT sample (Figure 3). After placement and treatment, the samples were covered with pre-constructed ventilated plywood covers. The covers measured 22" x 19.5" at their base and were 29" high in the front and 27" high in the back creating a sloped roof for rain runoff (Figure 2, far right). The covers were constructed from plywood and painted white to minimize heating. The front and back of each cover had three 1" diameter ventilation holes covered with mesh. Samples remained undisturbed for one year except to check moisture of six samples in three of the soil termiticide plots after six months. At the one year and two year ratings, two moisture readings were taken on the face of each sample using the Wagner meter, then the four moisture readings per sample were averaged and compared to readings taken before the test was initiated.

The test samples were installed in September 2017 and were rated and assessed for degree of decay and termite damage after 12 and 24 months. After 12 months, five of the non-treated control samples with termite attack were treated with boron spray as described above as a remedial treatment. Since the samples were large, the ratings reflect the bottom 2 inches of the sample in contact with the brick.

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C or R	P	P	C or R	X
T	T	C or R	T	C or R
C or R	X	X	P	P
P	C or R	C or R	X	C or R
X	C or R	T	C or R	T

Figure 1. Layout of randomized block design for the modified AWPA E21 ground proximity field test. P = Protective treatment with borate (DOT at 23%). T = Treatment with fipronil soil termiticide (0.125%). C or R = Control or Remedial treatment after one-year check. Remedial = borate (23% DOT). X = Subplot not used.

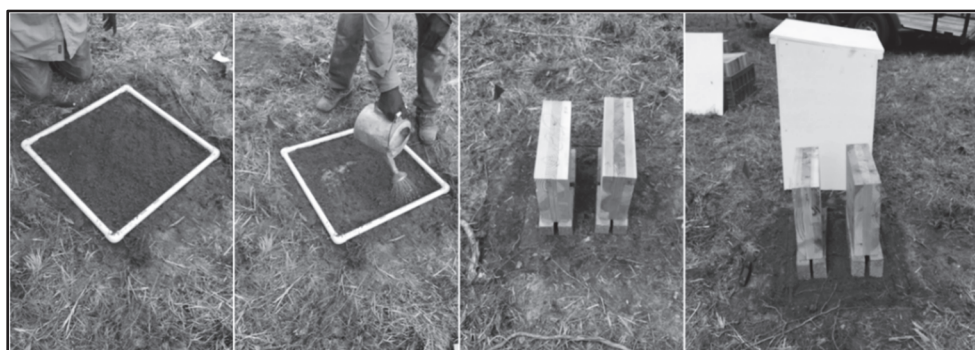


Figure 2. Treatment with fipronil soil termiticide and arrangement of ground bricks and CLT in soil termiticide subplots. Photographs showing hand tilled soil and application of fipronil, 0.125% solution (left); arrangement of ground bricks and CLT in subplots (third from left) and arrangement before placing cover (background) over the samples (far right).

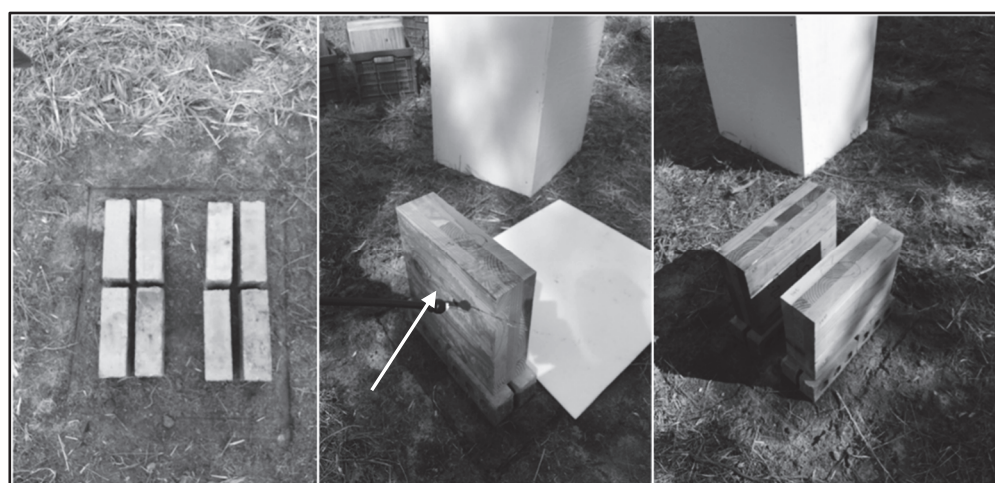


Figure 3. Photographs showing arrangement of ground bricks and CLT in subplots (left). Treatment with spray on borate (23% DOT; arrow shows tip of spray nozzle) in the preventive and remedial treatments (center) and arrangement of ground bricks and CLT before cover was placed over samples (right).

RESULTS AND DISCUSSION

Surface moisture contents of the CLT samples were 11.4% initially, which would be close to the 12% moisture content of the samples at the time of production. Figure 4 shows the average moisture content of the samples at six months, one year and two years compared to the initial moisture content. Average moisture content increased to nearly 23.7% at the end of the first six months of exposure suggesting that the humidity inside the cover boxes was high during this period. High average sample moisture contents were also recorded at the one- and two-year ratings at 29.14% and 26.44%, respectively. These results indicate that the CLT samples are sorbing moisture, despite the lack of an overhead moisture source or soil contact and are reaching moisture levels where biodeterioration would become a concern.

Table 1 shows the average decay and termite ratings of the samples for the various treatments. Samples in the remedial no boron spray and remedial boron spray were controls at initiation and controls at one-year when they were treated. They are grouped separately from non-treated controls to avoid confusion with actual controls and the two-year ratings. Control samples were being attacked by termites in four out of five of the subplots after one and two years. The four control plots that were attacked by termites incurred ratings of 7 and 8 after this period (Figure 5, right). Although the soil termiticide treatment (fipronil) limited termite attack, we noticed heavy decay in some of the fipronil treatments (Figure 5, Left). This suggests that decay fungi either flourished in the soil on components of the soil termiticide or the lack of termites encouraged fungal growth from the soil to the samples. The boron spray preventive treatments appear to be controlling both termites and decay compared to samples not treated initially with boron. Remedial treatment with boron spray after one year also appears to be limiting decay and termite attack. Active termite infestation on the sample observed in the remedial treatment after one year was not observed at the two-year point (one year after treatment).

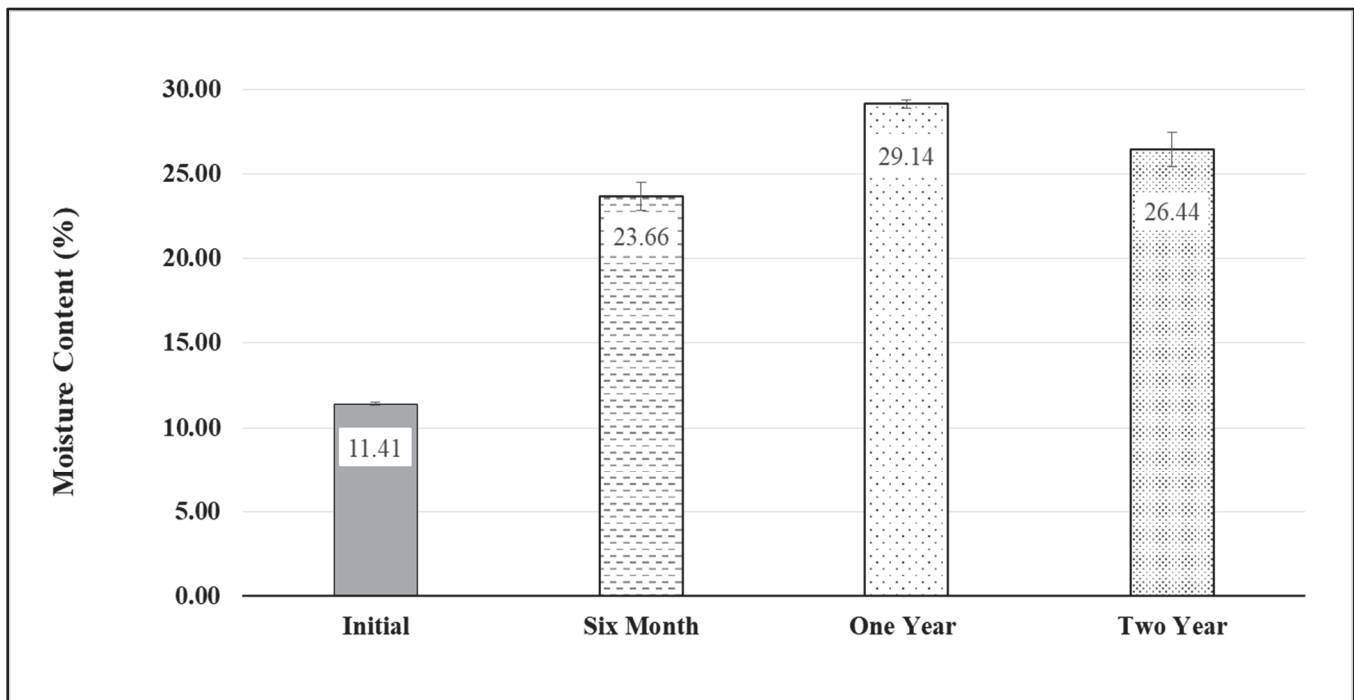


Figure 4. Average surface moisture content of CLT samples (n = 24) at test initiation as well as after six months, one year and two years of exposure in a ground proximity protected field test in Saucier, Mississippi.

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Table 1. Average decay and termite ratings* for 3-ply Douglas-fir CLT placed in the field in a ground proximity test after two years.

Treatment	One Year		Two Year	
	Decay	Termite	Decay	Termite
Control - No Treatment	9.4	9.1	9.2	8.9
Soil Treatment - Fipronil (0.125%)	9.5	10.0	8.8	10.0
Preventive Boron (23% DOT) Spray	9.8	10.0	9.6	9.8
Preventive No Boron Spray	9.4	9.4	9.2	9.0
Remedial at 1 Year Boron (23% DOT) Spray	9.6	8.8	9.4	9.2
Remedial at 1 Year No Boron Spray	9.8	9.4	9.4	9.0

* Control and soil termiticide, n = 10. All other treatments, n = 5.



Figure 5. Examples of fungal decay (left) and termite (right) damage to 3-ply Douglas-fir CLT in a covered ground proximity test after two years.

CONCLUSIONS

Moisture contents in CLT panels exposed in ground proximity under protective covers increased from 11.3% to 23.7% in six months of exposure. Moisture content remained above 25% after one and two years of exposure. Increased moisture levels suggested that the materials were at an increased risk of biodeterioration from termite and fungal attack. Termite attack was observed in almost all untreated samples after one year. Remedial treatment of termite attacked panels after one year of exposure appears to have arrested attack at the two-year assessment. Two-year results also indicated that the preventive (applied at initiation) boron treatment remained effective against termite attack as did the soil termiticide treatment for termites. Some of the soil termiticide treatment subplots showed heavy decay at two years. This is being investigated in a separate study. These panels will continue to be monitored to determine how soil treatments and boron sprays can protect mass timber and other wood in service in close contact with soil.

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