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Termite Resistant Properties of Wood and Natural Fiber Plastic Composites - AWPA E1 Test Data

Qinglin Wu[1], Todd Shupe[1], Jay Curole[1], Kevin Ragon[1], Matt Voitier[1], Mike Freeman[2], and Dennis Ring[1]

[1] Louisiana State University Agricultural Center, Baton Rouge, La 70803

[2] Independent Wood Scientist, Memphis, Tennessee

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IRG SECRETARIAT
Box 5609
SE-114 86 Stockholm
Sweden
www.irg-wp.com

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[1] Louisiana State University Agricultural Center, Baton Rouge, La 70803
[2] Independent Wood Scientist, Memphis, Tennessee

Abstract

This paper deals with resistance properties of wood plastic composites against Formosan Subterranean Termites (FSTs) based on the AWPA E1 test standard. Sixteen laboratory WPC formulations, four WPC commercial materials, and southern pine (*Pinus* sp.) wood control were tested for termite mortality, sample weight loss, and sample damage rating. The results show that FSTs did attack WPC products in the laboratory setting. The test was sensitive enough to demonstrate the effect of chemical treatment and type of surface (as-extruded exterior surface versus machined interior surface) on termite resistance. The type of plastics (e.g., HDPE vs PVC, and virgin vs recycled) and fibers (wood, bamboo, and bagasse) was less important, compared to wood fiber loading level and particle size. There was a large difference in damage mode and degree of damage from as-extruded exterior surface and machined interior surface of WPC. Commercial WPC was subjected to more termite attack from the exposed interior surfaces. An effective chemical treatment should prevent termite attack on both types of surfaces for WPC.

Keywords: plastics, wood, composites, termite, mortality, damage rating, weight loss

1. INTRODUCTION

Wood plastic composites (WPCs) represent a relatively new class of hybrid materials, which have been gaining rapid market share in North America (Clemons 2002). Since WPC formulations contain wood/natural fibers – a nutrient source, this material is susceptible to decay fungi, moulds, algae, termites, and marine borers. Extensive tests have been done with decay resistance of WPC products based on weight loss and mechanical property loss from lab (AWPA E10) and field (AWPA E7) tests. It has been shown that high fiber content and large fiber size led to more weight and strength loss from the decay fungi (Clemons and Ibach 2004). Thus, the decay performance of WPC material is strongly formulation dependent (Schirp et al. 2008).

Termite test data are more limited for WPC. The USDA FPL field test of extruded WPC showed visible termite nibbling on in-ground stakes after 3 year exposure in Saucier, MS, USA (Clemons and Ibach 2002). The Michigan Tech field test of extruded WPC in Hilo, Hawaii, USA showed little termite activity on WPC test blocks over a 27-month period (Schirp et. al. 2008). No published data on laboratory termite tests for WPC are available (Schirp et. al. 2008).

To date, no standards have been written for laboratory testing of termite resistance for WPC. However, AWPA E1 tests were designed to test termite resistance of solid wood. Although it was not developed for testing WPC material, the standard has been used by the industry to evaluate these materials. The objective of this study was to determine the termite resistance properties of extruded/compression molded wood/natural fiber plastic composites using the AWPA E1 method and to discuss our experience with the E1 test for these materials**.**

2. MATERIAL AND METHODS
2.1 Wood natural fiber plastic composite formulation

The WPC materials used include wood fiber-HDPE composites, bamboo fiber-HDPE composites, bagasse fiber–HDPE/PVC composites, and some commercial HDPE-based materials. Table 1 shows a summary of various materials.

Table 1. List of Various Wood/Nature Fiber Plastics Composites Tested for E1

Product Type	Product ID	Manufacturing Method	Formulation Information
Lab Made Products	L1	Melt blending and compression molding	HDPE(100%) Thickness: 4 mm (0.16 Inch)
	L2		HDPE(70%)/Bagasse (30%) Thickness: 4 mm (0.16 Inch)
	L3		HDPE(69%)/Bagasse(30)/N-CC(1.0%) Thickness: 4 mm (0.16 Inch)
	L4		HDPE(60%)/Bamboo(40%) Thickness: 4 mm (0.16 Inch)
	L5		HDPE(58%)/Bamboo(40%)/N-CC(2%) Thickness: 4 mm (0.16 Inch)
	L6		HDPE(56%)/Bamboo(40%)/N-CC(4%) Thickness: 4 mm (0.16 Inch)
	L7		HDPE(54%)/Bamboo(40%)/N-CC(6%) Thickness: 4 mm (0.16 Inch)
	L8		HDPE(70%)/Wood(30%) Thickness: 4 mm (0.16 Inch)
	L9		HDPE(70%)/Wood(30%)/N-CC(1%) Thickness: 4 mm (0.16 Inch)
	L10	Profile Extrusion	HDPE/Bagasse Thickness: 7 mm (0.28 Inch)
	L11		Recycled HDPE/Bagasse Thickness: 7 mm (0.28 Inch)
	L12		PVC/Bagasse Thickness: 7 mm (0.28 Inch)
	L13		Recycled PVC/Bagasse Thickness: 7 mm (0.28 Inch)
	L14		Recycled HDPE/Wood Thickness: 7 mm (0.28 Inch)
	L15		Recycled HDPE/Wood/Motor Oil/MA Thickness: 4 mm (0.16 Inch)
	L16		Recycled HDPE/Wood/Motor Oil/MAPE Thickness: 4 mm (0.16 Inch)
Commercial Products	C1	Profile Extrusion	HDPE/Wood (Formulation unknown)
	C2		HDPE/Wood (Formulation unknown)
	C3		HDPE/Wood (Formulation unknown)
	C4		HDPE/Wood (Formulation unknown)
Wood	WoodCTR	Solid Wood	Southern Pine (100%) Thickness: 6.4 mm (0.25 Inch)

Termite samples were machined from larger panels to 25.4 x 25.4 x thickness – mm (1x1xthickness – inch). Sample thickness varied among various products as shown in Table 1. The four commercial WPC materials were 19 mm (0.75 Inch) thick. Commercial materials (C1, C2, C3m and C4) were purchased locally. Material C1, C2, and C3 were tested at full thickness and Material C4 was tested by machining the thicker samples to obtain 7-mm (0.28 inch) thick samples with all exposed surfaces.

2.3 Termite Resistance Properties

Five matched samples from each treatment condition and five untreated southern pine controls were taken for No-Choice Laboratory Termite Tests according to AWPA E1. Prior to each termite test, the blocks were oven-dried at 105°C for 24 hours and sample weight (W_1) and dimensions were measured. Each test bottle (80 mm diameter x 100mm height) was autoclaved for 30 minutes at 105 kPa and dried. Autoclaved sand (150g) and distilled water (30mL) were added to each bottle. Finally, four hundred termites (360 workers and 40 soldiers) were added to the opposite sides of the test block in the container. All containers were maintained at room conditions for 4 weeks. The bottle cap was placed loosely. After testing, each bottle was dismantled. Live termites were counted, and test blocks were removed and cleaned. Each block was oven-dried again at 105°C for 24 hours to determine the dry sample weight (W_2). From the measurements, sample weight loss [$(W_1$-$W_2)/W_1$] and termite mortalities were determined. The tested samples were ranked visually by five people on a scale of 1-10 with 10 as no-damage and 1 with the most damages.

3. RESULTS AND DISCUSSION

3.1 Termite Mortality Rate

Figure 1 shows termite mortality from the AWPA E1 test for various WPC formulations.

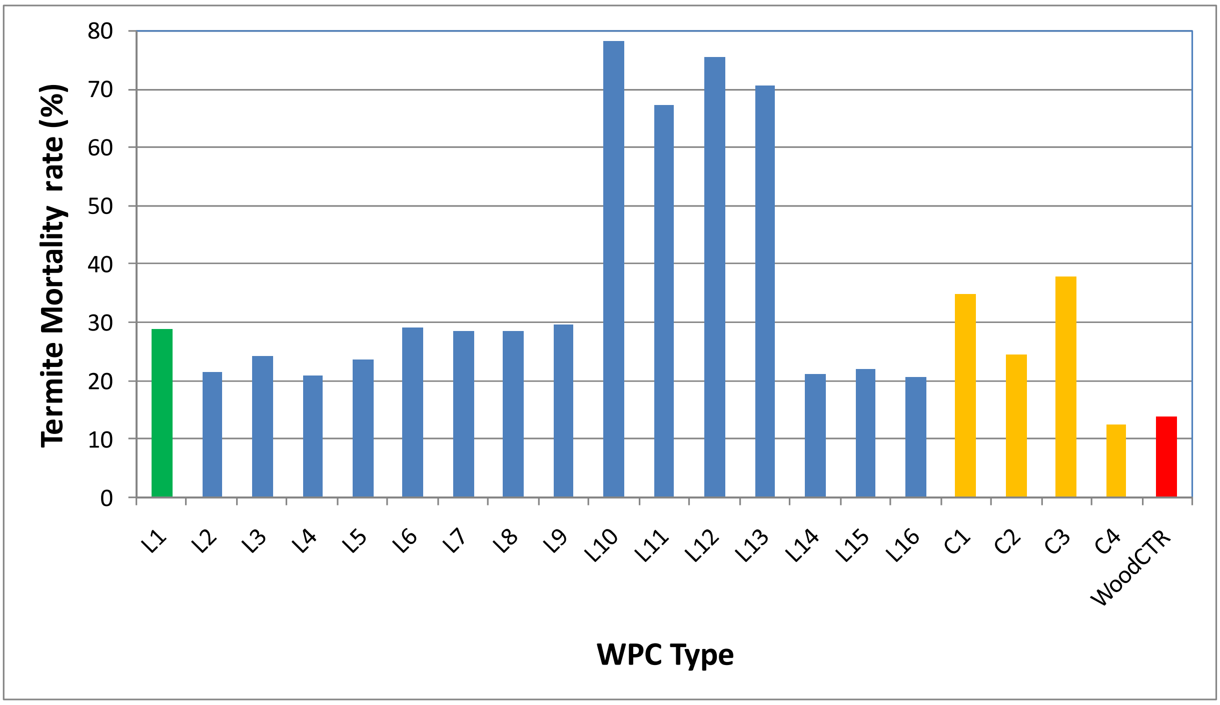

Figure 1. Termite mortality from the AWPA E1 test for various WPC formulations.

Pure HDPE composite (L1) had a termite mortality rate of 28.8% and solid wood (WoodCTR) had an average of mortality rate of 13.9%. Various composite formulations had mortality rate varying from 12.4% to 78.2% as shown. Materials from formulations L10, L11, L12, and L13 had unusual high mortality rate. Commercial WPC material L4 with all exposed interior surfaces had low mortality rate, which corresponds to larger sample damage as shown below.

*3.2 Sample Weight Loss Rate *

Figure 2 shows sample weight loss rate from AWPA E1 test for various WPC formulations. Pure HDPE composite (L1) had 0.10% weight loss, mainly due to the method used to calculate oven dry weight of the sample. Solid wood (WoodCTR) had an average of weight loss rate of 39.9%, showing the high vigor of termites used in these tests. Various composite formulations had weight loss rate varying from 0.28% to 7.9% as shown. Materials from formulations L8, L9, L10, and L11 contained a nano-copper based preservative with bamboo fibers. The weight loss was decreased from 4.53% (control – no additive) to 0.28%, showing obvious treatment effect. Commercial WPC material L4 with all exposed surfaces had the highest weight loss rate of 7.9% among the composites used. This was mainly due to exposed large wood fibers in the sample.

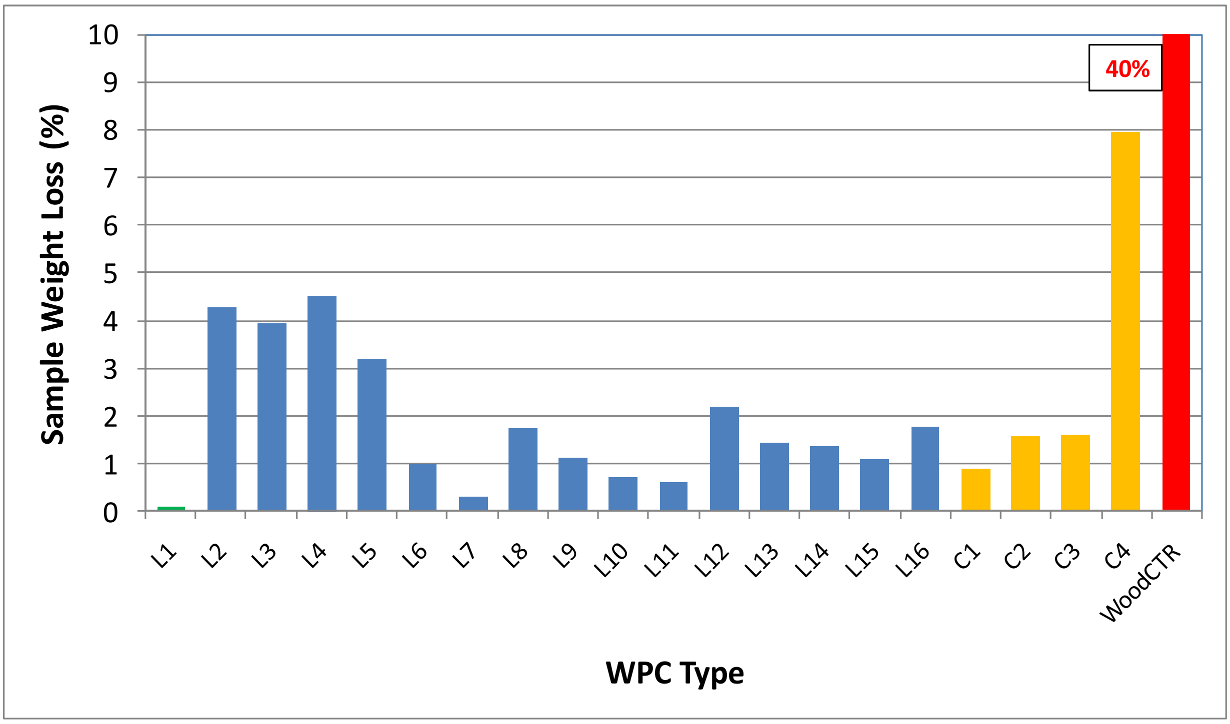

Figure 2. Sample weight loss rate from the AWPA E1 test for various WPC formulations.

3.3 Sample Damage Rating

Figure 3 shows sample damage rating from AWPA E1 test for various WPC formulations. Pure HDPE composite (L1) had a mean rating of 10, showing no sample damage. Solid wood (WoodCTR) had an average of damage rating of 0.9, showing major damage on the sample. Various composite formulations had sample damage rating varying from 6.6 to 9.8 as shown. Materials from formulations L8, L9, L10, and L11, which contained a nano-copper based preservative with bamboo fibers, showed improved damage rating from 7.5 to 9.0 with increase of the additive loading. Commercial WPC material L4 with all exposed interior surfaces had a 7.3 rating, showing obvious damage.

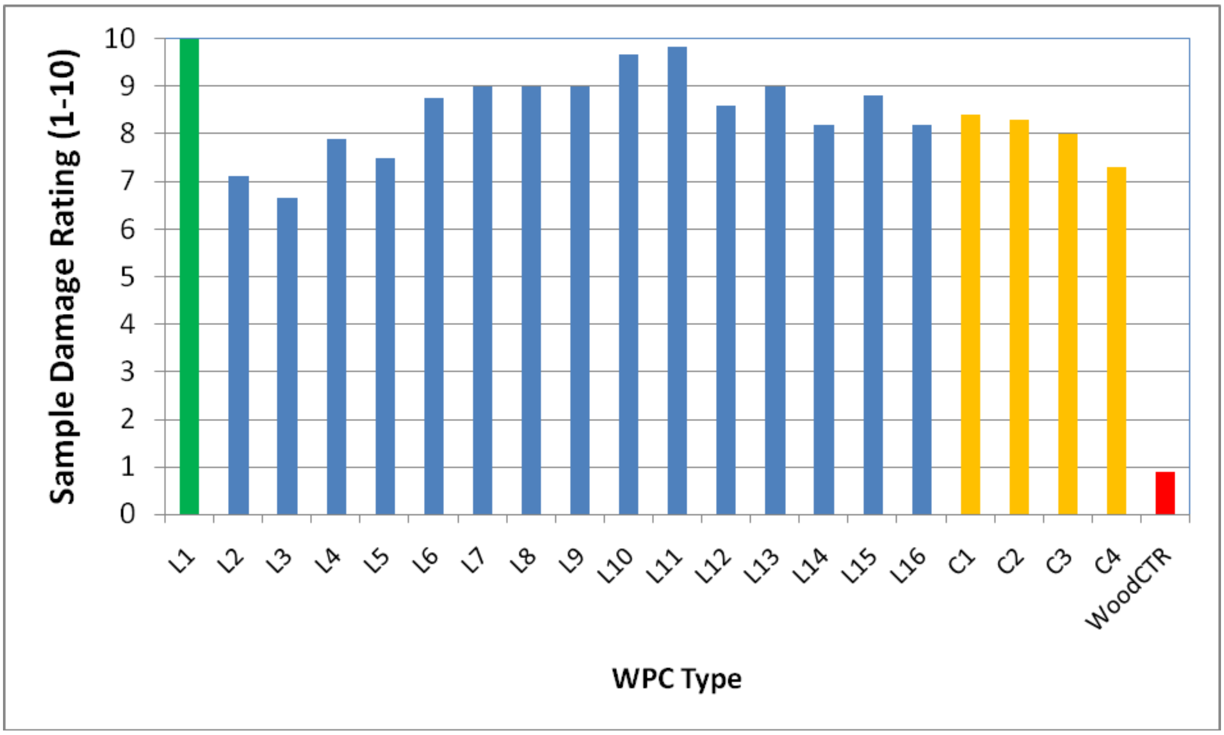

Figure 3. Sample damage rating from the AWPA E1 test for various WPC formulations.

3.4. Damage Mode

Figure 4 shows typical damage modes for various samples (Left: laboratory-made panel, Right: commercial panels). Damage on unexposed, as-extruded surfaces was mainly nibbling. The nibbling helped expose more fibers and led to more attack, especially for materials made with

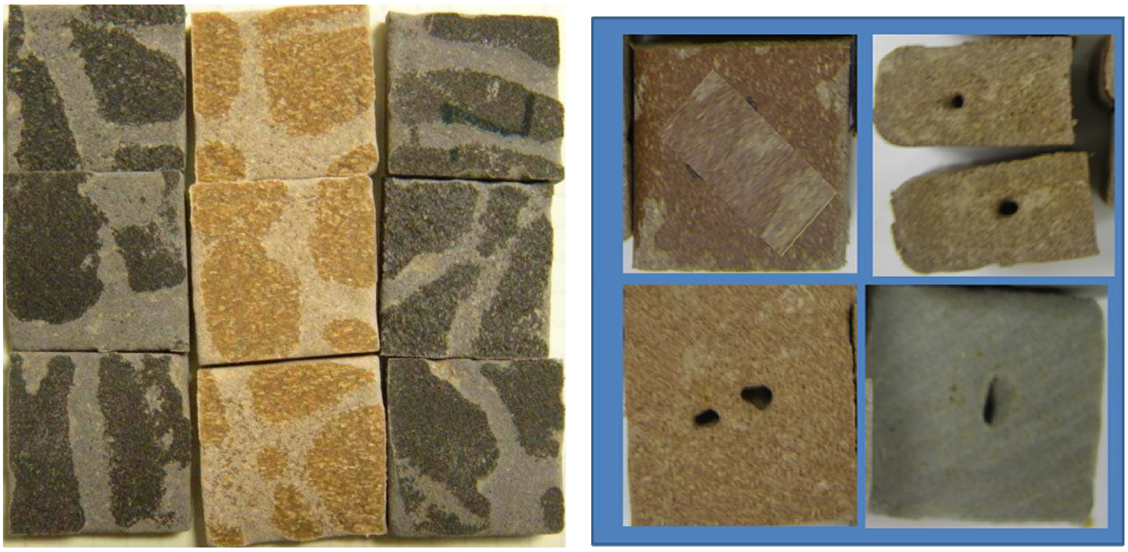

Figure 4. Typical damage mode of WPC from AWPA E1 test (Left: laboratory-made WPC, Right: commercial WPC).

larger particle sizes. Thus, the extruded surface provided some protection for the material from the termite attack. A breaking of the surface layer due to surface nibbling, weathering, machining, and other damages can lead to more termite attack on the material. Damage on machined, interior surface was both nibbling and through-holes as shown. AWPA E1 calls for a sample thickness of 6 mm (0.25 inch), while most commercial WPCs were made with larger thickness. Thus, a decision is needed on the sample thickness as machining of WPC has a large influence on test result. Termites attack machined sides for samples with as extruded thickness (e.g., 17 mm). WPC material treated with an effective preservative system should be able to resist termite attack on both as-extruded exterior surface and machined interior surface.

4. CONCLUSIONS

Sixteen laboratory WPC formulations, four WPC commercial materials, and southern pine (*Pinus* sp.) wood control were tested for termite mortality, sample weight loss, and sample damage rating. The results show that FSTs did attack WPC products in the laboratory setting. The test was sensitive enough to demonstrate the effect of chemical treatment and type of surface (as-extruded exterior surface versus machined interior surface) on termite resistance. The type of plastics (e.g., HDPE vs PVC, and virgin vs recycled) and fibers (wood, bamboo, and bagasse) was less important, compared to wood fiber loading level and particle size. There was a large difference in damage mode and degree of damage from as-extruded exterior surface and machined interior surface of WPC. Commercial WPC was subjected to more termite attack from the exposed interior surfaces. An effective chemical treatment should prevent termite attack on both types of surfaces for WPC.

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