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Section 4 Processes and Properties

Formosan Subterranean Termite Resistance to Heat Treatment of Scots Pine and Norway Spruce

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Abstract

New challenges to the durability of wood building materials have arisen in the U.S. The Formosan subterranean termite (*Coptotermes formosanus* Shiraki) now infests sizable portions of the U.S. south (Figure 1) and their range is extending. Heat treatments offer a unique opportunity for wood-based composites because many of the process techniques already employ various thermal applications and could be easily modified to design-in durability enhancements if specific benefits were understood. Information on resistance of oil-heat-treated wood against Formosan subterranean termites, however, was not currently available which provided impetus for this study. Samples of Scots pine sapwood (*Pinus sylvestris* L.) and Norway spruce sapwood (*Picea abies* L.) treated with hot rape seed oil were tested for their resistance to FST attack. Scots pine with a combination of hot oil treatment then vacuum pressure treated with hot oil was found to show promise in resistance to FST attack.

Keywords: Heat treatment, termites, pine, spruce, testing, Coptotermes formosanus

Introduction

Over the last ten years, new U.S. single-family housing starts have averaged 1.5 million units per year (Howard 2001). In 2002, despite a sluggish U.S. and world economy, there are estimated to be at least 1.6 million housing starts (Howard 2002). Additionally over the last 20 years the average new house size has increased from about 1750 ft^2 (163 m^2) to 2250 ft^2 (209 m^2) necessitating a 30% increase in building materials (Howard 2001). This increase in demand for wood building materials could have a negative influence on timber-sustainability unless corresponding increases in material durability and/or expected service-life can be found.

New challenges to the durability of wood building materials have also arisen in the U.S. The Formosan subterranean termite (*Coptotermes formosanus* Shiraki) now infests sizable portions of the U.S. south (Figure 1) and their range is extending. Coincidentally, this southern region of the U.S. has also experienced the greatest increase in new housing starts. Additionally, new wood-based composites and hybrid-wood composites (i.e., thermoplastic, inorganic-bound, and synthetic fiber-systems using fiberglass or Kevlar) are constantly being developed and entering the building materials markets (Winandy 2002). Many of these wood composites have far different resistance characteristics to moisture and biological attack by fungi and termites than did the solid-wood materials that have been historically used. The development of protective processes could dramatically benefit material durability and extend service-life.

The enhancement to durability from heat-treatments have long been known (Stamm 1964). Heat treatments offer a unique opportunity for wood-based composites because many of the process techniques already employ various thermal applications and could be easily modified to design-in durability enhancements if specific benefits were understood.

Within the last several years 4 different types of heat treatments have gained industrial significance in Europe. These four processes and the properties of the heat treated material produced were recently reviewed by Rapp (2001). An oil-heat-treatment (OHT) of wood is one of these processes. The most important material properties e.g. dimensional stability, strength properties and resistance against decay fungi have already been determined for this heat treatment method (Sailer et al 2000). The strength and decay performance of oil-heat-treated wood in relation to the other three heat treatments were also investigated by Welzbacher and Rapp (2002). Resistance of oil-heat-treated wood against marine organisms is currently under investigation. Since the majority of heat treated wood is intended for above ground use, above ground termite field tests according to AWPA E3-93 were started in 2001 and are continuing. Information on resistance of oil-heat-treated wood against Formosan subterranean termites, however, was not currently available which provided impetus for this study.

Material

Sample preparation was done by Bundesforschungsanstalt fur Forst- und Holzwirtschaft and provided to the Louisiana Forest Products Laboratory (LFPL). For oil-heat-treatment (OHT) and for untreated controls, matched samples were cut from Scots pine sapwood (*Pinus sylvestris* L.) and Norway spruce sapwood (*Picea abies* L.). A standard control was also used, southern yellow pine (Pinus spp.) sapwood. Each treatment included 10 replications for each formulation, 20 replications for the Spruce pine control, and 5 replications for the southern yellow pine control. Each sample received was 50.0 mm +/- 0.4 mm by 25.4 mm +/- 0.2mm (2 inch +/- 0.02 inch by 1.0 +/- 0.01 inch) rectangles. Each sample was cut at the LFPL into two 25 mm by 25 mm squares to provide a matched pair. One of these was used for the termite resistance test and the other for moisture content determination.

Twenty Scots pine and 10 Norway spruce specimens were subjected to an oil heat treatment at 220°C in rape seed oil according to the treatment schedule shown in Figure 2. After 32 minutes the middle of the specimens reached 220°C. This oil temperature (220°C) was maintained for four hours. Ten Scots pine specimens were also impregnated with hot oil. These were vacuum pressure treated (15 minutes vacuum at 20 mbar followed by 15 minutes pressure at 10 bar) with rape seed oil at 120°C and afterwards conditioned in 120°C hot air for 24 hours. The pine and spruce specimens without impregnation were directly conditioned in 120°C hot air for 24 hours. The change in density caused by the treatments can be seen in Figure 3. As shown in Figure 3, samples subjected to hot oil treatment only had very slight uptake of oil. Samples impregnated with oil had an average .40 gm/cc retention.

Procedures

The American Wood-Preservers' Association Standard E1-97 "Standard Method for Laboratory Evaluation to Determine Resistance to Subterranean Termites" was followed (AWPA 2001). A single choice method was used. The termite resistance tests were started on July 17, 2002 and completed August 14, 2002 with no interruptions or notable discrepancies.

Each testing jar was autoclaved prior to use. Afterwards, 150 grams of autoclaved sand and 30 ml of distilled water were added to each. One sample was placed in each jar with two corners touching the jar side. Four hundred termites were introduced to each jar on the side opposite the sample. Termites were obtained from a State Park in Louisiana July 10, 2002. Samples of termites were taken, weighed and an average weight per termite determined. An average of 0.00355 gm per termite was obtained therefore each jar contained 1.42 grams of termites. Termite composition consisted of approximately 20 soldiers and 380 workers. The jars were inspected each week.

The test was conducted for 28 days, after which the sample was removed and cleaned with distilled water to remove termites and sand, rated and ovendried. The rating system used is based on a visual value ranging from 0 to 10 based on the following categories:

10	Sound, surface nibbles permitted
9	Light attack
7	Moderate attack, penetration
4	Heavy attack
0	Failure

In addition to the rating of each sample, sample weight loss and termite mortality data were obtained. All data were analyzed statistically through an analysis of variance.

Results and Discussion

Table 1 contains a summary of the data including the means and standard deviations for the primary data of interest, i.e. percent mortality, percent weight loss, and treatment ratings. In addition it provides information on significant differences determined between treatments for these variables through analysis of variance using the Duncan test. If a treatment within a column contains the same letter as another, there is no significant difference at a 95% confidence interval.

Percent mortality was obtained by counting all live termites after the 28 day test and dividing by 400, the number of termites used in the test. Percent weight loss is based on the original oven dry weight. The test sample oven dry weight is calculated by determining the moisture content of the matched sample and using it to calculate the sample oven dry weight. The final oven dry weight is determined directly by oven drying the sample (103ºC ± 2ºC) after the test.

As can be seen in Table 1 there is one heat treatment that shows promise for resistance to Formosan subterranean termites. This is Scots pine impregnated with rape seed oil after being subjected to a hot oil heat treatment. All samples were significantly different in all three categories; weight loss, termite mortality, and rating. This treatment had the lowest significant average weight loss of 3.76% compared to 50% weight loss for the Scots Pine and 55.26% for the Norway spruce, each having heat treatment only. All controls lost between 37% and 54%. The only significant difference found in termite mortality was for the impregnated Scots pine treatment. It caused almost 68% mortality as compared to 23% to 38% for all other treatments and controls. Ratings were also high for the impregnation treatment receiving a value of 9.4 as compared to between 0.2 to 1.8 for all other treatments.

The results of this test show that heat treatment by the hot oil method alone does not resist attack by Formosan subterranean termites. Through impregnation with rape seed oil to a retention of 0.40 gm/cc does show excellent promise. It has not been determined if this retention value is a threshold or lesser retentions may work as well.

Conclusions
A laboratory no-choice test for the efficacy of high temperature treatment by hot rape seed oil and high temperature treatment plus oil impregnation was performed. This test showed that the high temperature treatment combined with oil impregnation to .40 gm/cc has potential for providing resistance to Formosan subterranean termites. Heat treatment only in hot oil was found not to be effective. Additional work is needed to determine the threshold for efficacy of oil impregnation.

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Figure 1. Distribution of Formosan subterranean termites in United States (Woodson et al 2001).

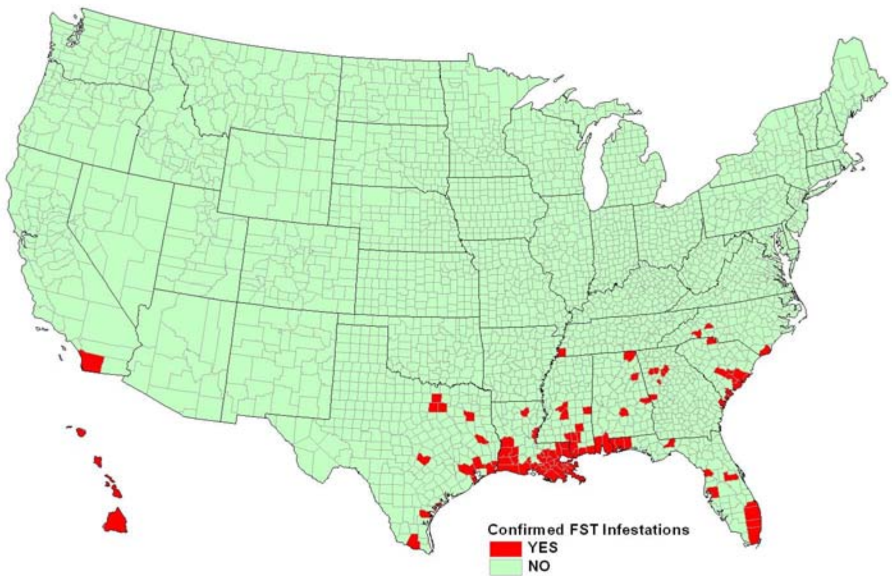

Figure 2. Hot oil treatment schedule.

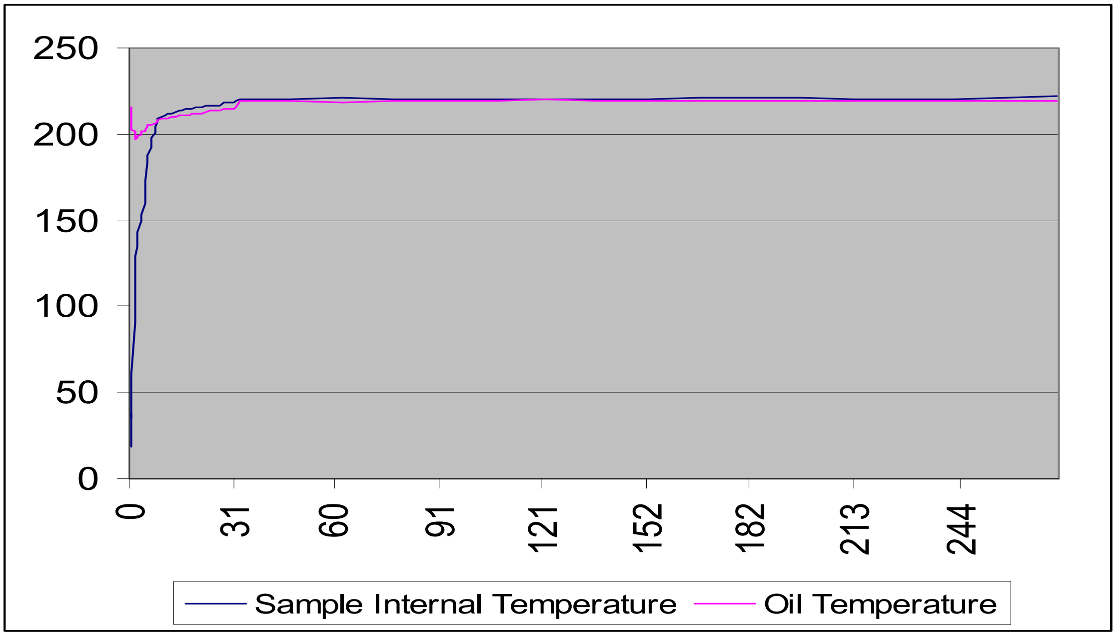

Figure 3. Average density of samples before and after hot oil treatments.

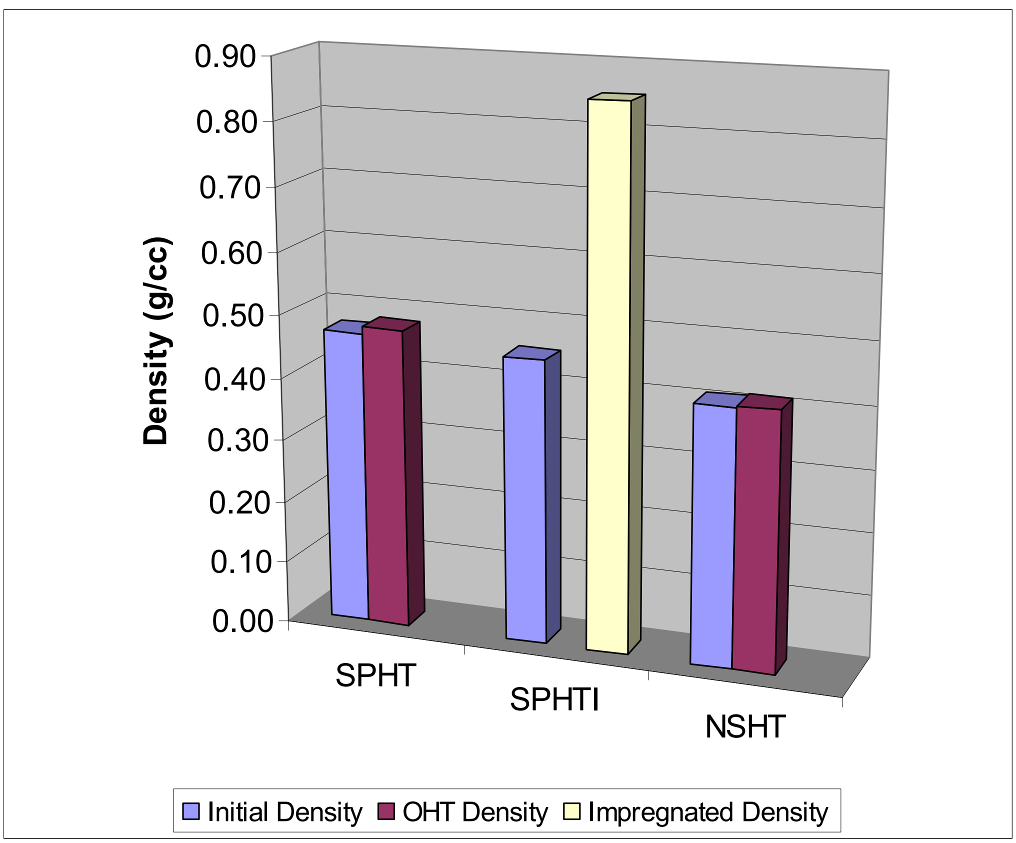

Figure 4. Results of sample weight loss and termite mortality after 28 day no choice laboratory test.

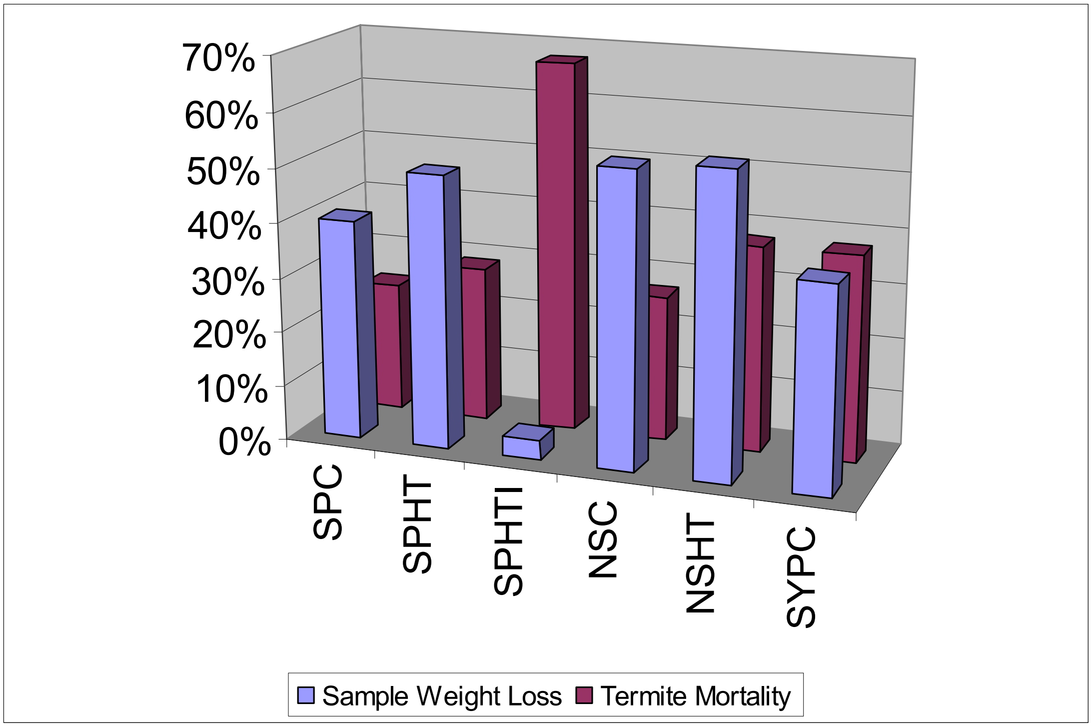

Figure 5. Results of sample rating after 28 day no choice laboratory test. (0 represents failure and 10 represents minimal attack)

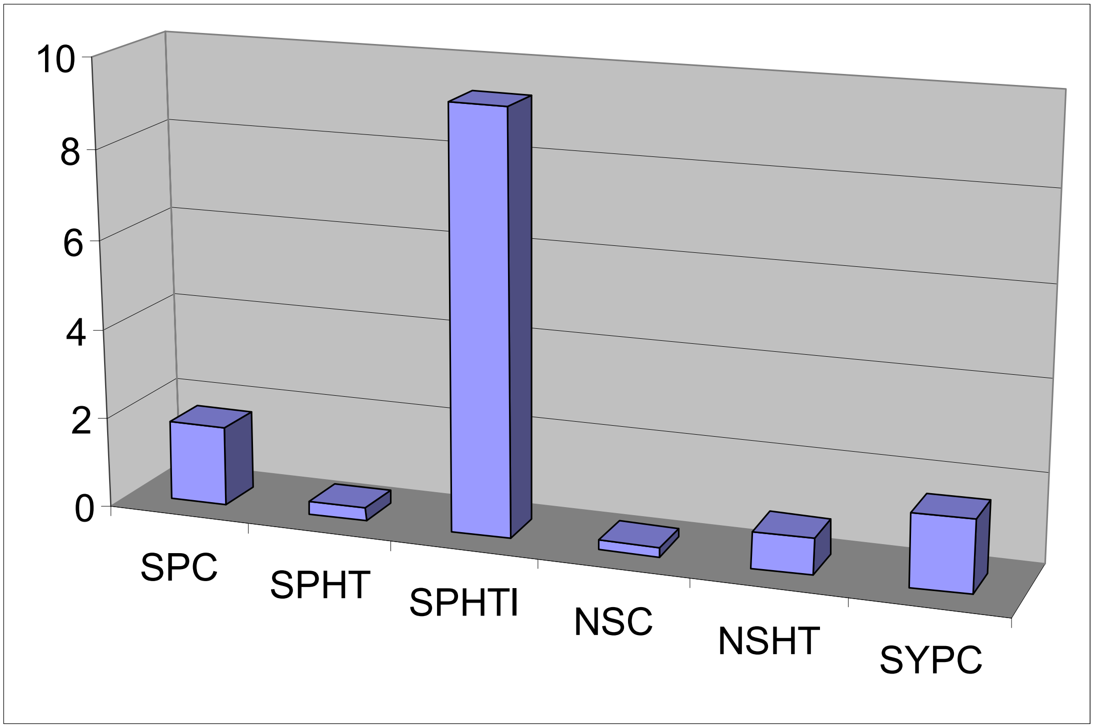

Table 1. Summary of results for Formosan subterranean termite 28-day laboratory tests.

Treatment	ID	N	Wt Loss [1] (%)	Sig[2]	Mortality[1] (%)	Sig[2]	Rating[1] (%)	Sig[2]
Scots Pine controls	SPC	20	40.30% (0.068)	B	23.7% (0.089)	B	1.8 (1.41)	B
Scots Pine heat treatment	SPHT	10	50.04% (0.083)	C	28.65% (0.161)	B	0.3 (0.68)	C
Scots Pine heat treatment and impregnation	SPHTI	10	3.76% (0.029	A	67.63% (0.234)	A	9.4 (0.94)	A
Norway Spruce controls	NSC	10	53.93% 0.074)	C	26.68% (0.097)	B	0.2 (0.42)	C
Norway Spruce with heat treatment	NSHT	10	55.26% (0.110)	C	37.68% (0.239)	B	0.8 (1.75)	BC
Southern Yellow Pine controls	SYPC	5	37.40% (0.072)	B	37.65% (0.220)	B	1.6 (2.19)	B

Note: [1]Values are average percentages with standard deviations in parentheses.
[2]Same letters in columns are not significantly different at 95%. Harmonic mean sample size is 9.231. The group sizes are unequal and Type 1 error levels are not garanteed.