Effect of Wet-Dry Cycling on the Decay Properties of Aspen Fiber High-Density Polypropylene Composites

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Abstract

Aspen fiber-polypropylene composites were prepared with various levels of fiber (0,30%, 40%, 50%, and 60%), polypropylene (PP) (100%, 98%, 70%, 68%, 60%, 58%, 50%, 48%, 40%, and 38%), and the compatibilizer maleated polypropylene (MAPP) (0 and 2%). Specimens were either subjected to 10 cycles of 1 week room temperature water soaking-oven drying or 2-hr. boiling water-oven drying. Thickness swelling and weight loss were calculated. Specimens were then exposed to the brown-rot fungus *G. trabeum* or the white-rot fungus *C. versicolor* for 12 weeks to determine the effect of repeated water cycling on decay. Results indicate that as the amount of aspen fiber increases there is an increase in weight and thickness swelling, as well as an increase in fungal attack after the water cycling tests. Presence of the compatibilizer seems to have an effect on the moisture weight gain, thickness swelling, and attack by fungi.

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Introduction

The use of wood-filled thermoplastic composites is increasing, especially for exterior applications. Composites used for decking, window frames, and exterior trim are nonstructural and not exposed to ground contact. There are some applications, however, such as fences and landscaping timbers in which wood-filled thermoplastic composites are directly exposed to soil. Untreated solid wood biologically decays when exposed to adverse environments so there is potential for these composites to also be susceptible to biological degradation since untreated wood fiber and flour are used.

Literature Review

There is little scientific literature addressing the biological degradation of wood-filled thermoplastics. Several poster abstracts are published in proceedings, but no papers were published with them (1-3). All of the research contained in these posters used commercial woodfiber-plastic composites, so there are no specifics on what wood fiber or polymer was used.

In a 12-week soil block test using *G. trabeum* as the test fungus, there was slow but increasing moisture uptake with incubation time, as well as a 2 percent weight loss (if not treated by fungicides) with one commercial wood-plastic composite (1). In laboratory and field exposure tests with a 50-50 wood plastic mixture, evaluations of the mechanical, chemical, biological, and weathering properties were evaluated (2). However, no results were given in the abstract. Several examples of premature deterioration, creep performance, and thermal instability of commercial wood plastic lumber were illustrated (3).

The first publication isolating fungi growing on a commercial recycled wood-plastic composite lumber (believed to be a 50:50 mixture of recycled wood fiber (hardwood and softwood) and recycled grocery bags and stretch film) found one brown-rot, *Gloeophyllum striatum* (L.: Fr), and one white-rot, *Pycnoporus sanguineus* (Swartz: Fr), fungus after only 4 years in service in Florida (4). There was no control study in this research and the authors state that this may not be a representation of the product or range of its application. They do not know if this is an isolated case or an example of a more common phenomenon.

A 12-week laboratory soil block test on 30 percent aspen fiber/70 percent polypropylene (PP) with and without the coupling agent maleated polypropylene (MAPP) was conducted (5). There was little weight loss with the composites (less than 0.25% with *G. trabeum* and no weight loss with *C. versicolor)* compared with the aspen solid wood controls (54% with *G. trabeum* and 27% with *C. versicolor.)* There was no weight loss with the 100 percent PP.

Laboratory fungal resistance of PP and polyethylene (PE) (with 40% to 80% wood filler), unfilled plastic, solid wood, and 2 commercial composites before and after water soaking, 2-hr. boiling, or 5 freeze-thaw cycles were performed (6). After exposure for 16 weeks to *G. trabeum* both PE and PP composites had less than 5 percent mass loss at fiber levels of 60 percent or less, regardless of the severity of the preconditioning.

More recent research shows colonization of *G. trabeum* on the surfaces of wood-thermoplastic composites with high wood content, but no significant weight loss in laboratory evaluations was found (7). High weight loss was found during laboratory evaluations in a 70 percent wood/30 percent high density polyethylene (HDPE) product (8). Hyphae were found in the voids of the composite using scanning electron microscopy (SEM) indicating fungal colonization. There was little or no attack in two different 50:50 HDPE composites.

Investigations of the fungal and termite resistance of PP/softwood composites by laboratory soil block, field stake and field termite tests found that the higher the wood content, the greater the susceptibility for biological degradation (9). Addition of a preservative, such as zinc borate, increased the fungal and termite resistance of the 50 percent wood content composite.

Present Study

The goal of the present study was to determine the effect of repeated wet-dry cycling on the biological resistance of aspen fiber-PP composites. The objectives were to:

1. prepare composite specimens with several different levels of aspen fiber and PP with and without compatibilizer,
2. submit these specimens to both 1 week room temperature water-oven drying and 2-hr. boiling water-oven drying cycles and determine swelling and weight loss,
3. submit the cycled specimens to a 12-week soil block test using *G. trabeum* or *C. versicolor* to determine the effect of repeated water cycling on decay properties.

Materials and Methods

Specimen Preparation

Aspen fiber, PP. and the compatibilizer MAPP, were compounded in a twin-screw extruder according to Table 1. Woodfiber-plastic composite specimens were prepared by injection molding.

Specimen Conditioning

Specimens were conditioned by one of the following two test methods:

Test 1. Ovendried specimens were soaked in water for 1 week and re-dried overnight. The procedure was repeated 10 times.

Test 2, Ovendried specimens were boiled in water for 2 hours and re-dried overnight. The procedure was repeated 10 times.

Weight gain and thickness swelling were measured after each cycle of Test l and Test 2.

Biological Testing

Specimens were exposed to either the brown-rot fungus *G. trabeum* or the white-rot fungus *C.*

Table 1. ~ *Composition of composite specimens.*

Aspen fiber	Polypropylene	MAPP
	- - - - - - - - - (% by weight) - - - - - - - - -	
0	100	0
0	98	2
30	70	0
30	68	2
40	60	0
40	58	2
50	50	0
50	48	2
60	40	0
60	38	2

Table 2. ~ *Weight gain and thickness increase after water soaking and boiling tests.*

	Water soaking		Boiling	
Specimen	Weight gain	Thickness increase	Weight gain	Thickness increase
	- - - - - - - - - - - (%) - - - - - - - - - - - -			
0/100	0.22	-1.2	0.1	-1.2
0/98/2	0.36	0.0	0.1	-0.8
30/70	2.7	0.4	1.2	0.8
30/68/2	2.2	0.8	1.2	0.0
40/60	4.5	2.1	1.8	0.8
40/58/2	5.1	3.3	1.9	0.8
50/50	8.6	3.7	3.1	0.8
50/48/2	7.1	3.7	2.8	2.1
60/40	10.9	7.4	4.4	0.4
60/38/2	8.8	5.3	3.5	2.9

versicolor in the standard ASTM D1413 soil block test with some modifications (10). The specimen size was 3 by 12 by 20 mm, and weight loss was calculated with 105°C ovendry weights.

Results and Discussion

In a preliminary 12-week soil block test, never wet, ovendried 30 percent aspen fiber/70 percent PP specimens had less than 0.25 percent weight loss with *G. trabeum* and no weight loss using *C. versicolor* (5). The reason for this was thought to be that the fungi could not get access to the fiber due to the plastic coating around it. Therefore in this study new specimens were prepared with varying levels of aspen fiber and submitted to cyclic water-oven drying and water boiling-oven drying tests and then placed in a 12-week soil block test using the same two fungi.

Table 3. ~ *Soil block test results after 12 weeks of fungal exposure.*

	Weight loss (%)	
Specimen	*G. trabeum*	*C. versicolor*
After water soaking test		
30/70	2.4	1.3
30/68/2	1.6	0.3
40/60	3.6	2.1
40/58/2	3.3	1.8
50/50	4.6	2.3
50/48/2	5.3	3.0
60/40	4.7	2.0
60/38/2	5.9	1.7
After boiling test		
30/70	1.8	1.4
30/68/2	0.4	0.0
40/60	3.5	1.8
40/58/2	2.2	1.3
50/50	6.1	3.5
50/48/2	4.3	2.5
60/40	8.0	3.3
60/38/2	7.4	4.1

Table 2 shows the weight gain and thickness increase of the specimens after water soaking or boiling 10 cycles. The results indicate that as the amount of aspen fiber increases, the increase in weight and thickness swelling due to the water cycling tests increases. The 100 percent PP and 98%PP/2% MAPP specimens show thickness decreases which are expected due to the potential melting at high temperature. The addition of 2 percent MAPP gave slightly less percentage weight gain and thickness increase with water soaking and boiling with a woodfiber content of 50 percent or higher. However the MAPP specimens gave a thickness increase for the boiling test.

Table 3 shows the percentage weight loss after 12 weeks of fungal exposure in the soil block test to either *G. trabeum* or *C. versicolor*. The results indicate that as the amount of aspen fiber increases, the amount of fungal attack after the water cycling tests increases. The addition of 2 percent MAPP shows less percentage weight loss except for the 50 percent higher fiber content water soaked Samples.

Conclusion and Future Research

As the content of aspen fiber increases in the composite: weight gain and thickness swelling due to water soaking or water boiling increases; weight loss in a 12-week soil block test due to attack by brown- and white-rot fungi increases; the compatibilizer seems to have an effect on both moisture weight gain, thickness swelling, and attack by fungi.

Research is continuing on the moisture, decay, and ultraviolet resistance of wood-filled HDPP and HDPE thermoplastic composites. Laboratory decay with brown-, white-, and soft-rot fungi, as well as outdoor field exposure, is in progress.

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