Moisture Content and Decay Resistance of Field-Exposed Wood Plastic Composites

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Abstract

Wood plastic composite (WPC) samples of varying formulations, with and without zinc borate biocide and UV stabilizer package, were exposed in Hilo, Hawaii, and Vancouver, British Columbia for up to 6 years. Samples were periodically collected and moisture content was monitored. After field exposure, samples were subject to laboratory soil block culture testing (conducted according to AWPA E-10). Data relating to the weight loss in wood due to decay versus moisture content, location of exposure and material composition were obtained and examined in this investigation. As expected, it was found that the weight loss in wood due to decay of WPC samples was dependent on the moisture content of the material, with decay resistance decreasing with increasing moisture content. It was also established that decay resistance seemed to depend on the exposure location of the tested samples, where samples exposed in the wet tropical climate of Hilo exhibited less decay resistance than samples of similar moisture content exposed in Vancouver. The data collected indicated that moisture content in wood seemed to increase over exposure time for samples exposed in sunny locations, but remained relatively constant for samples exposed in shadow locations. The addition of zinc borate to the tested WPC samples showed significant decay inhibition effects whereas the addition of UV stabilizer package to WPC formulations exhibited a limited effect on the decay susceptibility of the tested samples.

Introduction

There is limited and controversial experience within industry and academia related to the decay of wood plastic composite (WPC) materials subject to exterior exposure and laboratory testing. There is also a lack of data connecting field exposure and laboratory testing methods. The presented project demonstrates a comparison of the decay process in experimental wood plastic composites when exposed to different climatic conditions and AWPA E-10 soil block culture testing.

Objective

To investigate the effect of moisture content, zinc borate and UV stabilizer additives on the decay resistance of field exposed wood plastic composites and to find correlation between these factors and the performance of field-exposed WPCs subject to decay fungi via laboratory soil block culture testing.

Experimental

HPDE/Pine wood plastic composite (WPC) samples of varying formulations, with and without zinc borate biocide and UV stabilizer package (see Table 1), were exposed at sun and shadow sites in Hilo, Hawaii, and Vancouver, British Columbia for up to 6 years. Samples were periodically collected, evaluated, and frozen for future testing. After field exposure, select samples were evaluated for moisture content and additionally subject to laboratory soil block culture testing (according to AWPA E-10). Results of decay fungi activity were reported as the weight loss in wood of the WPC specimens or corresponding density decrease. Data relating to the weight loss in wood due to decay, moisture content, as well as the affect of zinc borate and UV stabilizer additives were obtained.

Table 1. Formulations of WPC Samples Tested

Sample #	Pine (wood) Content	Zinc Borate[1]	UV Stabilizer Package[2]
1	50%	No	Yes
5	50%	No	No
6	50%	Yes	No
8	65%	No	Yes
12	65%	No	No
13	65%	Yes	No

[1] 3% Zinc Borate

[2] UV stabilizer package – Tinuvin 770 (Ciba Geigy) 5 wt%, Tinuvin P (Ciba Geigy) 5 wt%, metal oxides pigments 15 wt%, HDPE (carrier) 75 wt%

WPC Manufacturing

Experimental WPCs were made for testing in such a way that they matched the manufacturing process, dimensions, and water absorption of select commercial decking boards. 1" x 6" boards were extruded in the Washington State University (WSU) Wood Materials and Engineering Lab using a Millicron 55 mm co-rotating twin screw extruder.

Figure 1. Manufacturing of experimental WPC boards at WSU Wood Materials and Engineering Lab

WPC Exposure

3' long WPC boards were exposed in two geographical locations, one a temperate climate (Vancouver, BC) and one a tropical climate (Hilo, Hawaii), both in sun and in shadow. The boards were periodically inspected and samples were cut, wrapped in plastic, and frozen for further laboratory evaluation.

(a) Sun location in Vancouver, BC (c) Sun location in Hilo, Hawaii

(b) Shadow location in Vancouver, BC (d) Shadow location in Hilo, Hawaii

Figure 2. Representative images of exterior exposure locations and sites

Sample Preparation

Frozen exposed WPC samples were cut with caution taken to avoid moisture loss during handling. The exposed samples were sectioned to meet the approximate volume (6913mm^3) of standard 19.05mm x 19.05mm x 19.05mm soil block testing specimens. For 65% wood content samples with nominal 25.4mm thickness, specimens were cut to a target size of 25.4mm x 14.5mm x 19.0mm. For 50% wood content samples with nominal 12.7mm thickness, specimens were cut to a target size of 19.5mm x 27.0mm x 12.7mm.

Reference unexposed materials were also cut to match the size of the exposed samples. All cut specimens were measured with a micrometer, weighed using an analytical balance, vacuum packaged, and radiation sterilized prior to soil block culture testing. It should be noted that all exposed samples were kept frozen (-20°C or lower) during storage and transportation.

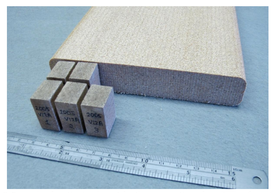

Figure 3. Example of sectioning-layout for the preparation of specimens for soil block culture testing for 65% wood content samples with nominal 25.4mm thickness

Soil Block Culture Testing

Samples were tested according to AWPA standard E-10 by USDA Forest Products Laboratory in Madison, WI. Brown-rot fungus (*G. trabeum*) was used knowing that it is more aggressive for soft wood species like the pine present in the tested WPC samples.

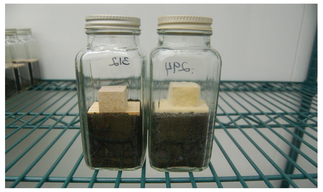

Figure 4. Brown-rot fungus, *Gloeophyllum trabeum* (tested WPCs contained pine wood) Test duration 12 weeks

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- USDA Forest Products Laboratory personnel Narimah Ehr for soil block testing assistance

Results

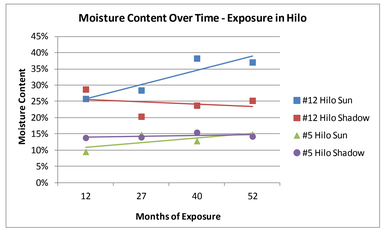

Figure 5a. Moisture content of WPC #5 and #12 exposed in Hilo over time

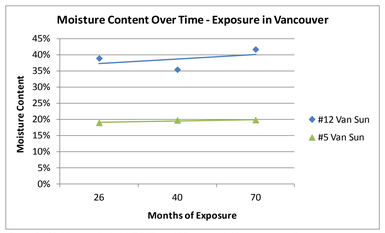

Figure 5b. Moisture content of WPC #5 and #12 exposed in Vancouver over time

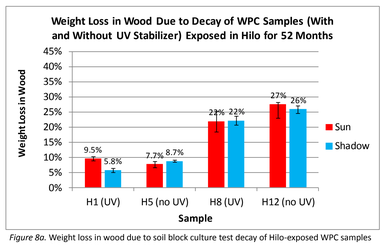

Figure 8a. Weight loss in wood due to soil block culture test decay of Hilo-exposed WPC samples with and without UV stabilizer package

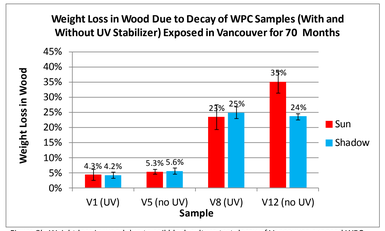

Figure 8b. Weight loss in wood due to soil block culture test decay of Vancouver-exposed WPC samples with and without UV stabilizer package

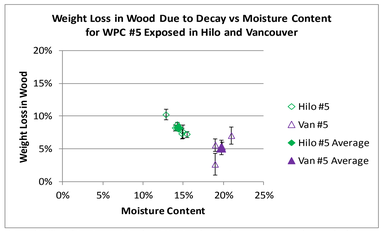

Figure 6a. Weight loss in wood due to soil block culture test decay versus moisture content for WPC #5 samples exposed in Hilo and Vancouver

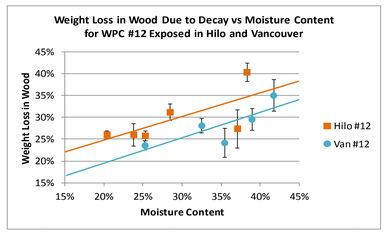

Figure 6b. Weight loss in wood due to soil block culture test decay versus moisture content for WPC #12 samples exposed in Hilo and Vancouver

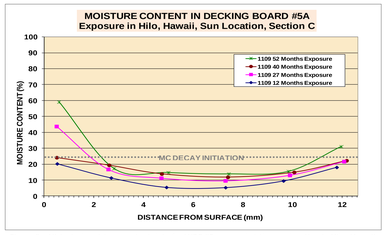

Figure 9a. Historical moisture content data for WPC #5 exposed at the sun location in Hilo, Hawaii, showing the moisture distribution from the surface of the board for varying exposure time

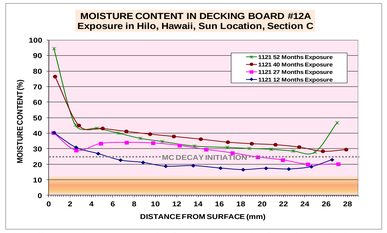

Figure 9b. Historical moisture content data for WPC #12 exposed at the sun location in Hilo, Hawaii, showing the moisture distribution from the surface of the board for varying exposure time

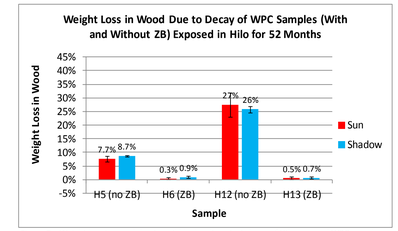

Figure 7a. Weight loss in wood due to soil block culture test decay of Hilo-exposed WPC samples with and without zinc borate

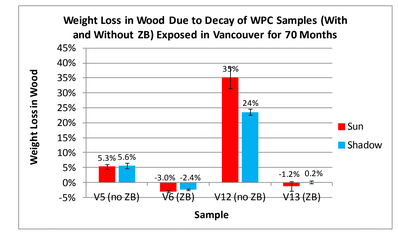

Figure 7b. Weight loss in wood due to soil block culture test decay of Vancouver-exposed WPC samples with and without zinc borate

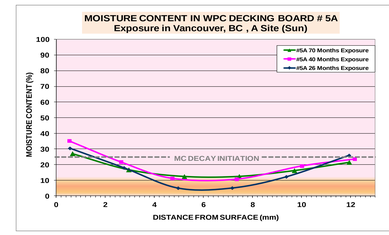

Figure 10a. Historical moisture content data for WPC #5 exposed at the sun location in Vancouver, BC, showing the moisture distribution from the surface of the board for varying exposure time

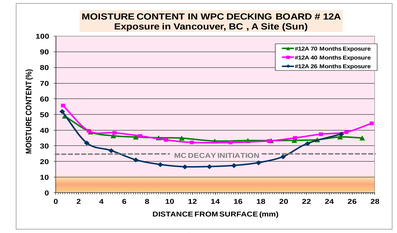

Figure 10b. Historical moisture content data for WPC #12 exposed at the sun location in Vancouver, BC, showing the moisture distribution from the surface of the board for varying exposure time

Comments and Conclusions

As could be expected, weight loss in wood due to decay in soil block culture testing (AWPA E-10) depended on the moisture content of the WPC. With decreasing moisture content in wood, the resistance to decay increased. The rate of decay also seemed to depend on the exposure location for the tested samples. Samples exposed in the tropical climate of Hilo decayed more in comparison with samples of similar moisture content which were exposed in Vancouver. Moisture content in wood seemed to increase over the exposure time for samples exposed in sunny locations. It was difficult to assess the changes in moisture content of samples exposed in shadow locations because of the limited number of samples available. The historical data showing moisture content distribution from the board surface of field-exposed samples confirmed the differences in moisture content between exposure climatic zones and exposure time period. Decay resistance depended on the weathering history of WPC samples.

Decay in soil block testing was not observed for samples containing zinc borate regardless of exposure time, such as for up to 52 months in Hilo and 70 months in Vancouver. The addition of UV stabilizer package to WPC formulations seemed to have a limited effect on the decay susceptibility of wood plastic composites exposed to exterior conditions. Samples containing UV stabilizer package had similar decay resistance in comparison to samples without UV stabilizer package, except for one experiment where samples were exposed at a sunny location in Vancouver. In this case, samples without UV stabilizer package seemed to exhibit an increase in decay.

It should be mentioned that the field decay evaluated as weight loss in wood for WPC #12 was in the range of 10% of the soil block culture test decay value while the field decay detected for #5 and #13 was not detectable. High field decay wood depletion was observed for WPC #8, in the range of up to 17% for samples exposed in Hilo and up to 7% for samples exposed in Vancouver.

Soil block culture testing is frequently recommended for evaluation of WPCs in respect to their resistance to decay. Many composites are used commercially with an expectation for long lifespan. The obtained results show that testing procedures as presented in existing standards, such as testing of freshly made specimens, may not sufficiently predict long term WPC performance in the field.