TESTING OF WOOD PLASTIC COMPOSITES

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INTRODUCTION

Wood-plastic composites (WPC) are a group of relatively new materials made from a combination of wood particles and plastics, most frequently thermoplastic resins. Recent expansion of WPC into the construction industry, including exterior decking and railing material, brings requirements for a more uniform and accurate evaluation of product properties across the industry. Laboratories or regulatory bodies have tried to recommend or apply testing standards developed for wood or plastics to WPC with mixed success.

There is a significant difference in materials structure when wood, plastics, and wood-plastic composites are compared. This causes different responses to test conditions, including durability. The size of specimens required for testing often creates difficulties with respect to shape of extruded profiles vs. commercial lumber or wood composites used to set up standards.

As test examples, water absorption, accelerated weathering, and fungal resistance of WPC will be discussed. Surface properties and structure will be described as well.

OBJECTIVE

The objective of the presented research was to identify the response of a variety of commercial and experimental wood plastic composite materials to different testing procedures particularly related to:

- water absorption
- weathering
- fungi resistance

EXAMPLES OF RECOMMENDED STANDARDS

	Properties	Plastics PE, PP or PVC	Wood Composites	Wood Plastic Composites
#1	Water absorption	ASTM D 570	ASTM D 1037	ASTM D 1037
#2	Accelerated weathering	ASTM D 2565 ASTM G 53 ASTM G 154	ASTM D 2565 ASTM G 53 ASTM G 154	ASTM D 2565 ASTM G 53 ASTM G 154
#3	Fungi resistance	ASTM G 21	ASTM D 1413 AWPA Method E10	ASTM D 1413 ASTM G 21

EXAMPLES OF LIMITATIONS OF TESTING METHODS DEVELOPED FOR PLASTICS OR WOOD COMPOSITES IN APPLICATION TO WOOD PLASTIC COMPOSITES

Properties	Plastics	Wood Composites	Wood Plastic Composites
Water absorption	Equilibrium: 0.5% - 10% Reached in weeks	Equilibrium: 30% - 120% Reached in hours/weeks (can be accelerated by pressure)	Equilibrium: 15% - 45% Reached in months Comments: Equilibrium difficult to reach for test methods applied by industry
Weathering	Colour Change: Whitening or no colour change Surface Damage: Crazing, checking and cracking	Colour Change: Initial darkening followed by whitening Surface Damage: Checking, loss of integrity	Colour Change: Initial darkening, whitening or no colour change Surface Damage: Crazing, checking may be difficult to identify Comments: Weathering could be difficult to detect using established test methods
Fungi resistance	Infection development: Predominant surface growth	Infection development: Surface and the bulk of the specimens are infected	Infection development: Surface and the bulk of composites may be infected. Comments: A large variety of fungi could be active and used for testing. Moisture migration, essential for microbiological activity, seems to be a factor which is significantly different for wood and wood/plastic composites. Specimen size required by standard cannot always be cut from commercial products.

WATER ABSORPTION

It is expected that water absorption of wood plastic composites (WPC) follows the law of diffusion. Moisture content of WPC immersed in water is not uniformly distributed within the composite body. The surface layer reaches equilibrium very quickly while the core is still dry. Knowledge of liquid water absorption of WPC in equilibrium is very important because moisture content of material is a significant factor affecting microbiological activity and weathering.

Data available in literature with respect to water absorption of WPC seems to focus on the average moisture content for thick tested samples, which likely cannot reach equilibrium during testing. For this reason, 14 randomly selected products available on the North American market and 7 experimental products made by the laboratory were tested for water absorption in equilibrium.

Other factors which may contribute to water absorption of WPC such as surface texture and defects or resin content were briefly evaluated as well in the presented work.

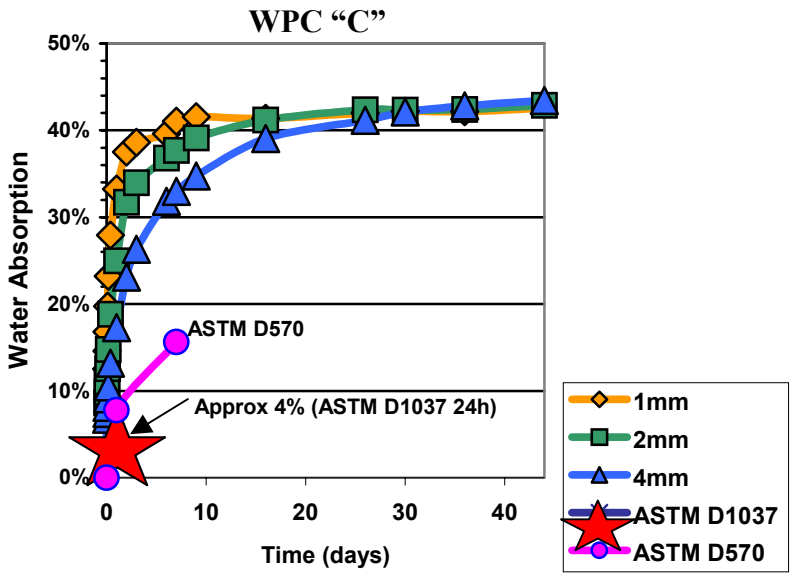
WATER ABSORPTION TESTING PROCEDURE

Water absorption as a function of specimen thickness was evaluated for samples of wood plastic composites “C” and”Q” which were on the high and low extreme ends of water absorption. 1” x 2” specimens with thickness of 1 mm, 2 mm, and 4 mm were cut from the core of the material and dried in the oven at 100^{o}C to constant weight, then immersed in distilled water at room temperature. Specimens were weighed periodically to test weight gain over time. The test was conducted to the point that equilibrium was reached and constant weight recorded for all three specimens. Moisture content was calculated based on total weight of specimen (wood and plastic).

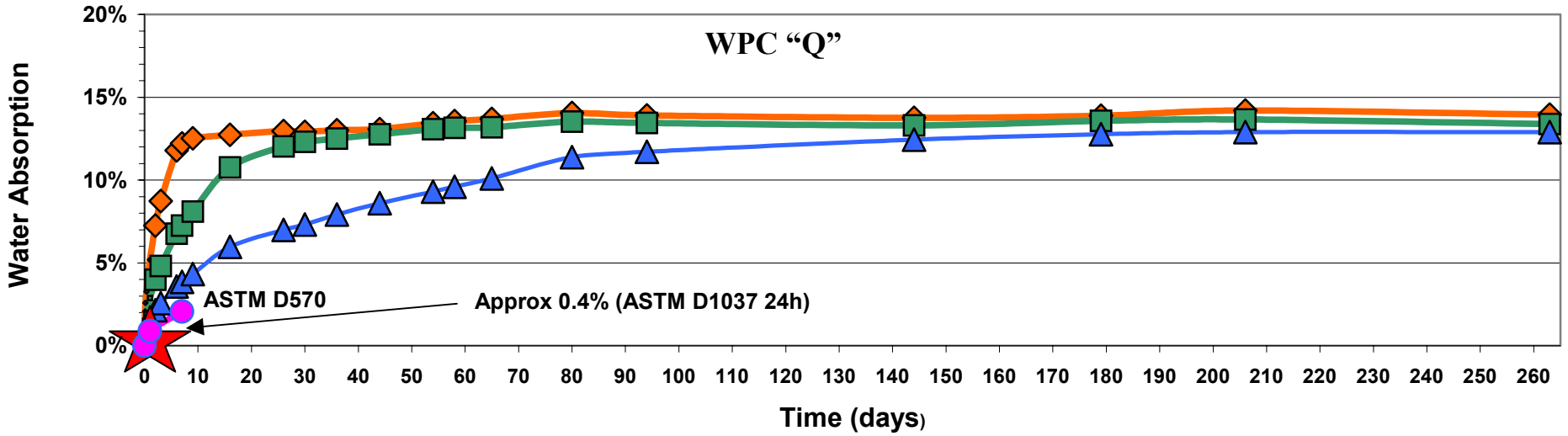
Furthermore, 14 randomly selected products available on the North American market and 7 experimental products made by the laboratory were tested for water absorption in equilibrium using 1 mm thick specimens.

Specific properties of surface extruded wood plastic composites were taken under consideration as well. Relative polyethylene content was tested on approximately 0.2 mm thick wafers cut from the surface and core of the samples. Heat of fusion values (DSC), which are proportional to polyethylene resin content for core and face samples were shown on the bar graph. To identify the effect of polyethylene enhancement of WPC surface, water absorption for matching core and surface specimens was evaluated.

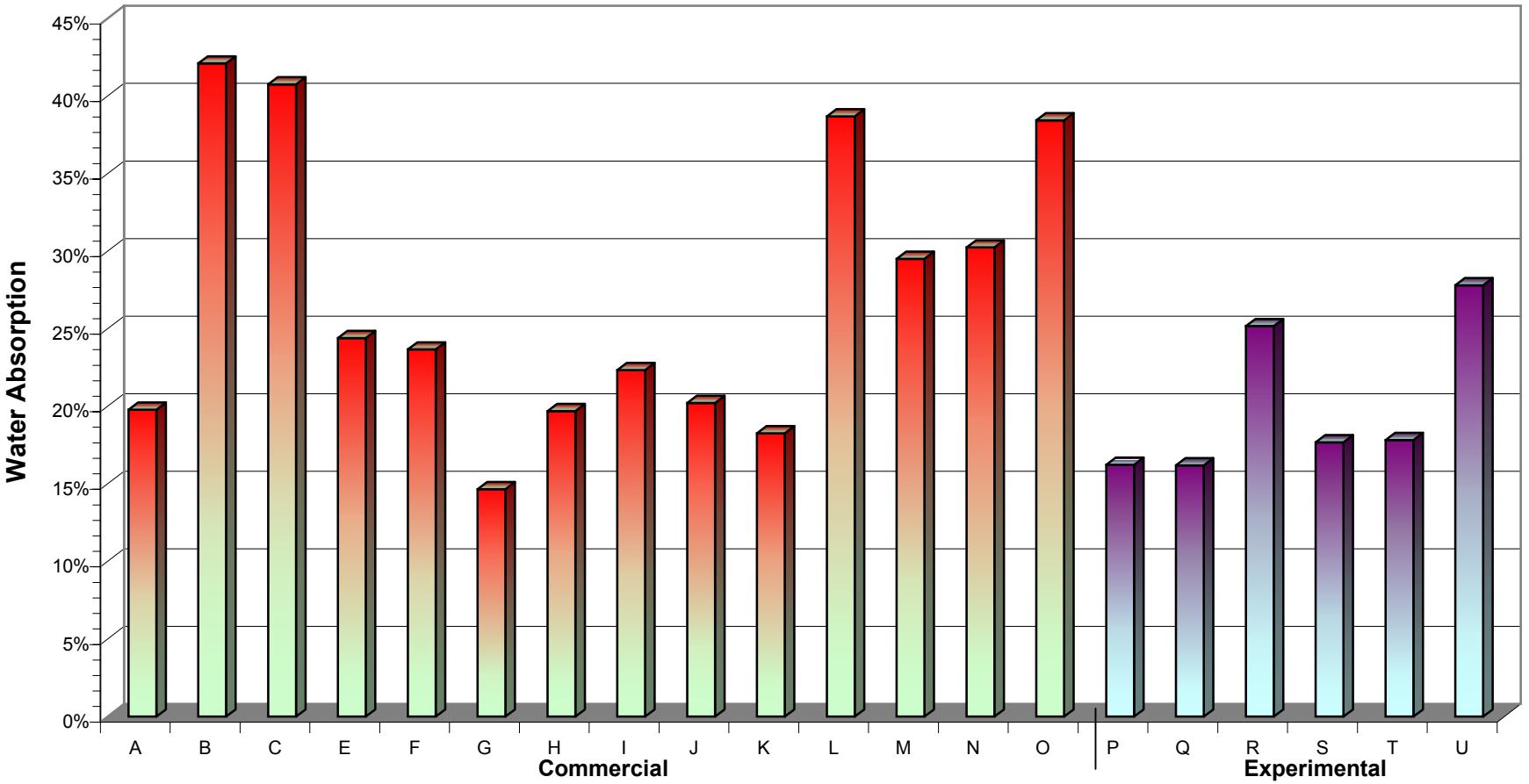
WATER ABSORPTION IN WOOD PLASTIC COMPOSITES



- WPC SAMPLES REACHED THE SAME EQUILIBRIUM OF WATER ABSORPTION REGARDLESS OF THE THICKNESS OF THE SPECIMEN TESTED
- EQUILIBRIUM IS REACHED SIGNIFICANTLY FASTER FOR SPECIMENS 1mm (40 mils) IN THICKNESS
- TESTING WATER ABSORPTION OF WPC USING STANDARDS DEVELOPED FOR PLASTIC OR WOOD IS DIFFICULT
- THIN SPECIMENS RESEMBLE SURFACE LAYER OF WPC EXPOSED TO LIQUID WATER IN EXTERIOR CONDITIONS, FOR EXAMPLE MELTING SNOW, LONG RAINFALL ETC.



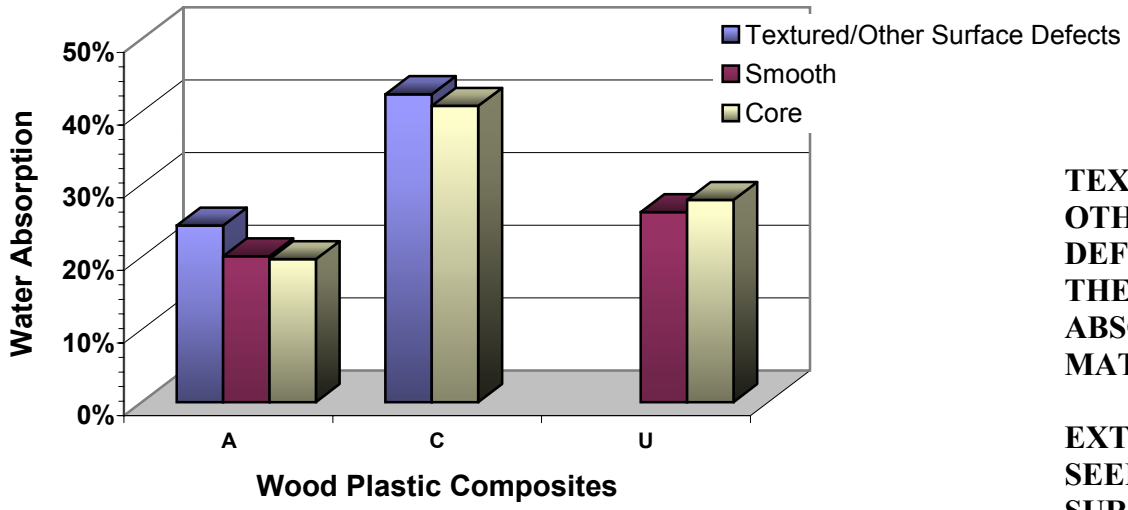
WATER ABSORPTION IN EQUILIBRIUM FOR A VARIETY OF COMMERCIAL AND EXPERIMENTAL WPC



- **TESTING WAS CARRIED ON FOR 3 WEEKS TO SEVERAL MONTHS DEPENDING ON MATERIAL PROPERTIES**
- **WATER ABSORPTION IN EQUILIBRIUM FOR SAMPLES TESTED IS IN THE RANGE OF 15% TO 42% AS CALCULATED BASED ON DRY WEIGHT OF MATERIAL**
- **IT IS REASONABLE TO EXPECT THAT MOISTURE CONTENT IN THE WOOD PORTION OF THE COMPOSITE MAY EXCEED THE 20-25% REQUIRED FOR INITIATION OF BIOLOGICAL ACTIVITY FOR ALL TESTED SAMPLES**

SURFACE PROPERTIES OF WOOD PLASTIC COMPOSITES

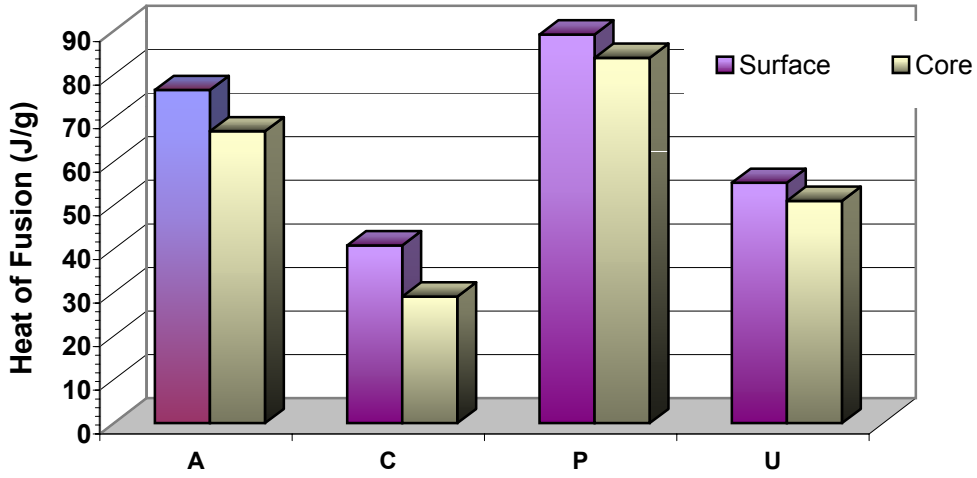
WATER ABSORPTION IN EQUILIBRIUM OF SURFACE AND CORE OF EXTRUDED WPC



TEXTURING OR OTHER SURFACE DEFECTS INCREASE THE WATER ABSORPTION OF MATERIAL

EXTRUDED WPC SEEMS TO HAVE A SURFACE LAYER ENHANCED IN RESIN. THIS ENHANCEMENT SEEMS TO HAVE A NEGLIGIBLE EFFECT ON WATER ABSORPTION

DSC ANALYSIS OF SURFACE AND CORE MATERIAL OF A VARIETY OF WPC



ACCELERATED WEATHERING

Materials like plastic or wood, exposed to weather elements will undergo degradation. Weathering should have a similar effect on wood plastic composites.

The method of assessment of the rate of degradation is frequently left to the researchers discretion. Changes in colour, physical properties, or surface microstructure may be used as a criteria. To compare different methods of assessment of weathering of wood plastic composites, different materials were tested for colour change, microstructure and water absorption.

TESTING PROCEDURE

Specimens of three selected wood plastic composites (two commercial and one experimental) were exposed to weathering using a QUV accelerated weathering chamber.

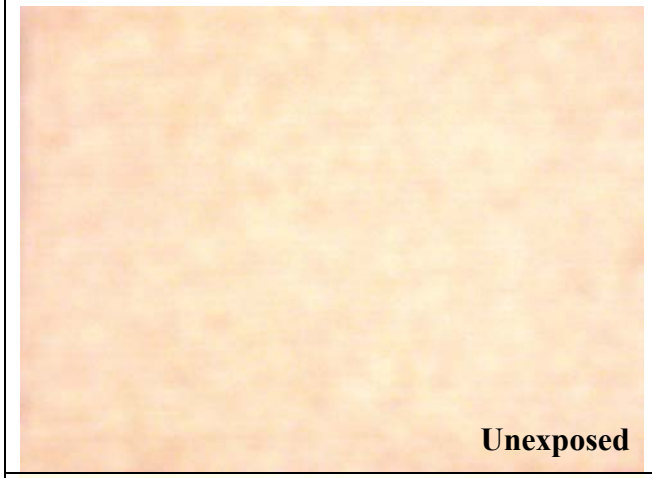
Exposure was done with 8 hours UV cycle at 60^{o}C, 4 hours condensation at 50^{o}C, 4 hour water immersion, and 4 hours drying at RT followed by every 16 hours light/condensation exposure during working weekdays.

After approximately 2000h hours total exposure specimens were evaluated for:

- surface colour change (using Gretag MacBeth Coloreye XTH)
- surface integrity (using Leica MZ-12 stereoscopic microscope)
- water absorption

WEATHERING OF WOOD PLASTIC COMPOSITES

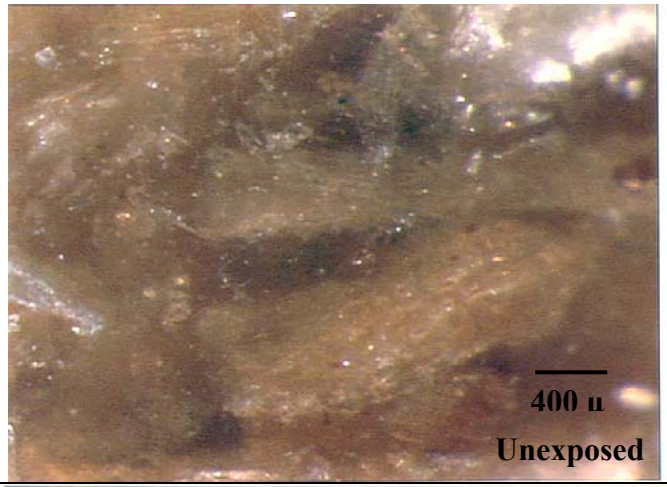
WPC A **SURFACE**



Unexposed

QUV exposed
Colour change ΔE = 14.4

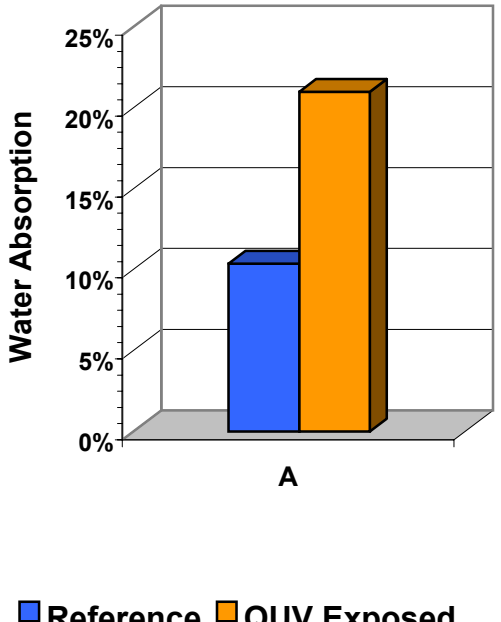
SURFACE MICROPHOTOGRAPHS



Unexposed

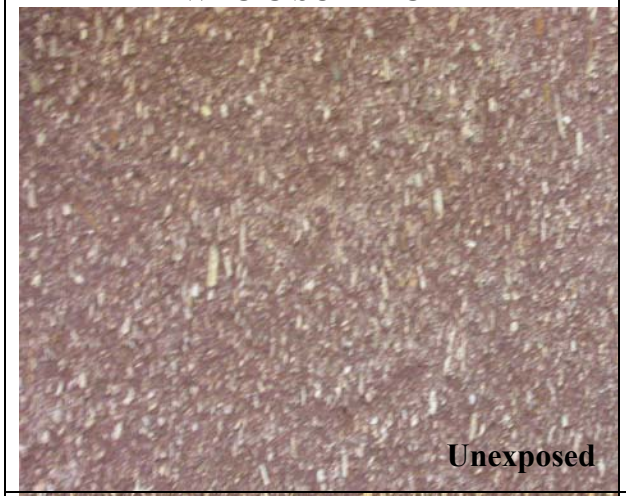
QUV exposed

SURFACE LAYER (1mm) WATER ABSORPTION (2 hours)

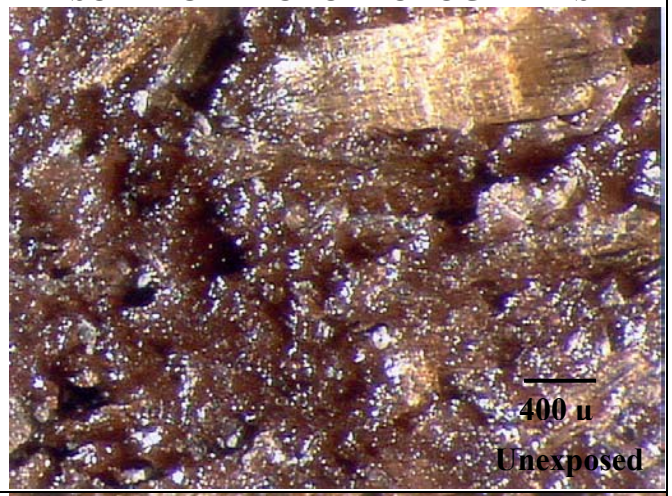


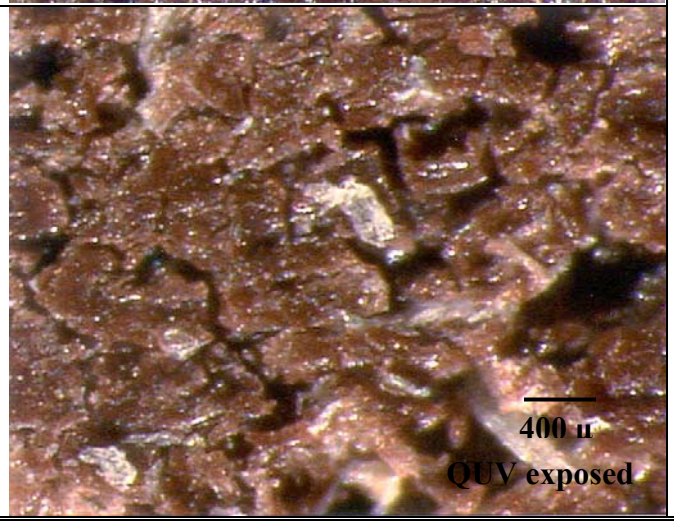
WEATHERING OF WOOD PLASTIC COMPOSITES

WPC C SURFACE

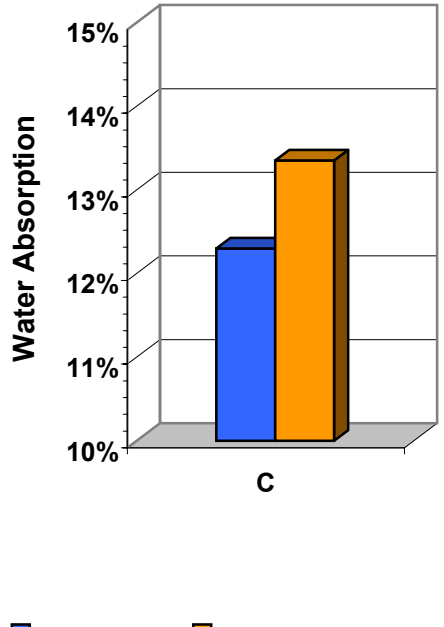


SURFACE MICROPHOTOGRAPHS





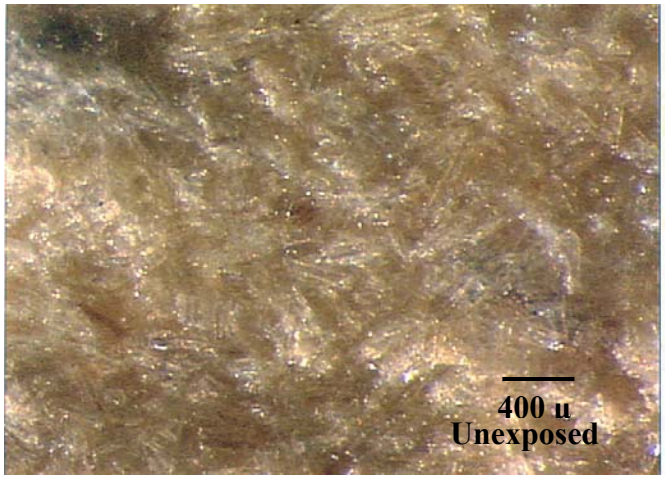
SURFACE LAYER (1mm) WATER ABSORPTION (0.5 hours)

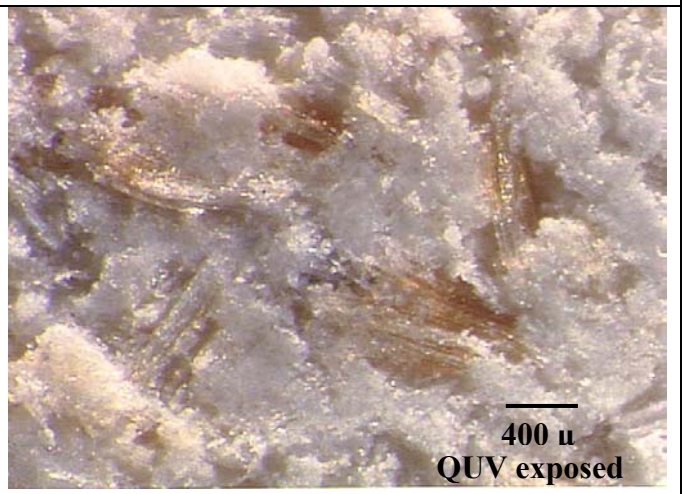


WEATHERING OF WOOD PLASTIC COMPOSITES

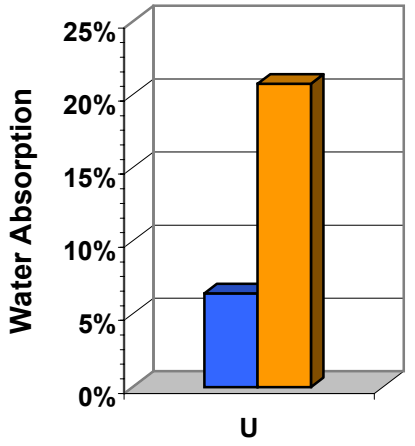
WPC U SURFACE

SURFACE MICROPHOTOGRAPHS





SURFACE LAYER (1mm) WATER ABSORPTION (2 hours)



FUNGAL RESISTANCE

There is some controversy with respect to fungal resistance of wood plastic composites. Many samples of wood plastic composites showed limited resistance to fungal growth. This is confirmed by PEC experience and a variety of publications.

Demonstration tests were conducted using different testing procedures to confirm the limited resistance of WPC to fungi and the effect of fungal activity on material structure.

TESTING PROCEDURE

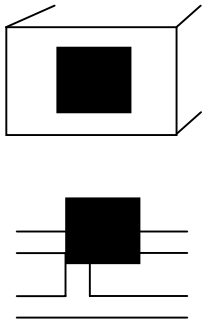
Two wood plastic composite materials were selected for fungal resistance tests:

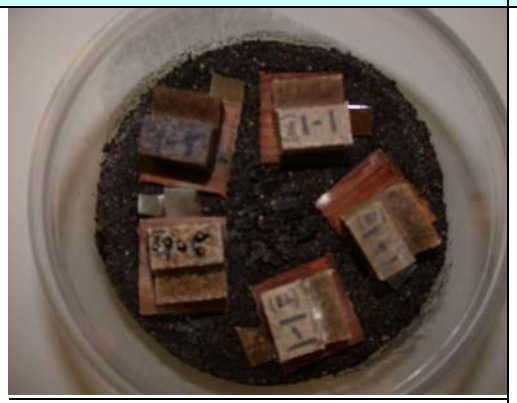
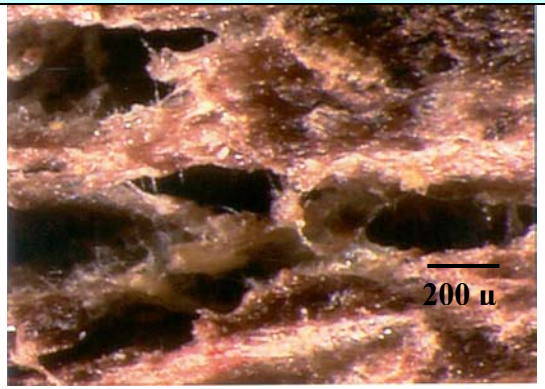
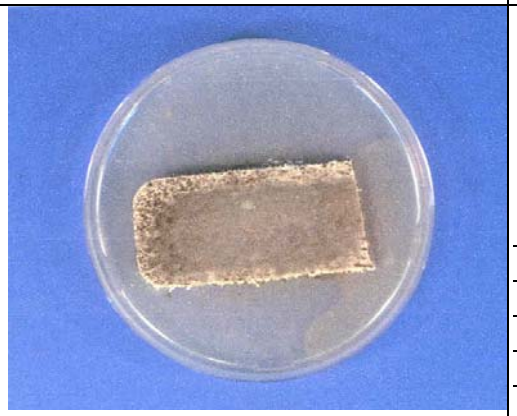
- "Soil block test" – ASTM – D 1413, AWPA E10
- Determining resistance of synthetic polymeric materials to fungi – ASTM G-21.

Tests were conducted by U.S. Borax and Clariant laboratories.

After soil block test, specimens were additionally examined using a Leica MZ-12 high power stereoscopic microscope.

FUNGAL RESISTANCE

<table>
<tr><th>Test Method</th><th>Sample Size</th><th>Fungi</th><th>Test Setup</th><th>Examples of Results</th></tr>
<tr>
<td>ASTM D 1413</td>
<td>¾” cube
  </td>
<td><u>SOFTWOOD</u>
Letinus lepideus
Gleophyllum trabeum
Poria placenta

<u>HARDWOOD</u>
Letinus lepideus
Gleophyllum trabeum
Poria placenta
Coriolus versicolor</td>
<td> 
Courtesv of U.S. Borax</td>
<td> 
Weight loss 22% based on wood content</td>
</tr>
<tr>
<td>ASTM G 21</td>
<td>2” in size square or round</td>
<td>Aspergillus niger
Penicillium-pinophilum
Chaetomium-globosum
Gliocladium virens
Aureobasidium-pullulans</td>
<td> 
Courtesy of Clariant Corporation</td>
<td>4 – Heavy Growth
<table><tr><th></th><th></th><th>Rating:</th></tr><tr><td>No growth</td><td></td><td>0</td></tr><tr><td>Traces of growth</td><td>(less than 10%)</td><td>1</td></tr><tr><td>Light growth</td><td>(10 – 30%)</td><td>2</td></tr><tr><td>Medium growth</td><td>(30-60%)</td><td>3</td></tr><tr><td>Heavy growth</td><td>(>60%)</td><td>4</td></tr></table></td>
</tr>
</table>

CONCLUSIONS

1. Wood Plastic Composites, because of their structure and properties, are difficult to test using standard methods developed for wood, wood composites, or plastics. The results of such testing can often be confusing.

2. In equilibrium, tested commercial and experimental WPC absorb a significant amount of water consisting of 15% - 44% of their total initial weight. This is not frequently recognized due to testing methods that do not allow equilibrium to be reached.

3. Weathering of WPC is not always associated with product discolouration, changes in material properties not may be detected without additional testing, as for example:
   - microscopic examination
   - water absorption test for surface layer of material

4. It was found that weathering significantly increases the water absorption of the surface layer of wood plastic composites and additionally exposes wood.

5. Many tests and publications indicate that wood plastic composite can support biological activity which may lead to mould growth and decay in both field and laboratory samples.
   Relatively high water absorption of these materials is likely an important factor promoting this process, particularly after surface weathering which accelerates water absorption.