



## MICROCT EVALUATION OF VOIDS IN DECAYED WOOD PLASTIC COMPOSITES

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# OUTLINE

### Introduction

- Polymer Engineering Company
- Wood Plastic Composites (WPC's)
- Background on WPC Research
  - Samples Exposure
  - SEM Examination
- microCT Imaging and Analysis
  - Parameters and samples
  - 14 µm voxel size
  - > 20 µm voxel size
- Conclusions

# POLYMER ENGINEERING COMPANY (PEC)

### Areas of Expertise

- Plastics
- Rubbers
- Polymer blends
- $\rightarrow$  Coatings and paints
- Adhesives and sealants
- Unique polymer applications
- Surface phenomena
- Barrier Materials







## POLYMER ENGINEERING COMPANY & WPC'S







# AN INTRODUCTION TO WPC'S

- Wood plastic composites (WPC's) consist of wood particles dispersed in a thermoplastic polymer matrix
- Used in a variety of applications, often as outdoor building materials such as decking, railings, fencing, siding, and trim
- Initially expected to be durable, but found to be susceptible to decay



# WPC MICROSTRUCTURE



 This microstructure is responsible for water migration and penetration of decay fungi

#### WPC's are porous by nature

- Wood itself contains micro and nano scale voids
- Voids can also be created during manufacturing



# EXPOSURE OF SAMPLES FOR EVALUATION

Laboratory

- Soil block culture testing according to AWPA E10
- Field

8 year exposure at Sun and Shadow sites in Hilo, HI

#### Soil block testing







# SEM EXAMINATION OF WPC'S

- Decay (and voids) can be seen in exposed samples
- Limitations of the method
  - Very localized and time consuming
  - Only 2-dimensional assessment is possible





# CT IMAGING AND ANALYSIS

### Equipment & Software

- GE phoenix | x-ray nanotom m
- datos | x 2.2 acquisition and reconstruction software
- VGStudio Max 2.2





#### Scanning Parameters

- 14 µm voxel size
  (90 kV and 200 µA)
- 20 µm voxel size
  (90 kV and 300 µA)

# SAMPLES FOR CT EVALUATION



#### Reference & field samples (14 µm voxel size)



## ← Soil block samples (14 µm voxel size)

Reference & field samples  $\rightarrow$  (20 µm voxel size)



# REFERENCE SAMPLE (14µm voxel size)



## FIELD-EXPOSED SAMPLES (14µm voxel size)

Defect volume [mm<sup>3</sup>]



## LAB-EXPOSED SAMPLES (14µm voxel size)



# COMPARISON OF VOID VOLUME

Voxel Size (µm)	Sample Description	Calculated Void Volume (%)	Detected Void Volume (%)	Detected Volume Range (mm <sup>3</sup> )
14	Reference	17.3	10.2	2.7 x 10⁻ <sup>6</sup> – 18
	No cond., No Fungi	17.7	8.2	2.7 x 10⁻ <sup>6</sup> – 8
	No cond., Brown Rot	23.3	13.3	2.7 x 10 <sup>-6</sup> − 227
	No cond., White Rot	21.9	11.6	2.7 x 10⁻ <sup>6</sup> – 99
	Conditioned, No Fungi	19.1	12.5	2.7 x 10 <sup>-6</sup> − 138
	Conditioned, Brown Rot	24.4	12.5	2.7 x 10 <sup>-6</sup> − 185
	Conditioned, White Rot	25.9	13.5	2.7 x 10 <sup>-6</sup> − 285
	Shadow (8 year Hilo)	34.0	37.7	2.7 x 10⁻ <sup>6</sup> – 939
	Sun (8 year Hilo)	29.6	34.3	2.7 x 10 <sup>-6</sup> − 732

# **DISTRIBUTION OF DETECTED VOIDS**



Void Volume Range (mm<sup>3</sup>)

#### Reference

MDV = Min. Detected Volume =  $2.7 \times 10^{-6} \text{ mm}^3$ 

# **DISTRIBUTION OF DETECTED VOIDS**



MDV = Min. Detected Volume =  $2.7 \times 10^{-6} \text{ mm}^3$ 

### REFERENCE & FIELD SAMPLES (20µm voxel size)

#### Defect volume [mm<sup>3</sup>]

0.200 0.180 0.160 0.140 0.120 0.100 0.080 0.060 0.040 0.020 0.000



Defect volume [mm<sup>3</sup>]

50.00 45.00 40.00 35.00 30.00 25.00 20.00 15.00 10.00 5.00 0.00



Shadow

### **COMPARISON OF VOID VOLUME** at 14 and 20 µm voxel size

Voxel Size (µm)	Sample Description	Calculated Void Volume (%)	Detected Void Volume (%)	Minimum Detected Volume (mm <sup>3</sup> )
14	Reference	17.3	10.2	2.7 x 10⁻ <sup>6</sup>
	Shadow (8 year Hilo)	34.0	37.7	2.7 x 10⁻ <sup>6</sup>
20	Reference	17.3*	5.4	8.0 x 10 <sup>-6</sup>
	Shadow (8 year Hilo)	34.0*	31.3	8.0 x 10 <sup>-6</sup>

\*Assumed to be the same as reference and shadow samples evaluated in same vicinity

# CONCLUSIONS

- X-ray microCT is an effective method for imaging the internal structure of WPC's and detection of voids
- Voids are inherently present in WPC and become interconnected in the presence of moisture and/or fungal activity
  - Initial fungal attack created relatively small voids whereas further digestion of wood resulted in a large void network spanning the size of the tested samples

The comparability of calculated and detected void volume depends on the size of voids present in the material and the achievable resolution which is governed by sample size

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# QUESTIONS?

## CALCULATED VOID VOLUME EQUATIONS

$$\left(\frac{V_V}{V_{WPC}}\right) x 100\% = \left(\frac{V_{WPC}}{V_{WPC}} - \frac{V_W}{V_{WPC}} - \frac{V_P}{V_{WPC}}\right) x 100\%$$

$$V_V = \frac{M_{WPC}}{D_{WPC}} - \frac{M_W}{D_W} - \frac{M_P}{D_P}$$

$$V_V = \frac{M_{WPC}}{D_{WPC}} - \frac{M_{WPC} x C_W}{D_W} - \frac{M_{WPC} x (1 - C_W)}{D_P}$$

 $C_W = C_R - C_R x W_{WL}$