MULTI-SCALE INVESTIGATION OF ADHESIVE BOND DURABILITY

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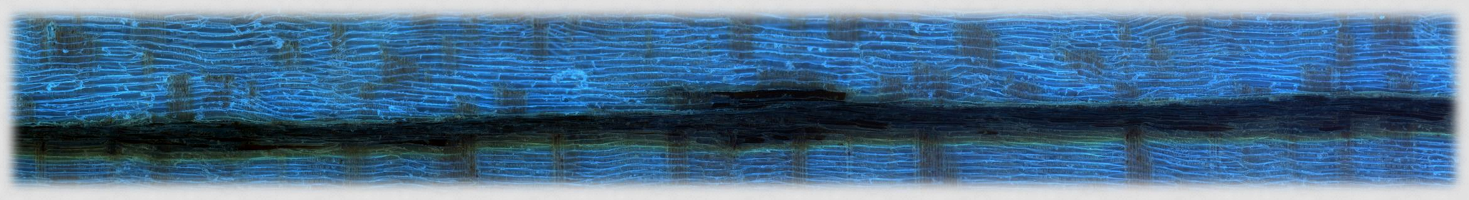


Figure 1. Fluorescence Microscope Image of Douglas-fir Bonded with High Molecular Weight I-PF

Introduction

Moisture durability is essential for wood composite products, especially those used in building construction, where materials are prone to weathering. Since there are many precise steps that go into measuring adhesive penetration into the wood cell wall, there remain unknowns. This project will use various techniques, such as mechanical bondline tests with Digital Image Correlation (DIC), along with micro- and nano- X-Ray Computed Tomography (XCT) scans and Digital Volume Correlation (DVC) to determine if molecular penetration of adhesive into the cell wall improves moisture resistance.

Objectives

- Determine if adhesive penetration into the cell wall has a positive influence on bond durability
- Directly correlate both micro- and nano-XCT observations with mechanical bond performance
- Quantitatively measure effects of moisture on the bondline

Methods

- Formulate high and low molecular weight phenol-formaldehyde (PF) and pre-polymeric diphenylmethane diisocyanate (pMDI) with iodine tag and bond the Douglas-fir test specimens with varying earlywood-latewood bonding surfaces
- SEM/EDS analysis of iodine tag in adhesives (Table 1 and Figure 2)

Figure 3. Lap shear test with DIC

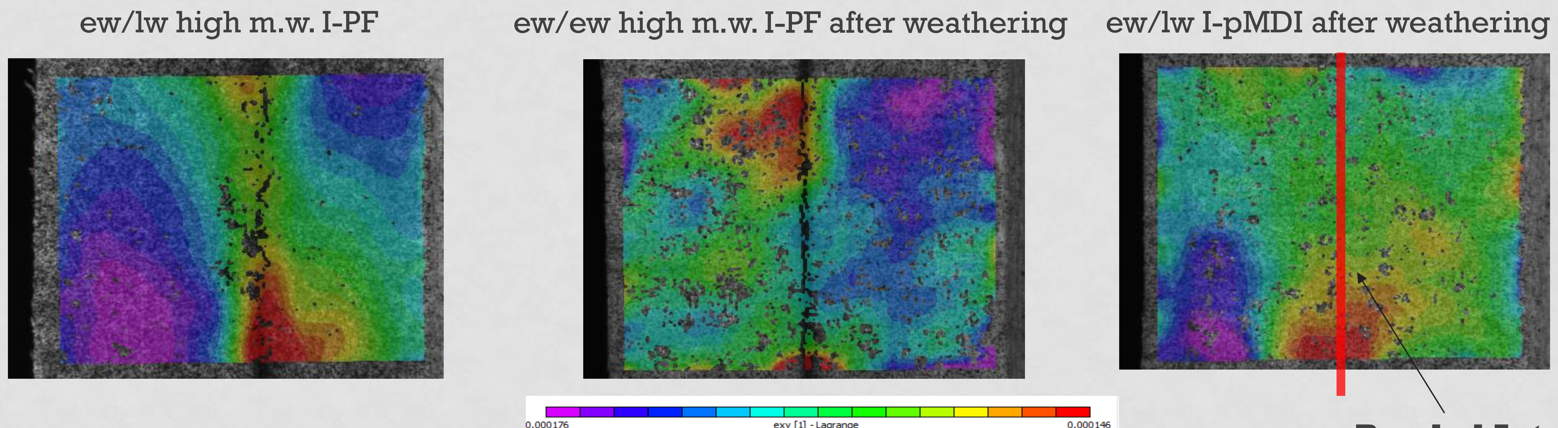
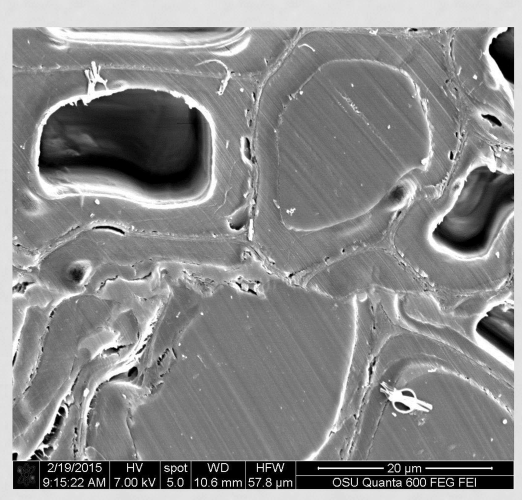


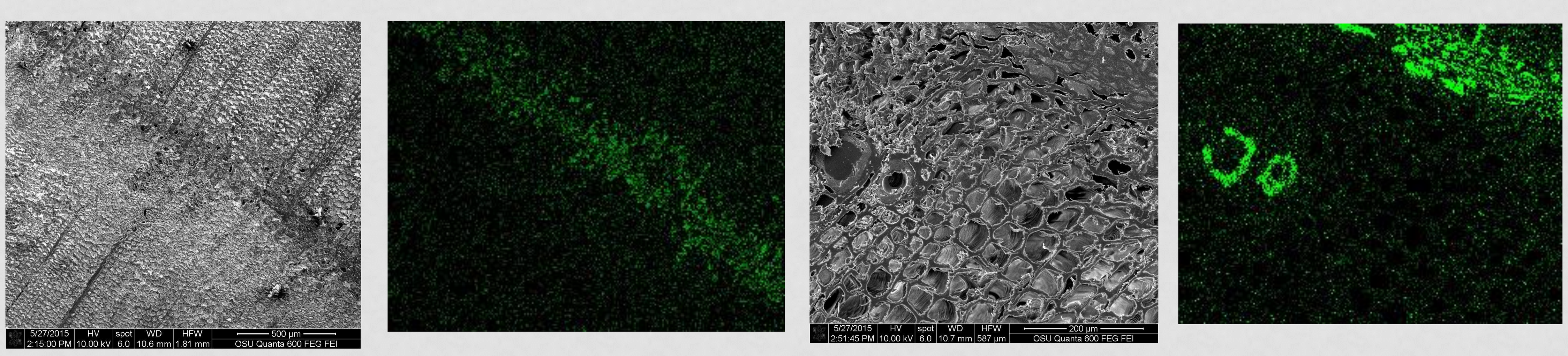
Figure 4. Shear strain data from DIC on three specimens, all with equal applied force

Specimen Type	Average Net Intensity Iodine	Variation (error/intensity)
DF:control	1.40	22.60
DF:I-pMDI-A	13.36	8.35
DF:I-pMDI-B	2.14	146.42
DF:low I-PF	21.42	0.28
DF:high I-PF	27.99	0.11
Pure I-pMDI	38.41	0.09
Outside of Bondline	1.82	55.62

Table 1. SEM/EDS Analysis Summary of Results, 52 total scans



SEM of Cells Filled with I-PMDI Adhesive



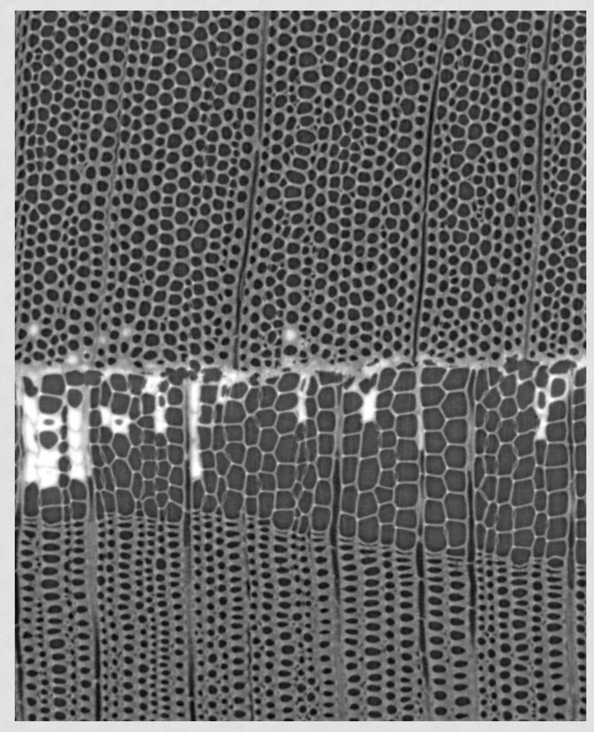
SEM: Douglas-fir Latewood/Latewood Sample Bonded with I-pMDI

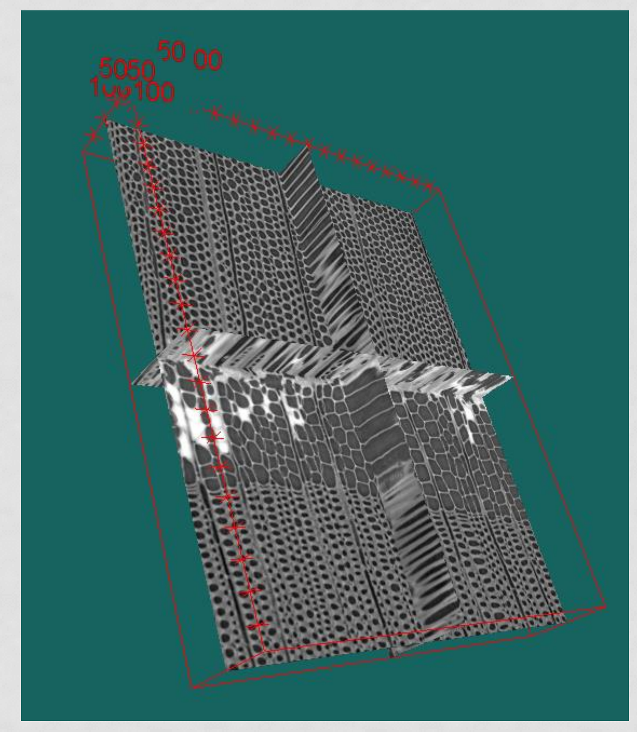
EDS Map of Iodine for I-pMDI Sample

SEM: Douglas-fir Earlywood/Earlywood Sample Bonded with I-PF

EDS Map of Iodine for I-PF Sample

Figure 2. SEM/EDS of specimens bonded with I-pMDI and I-PF





Figures 6 and 7. XCT scan of Douglas-fir earlywood/latewood bonded with high molecular weight iodinated-PF

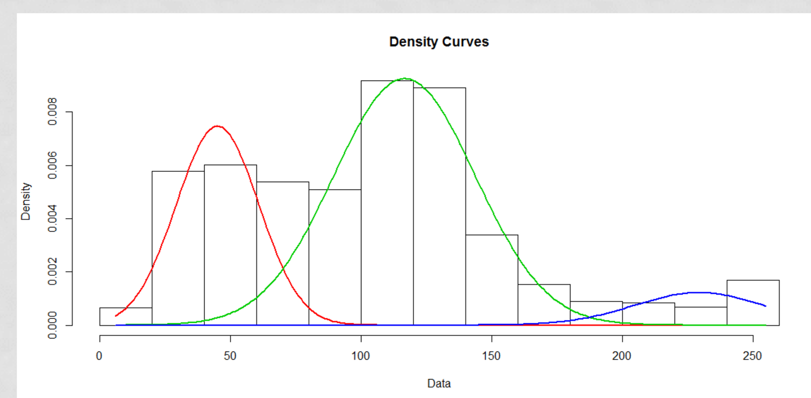
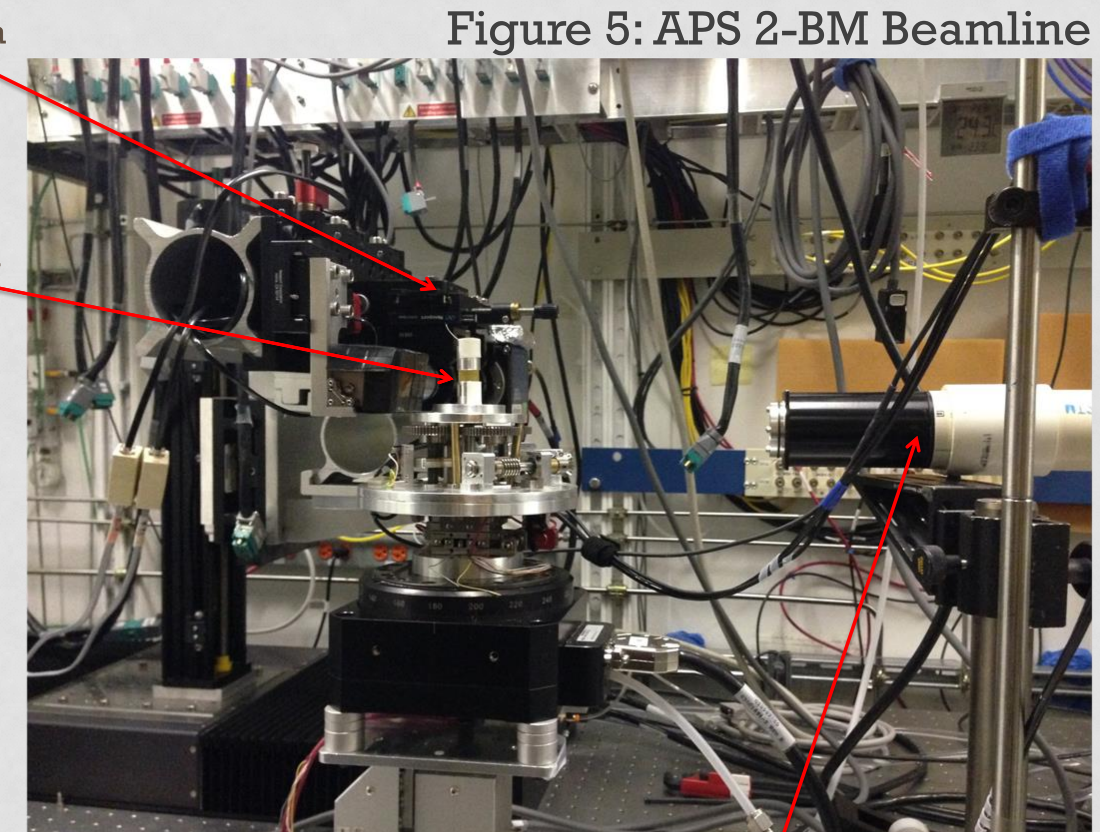


Figure 8. Segmenting method in R Studio to separate void space (far left peak), cell wall (middle peak), and adhesive (far right peak)

Work in Progress

- One half of specimens weathered (9 hours of vacuum/pressure soak in warm water, 15 hours of drying at 75 °C)
- Test to failure in lap-shear with DIC (Figures 3 and 4)
- Cut XCT specimens from previously tested specimens
- Scan XCT specimens (2mm x 2mm x 10mm) at Advanced Photon Source on 2-BM Beamline
- Image Reconstruction (resolution: 1.3 µm/ side of voxel) and phase separation (Figure 6-8)
- Identify cell wall penetration from micro-XCT images
- Cut nano specimens (0.05 x 0.05 mm) on ultra microtome in area of interest

Figure 5: APS 2-BM Beamline



Future Work

- Nano-XCT scanning at APS on 32-ID Beamline
- DVC on XCT specimens subjected to *in situ* relative humidity cycling
- Compare dry results with moisture-induced results

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