# Successful Widespread Adoption of Mass Timber Requires Comprehensive Adhesive Qualification

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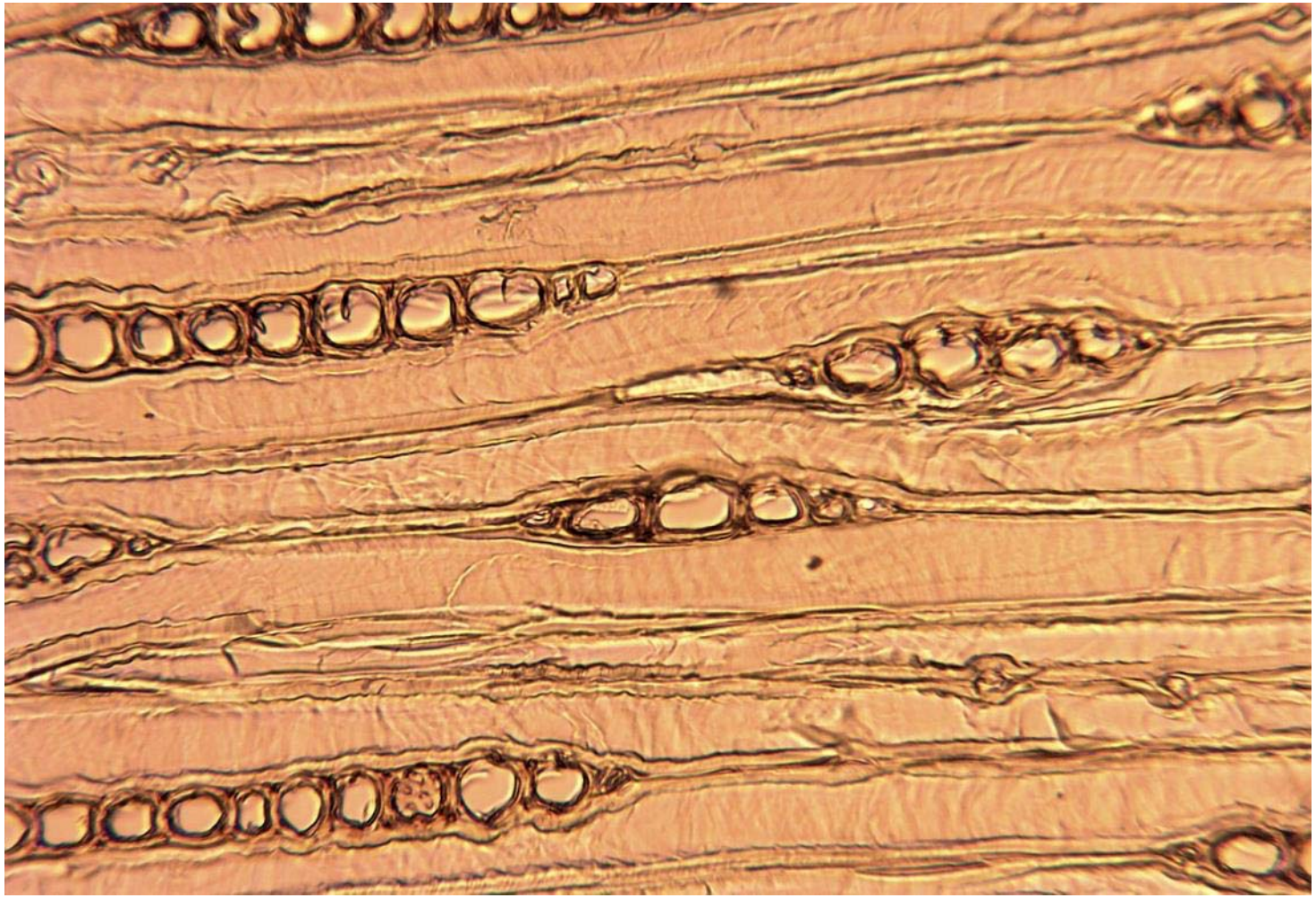
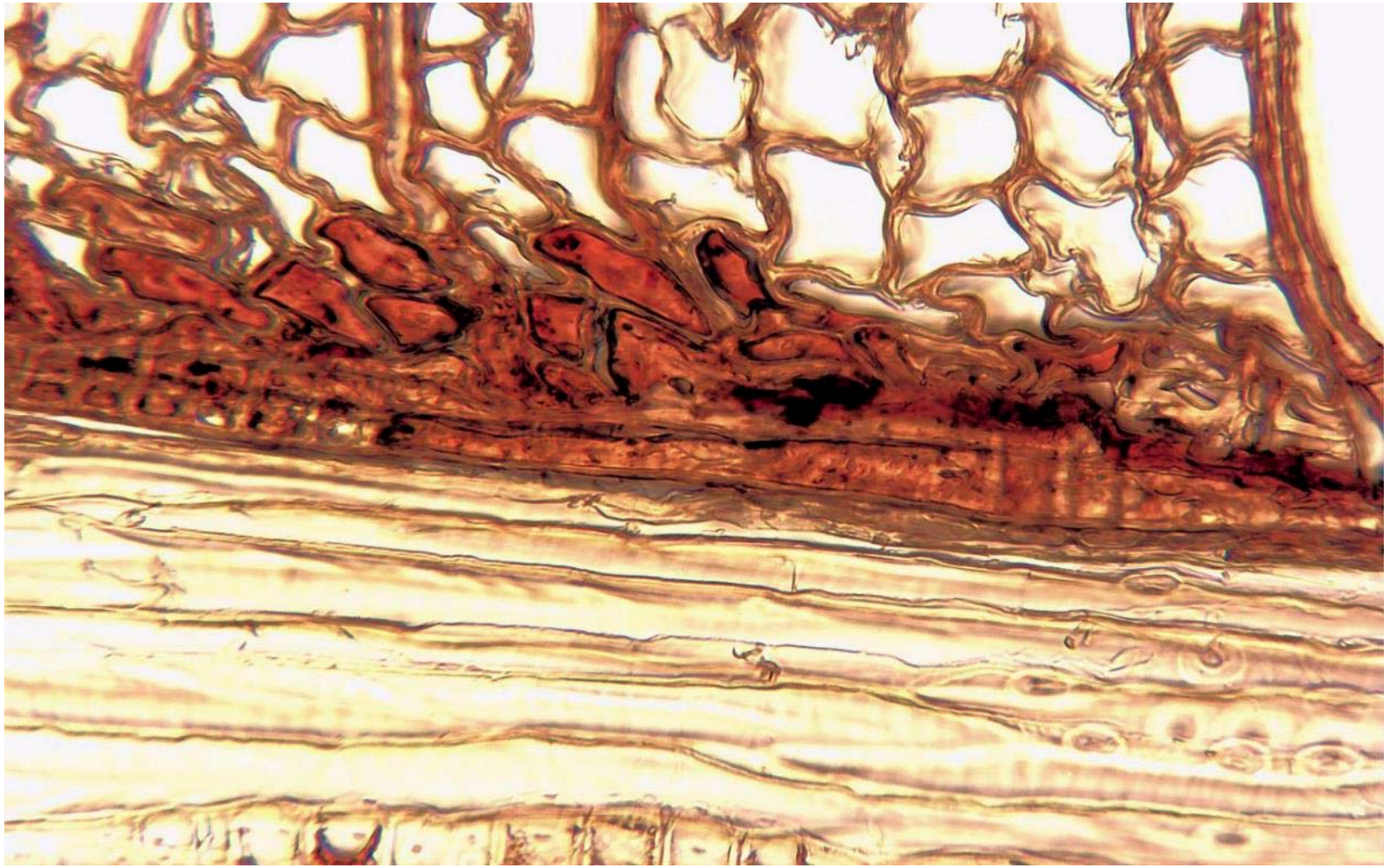
# Redirect your View from 18 Story+ 500,000 ft$^2$ to the Microscopic, BioNanoComposite Fiber

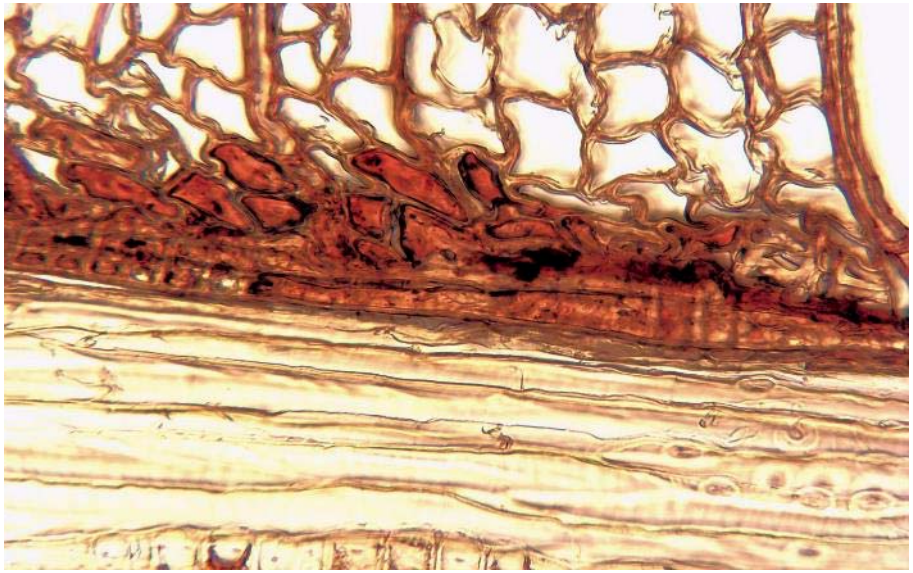


# Mass Timber: Bonding Lumber to Produce Mass Timber a Micro-Level process



# Understanding this Micro-Level process the Key to Evaluation Methodology

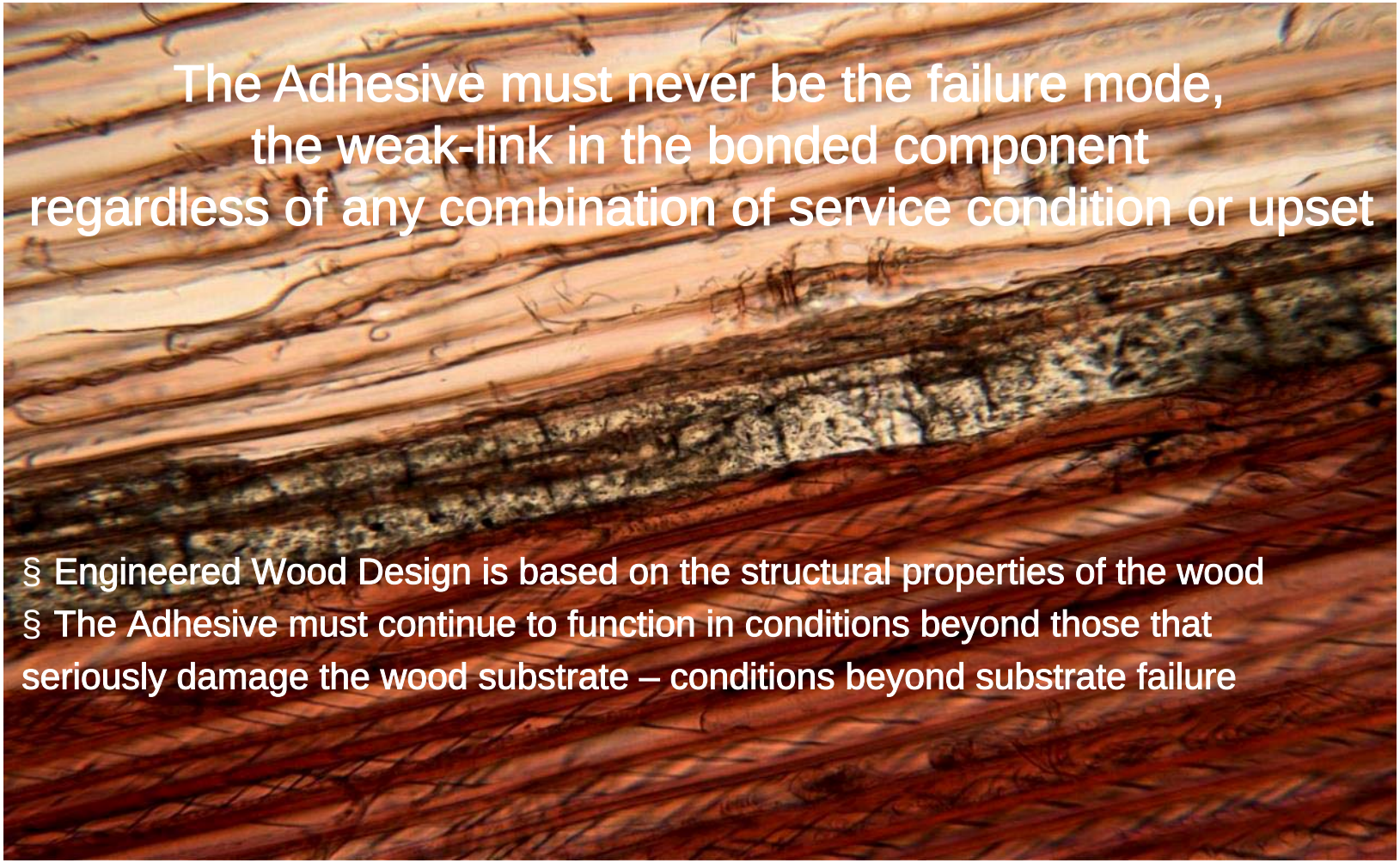
**Objective:** Understanding the microscopic engagement of the wood and adhesive clarifies the purpose and methods of adhesive evaluation



**Outcomes:**

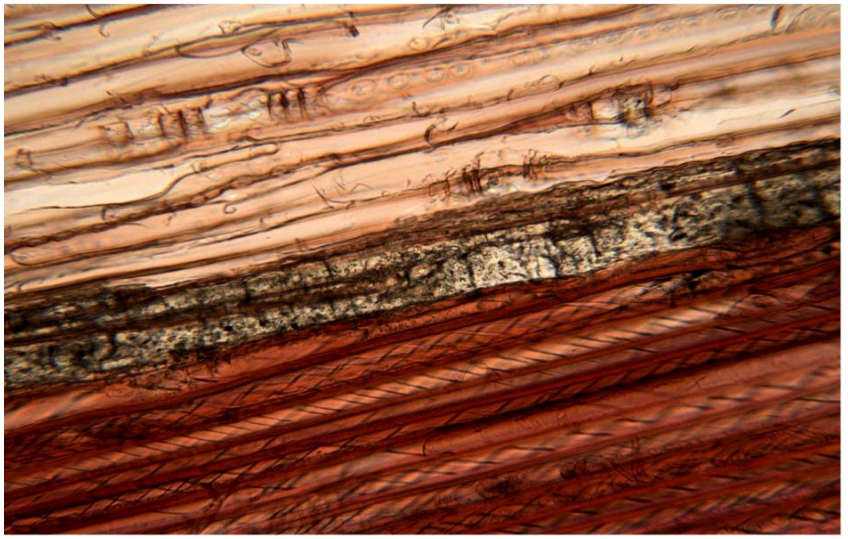
1. Clarify areas of concern and improve understanding of the structural adhesive evaluation
   - The necessary attributes of a Mass Timber adhesive
   - Methodologies used for evaluation
   - Translation of results to ensure product performance
2. Outline Mass Timber adhesive testing requirements
3. Discuss the adhesive component's contribution to sustainability

# The Structural Adhesive Premise



# Structural Adhesive Attributes Requiring Evaluation

- Strength – Transfer stresses between component elements
- Durability – Withstand repeated cycles of soaking and drying and resist the hydroscopic forces of swelling and shrinking wood
- Creep Resistance – Maintain stress transfer over time without movement
- High Temperature Resistance – Bonding maintained at fire scenario temperatures
- Organic Resistance – does not support mold or fungus growth, insect attack



## Adhesive performance is product blind

# Structural Adhesive Evaluation Design Considerations

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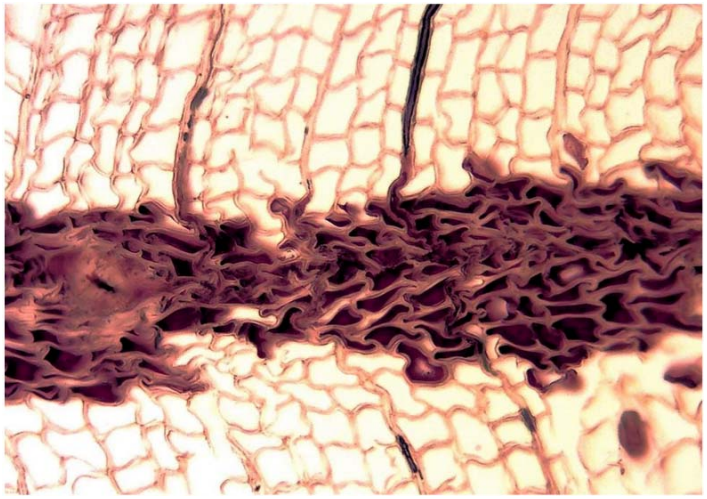
## Evaluation uses Bonded Wood Specimens

- § Wood Adhesive Interactions
- § Physical entanglement of cell walls and adhesive
- § Provide the process conditions for adhesive cure



Evaluation Design must minimize the variability of the Wood Substrate by:

1. Using small-scale clear wood substrates and controlling for
   - Density – Predicated upon the National Design Standard values
   - Defect Free, straight grain slope, specified growth ring orientation
   - Moisture content conditioning to equilibrium before testing
   - Post Exposure Conditioning to original weight/specified target
2. Ensuring Adequate Numbers of Test Specimens to reduce COV effects

# Structural Adhesive Testing
# Strength in Shear – Various Exposures


Provides Strength and Wood Failure % Data for several Exposure conditions:

360 Blocks are tested

- Dry – 95% Clear Species Value, 85% Wood failure
- Submerged Vacuum-Pressure Cycle– Wood fully saturated
  - Tested wet – 60% Clear Species Value, 85% Wood Failure
- Soak, -34°C Freeze – Wood Fully Saturated before freeze, Test Frozen
  - 90% Clear Solid Control Value, 75% Wood Failure
- Salt Water Soak, -57°C Freeze, Re-Soak
  - 90% Clear Solid Control Value, 75% Wood Failure
- 9 Cycles of Boil, Dry, Freeze - Test wet after final Boil cycle
  - 35% Clear Species Value, retain 85% Wood Failure
- Elevated Temperature Exposure – test at 220°C bondline temp
  - 95% solid wood control's ambient-exposure ratio
  - 10 minute minimum exposure, 30% strength retention of exposed control

# Structural Adhesive Testing
# Resistance to Delamination

## Withstanding swelling and shrinking forces of the wood substrate

Accelerated Artificial Aging

- Forces generated can exceed 1000psi
- Delamination must not exceed 1%
- 65 individual 6-ply blocks 5” wide x 3” thick
- One Impregnation/Drying cycle = 5 Years exterior exposure

1. Two alternate Submerged Vacuum/75psi Pressure cycles
   - Specimens completely saturated
2. 150°F Drying Cycle for 21-22 hours to return weight within 115% original
   - Outer Faces of Blocks are completely dry, while interior is damp
3. Two hours saturated steam exposure then submerged 75psi Pressure
4. Repeat 150°F – 21-22 hour Drying cycle
5. Repeat the two submerged Vacuum/75psi water impregnation cycles
6. Final 150°F Drying to 115% of original weight – graded immediately

# Structural Adhesive Testing
# Resistance to Creep over time

## Does the Adhesive transfer loads over time without slippage?

- Constant stress of 320psi with moisture and temperature exposures
  - 7 days @ 68°F and 95% rH
  - 7 days @ 158°F with Ambient rH
  - 2 hours @ 356°F with Ambient rH
  - 28 days @ 122°F with water impregnated specimen

- While the standards allow minimal movement, the reality is:
  - Either a successful test with no creep
  - Or complete specimen failure
  - The multi-joint, symmetrical specimen configuration is sensitive to any imbalance once creep initiates

# Structural Adhesive Testing
# Fire Exposure – Resistance to Disassociation

- Mass Timber must exhibit the same response to fire as Solid Wood
  - Mass Timber Frame should withstand Full Fire Exposure without suppression
  - Fire should proceed to burnout without structural collapse or failure
- The Adhesive cannot fail to bond regardless of exposure temperature
- How Then Do We Test?
  - Small Scale – Medium Scale – Full Size?
  - Fire Exposure Temps – Parametric Comparisons – Time/Temp Curve?
- Four Available Testing methodologies
  - Bench and Full scale tests were added to the CLT standard
    - Bench test also added to the US Glulam standard
  - Several proposals for medium scale tests
- Testing must target the adhesive's ability to withstand disassociation
  Not the Product performance symptom termed delamination

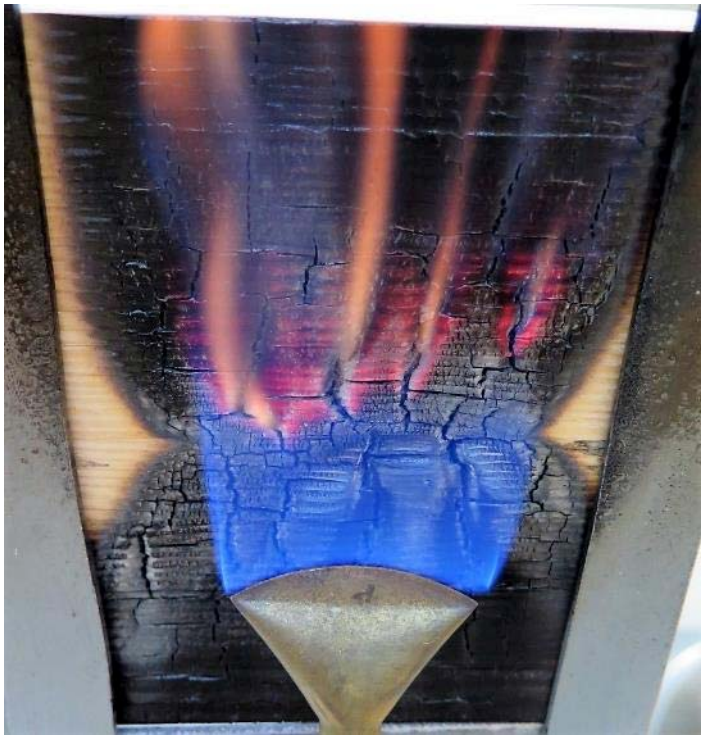
# Testing Resistance to Disassociation Medium Scale

- Number of Constructions and Test Exposures
  - Lamination Thickness
  - Specimen Size
  - Parametric or Standard Time Temperature Curves
  - Loaded or Unloaded specimen
- Good Exposure Severity to Bondline possible
  - If thin (20mm or less) lamella are specified
  - Standard Time/Temperature curve employed
    - The use of the NFPA/NIST 1-4 parameters reduces bondline exposure temperatures
- Evaluation Criteria uses embedded TC
  - Significant TC Temperature rise
  - Triggered by significant delamination
  - Attributed to Adhesive Disassociation

# Testing Resistance to Disassociation
# Large Scale Southwest Research Institute

- Demonstration Adhesive Comparison
  - Size: 8’ x 14’ Horizontal Exposure
  - Temperature: NIST 1-4 Parametric Exposure
  - Duration: 4 Hours
- Lowest Bondline Temperature Exposure
  - 240 - 260°C first bondline
  - 115 - 120°C second bondline
- Evaluation Criteria
  - Detection of a second Flashover
  - Triggered by significant delamination
  - Caused by Adhesive Disassociation

# Testing Resistance to Disassociation
# Bench Scale CSA O177 A.2 Flame Test



- Right Size, Right Time Method
  - Method in Mass Timber Standards
    - 2006 Canadian Glulam
    - 2018 CLT and US Glulam
- Focused Adhesive Attribute Evaluation
  - Specimen Construction
    - Layered 90° Grain orientation
    - Ensures Cross-Grain Stress
  - Full Fire Exposure Temperatures
    - Concentrated on the Bondline
  - Two Dimensional Data Evaluation
    - Failure along the Char Front Face
    - Failure from the Char Face through the Pyrolysis Zone
- Data Resolution sufficient to discriminate Adhesive Performance

# Testing Resistance to Disassociation

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- Evaluation or Perception ?
  - We have the Evaluation Tool in Place
- Full & Medium Scale Concerns
  - Reduced Bondline Temperatures
  - Evaluation Criteria twice removed
  - Confusion of Product Performance with the necessary Adhesive Attribute
- Bench-Scale Focuses Full Exposure
  - Fire Exposure Temperature
  - Specimen Construction for Maximum Stress
  - Direct Measure of Adhesive Performance.
- A Mass Timber Perception Challenge

- Wood in the way only obscures Adhesive Disassociation Evaluation

# Structural Wood Adhesives for Mass Timber Manufacture

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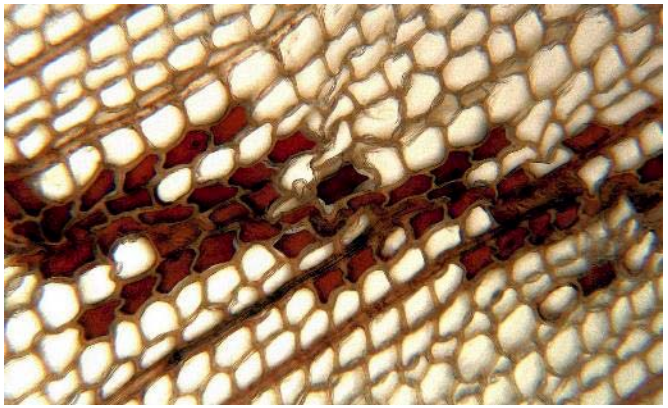
- Currently Four Suitable Mass Timber Adhesive Chemistries
  - Each with a distinct usage and performance trade-offs
  - Adhesive Chemistry Choice influences Production Facility Design

- MF – Melamine Formaldehyde
- 1K PUR – One Component Polyurethane
- EPI – Emulsion Polymer Isocyanate
- PRF – Phenol Resorcinol Formaldehyde



- Common to all Structural Adhesives Qualified in North America
  - Background Levels of VOC and Formaldehyde Emissions
  - Entirely Fossil Carbon Synthetic Polymers
  - All utilize Formaldehyde in their synthesis
  - The cured polymers are all “Food Safe”
  - All have a Work-Place Exposure issue requiring Mitigation Measures

# Structural Wood Adhesives are Mass Timber's Enabling Technology

- Evaluation is Key and Must be Bondline Focused
  - Adhesive is blind to Mass Timber Product
  - Adhesive must never relinquish, fail to perform
    - Performance = to Wood is Insufficient

- Adhesive Performance the summation of Structural Attributes
  - Testing focused on the Wood-Adhesive Interface
    - Small-Scale, Standardized Tests with controlled Substrates
  - Large-Scale testing cannot provide sufficient challenge.
    - More wood = less focus, greater variability

- The Mass Timber Sustainable Message must be inclusive
  - Insist on Performance Based criteria
  - Rigorous Product Specifications
  - Clear and Focused Standard Test Methods

# Thank You !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