Fire Performance of Edge-Glued Southern Pine Cross-Laminated Timber

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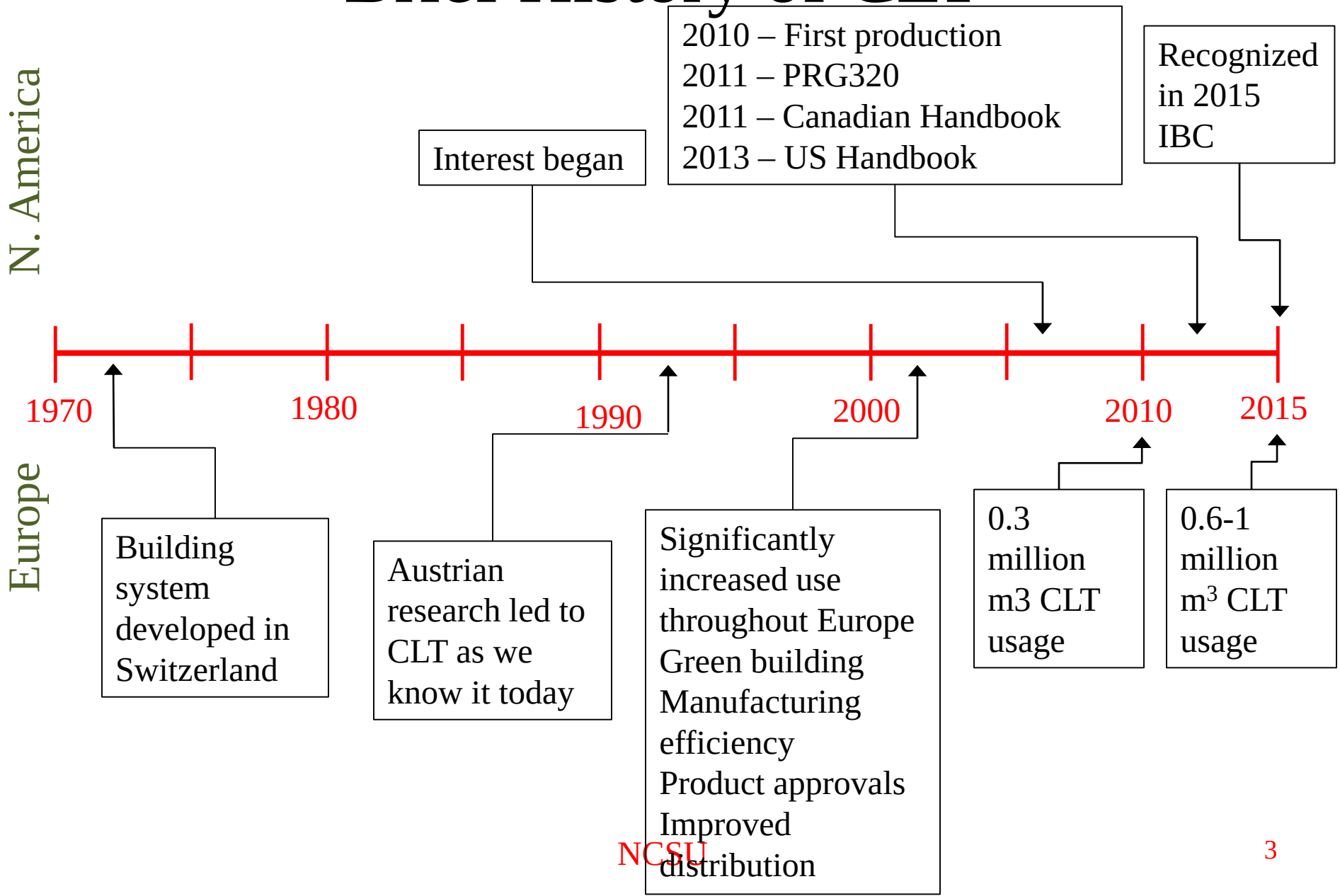
Cross-Laminated Timber

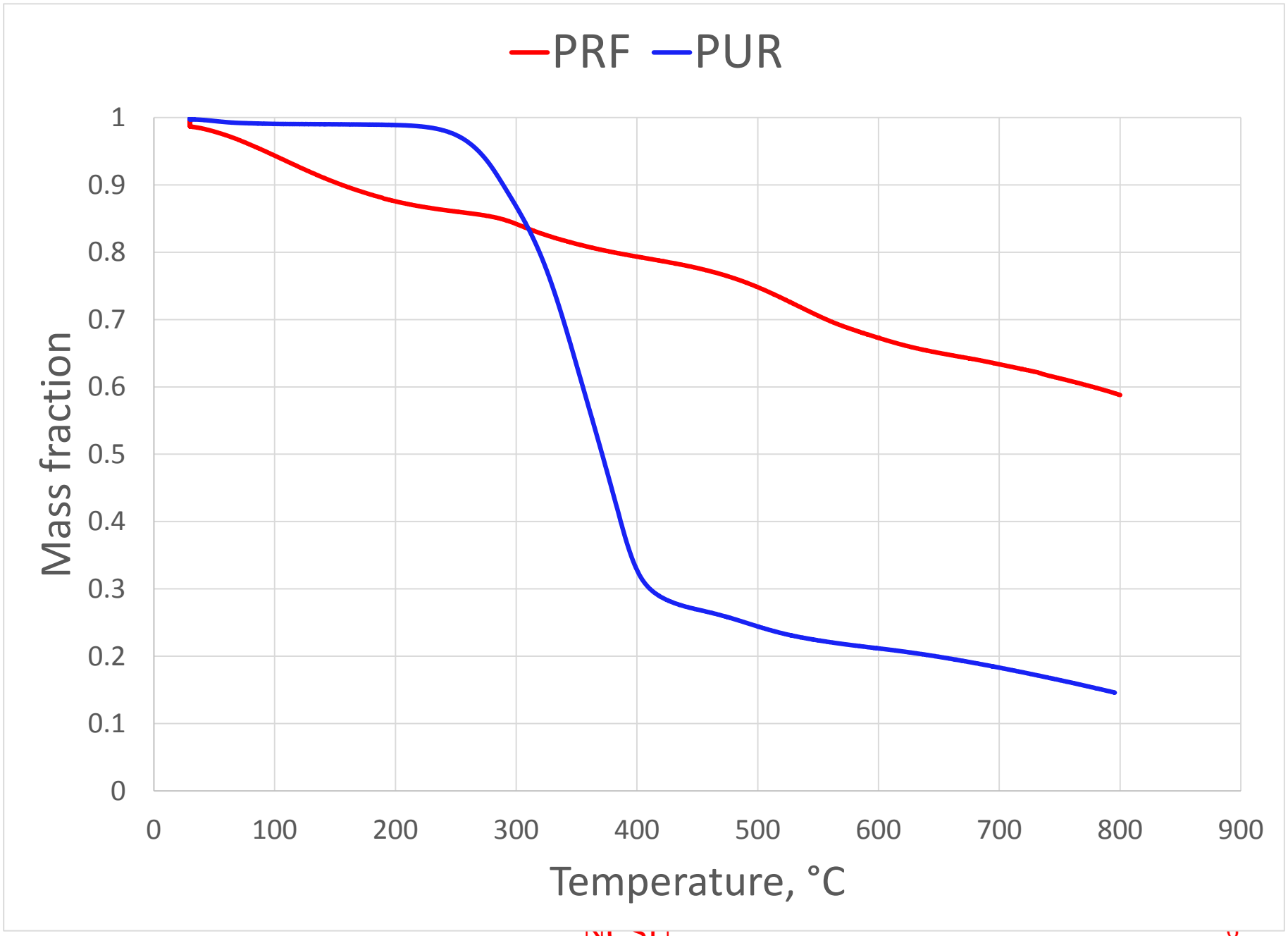
- Odd number of layers of solid-sawn or structural composite lumber (at least 3 layers)
- Grain orientation of adjacent layers are perpendicular to each other
- Widths: 2, 4, 8, and 10 ft. (0.6, 1.2, and 3 m)
- Lengths: up to 60 ft (18 m)
- Thickness: up to 20 inches (0.5 m)

Brief History of CLT



Southern Pine CLT

- Most widely planted tree species group in the U.S. and perhaps in the world
- Comprises 75% of all seedlings planted each year
- “America’s wood basket”
- Provides about 15% of the world’s industrial roundwood and almost 60% of U.S. harvests


PRF
PUR
Mass fraction
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
600
700
800
900
Temperature, °C

Fire Performance of CLT

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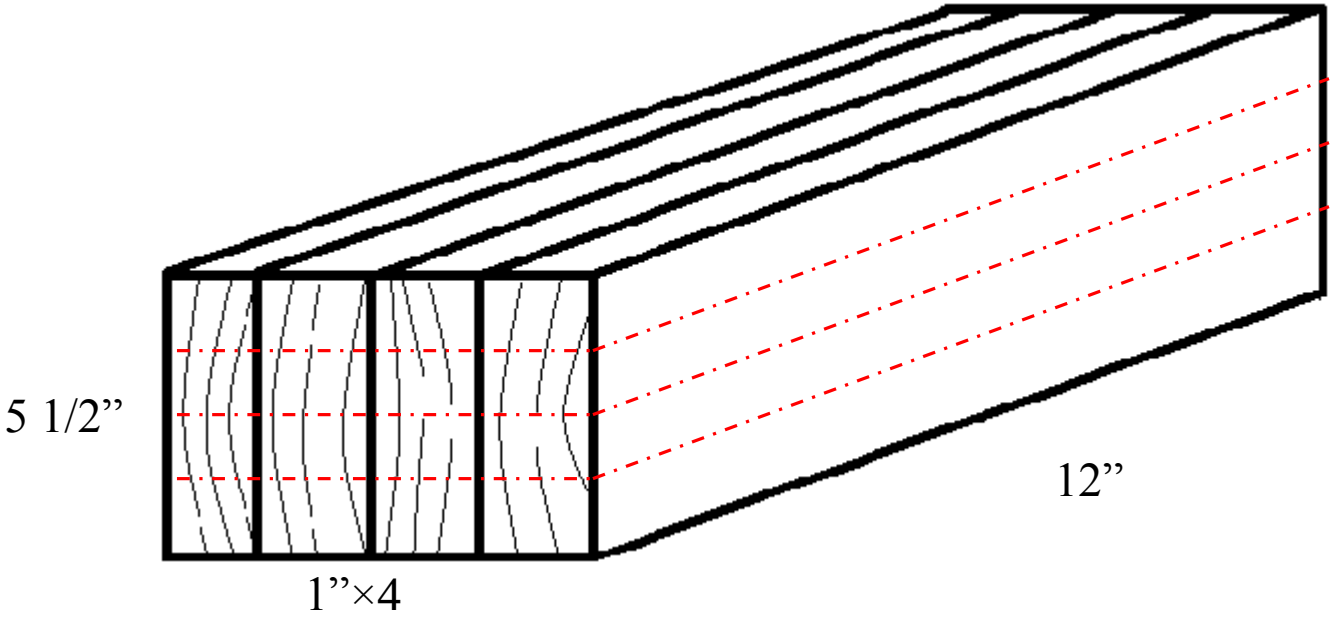
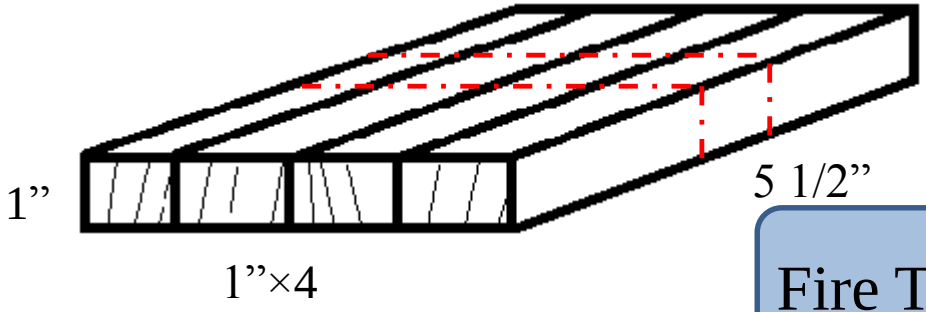
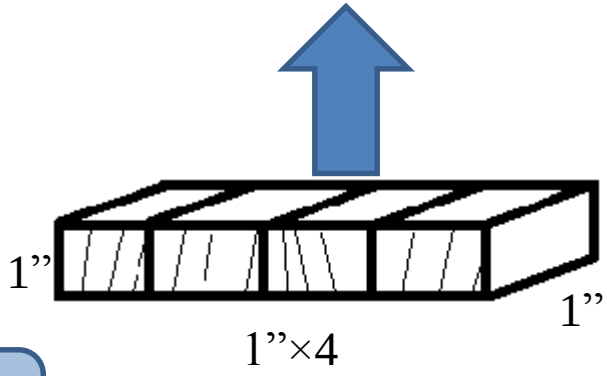
Sample Preparations



- Southern Pine
- Adhesives
  - MF
  - PRF
  - PU

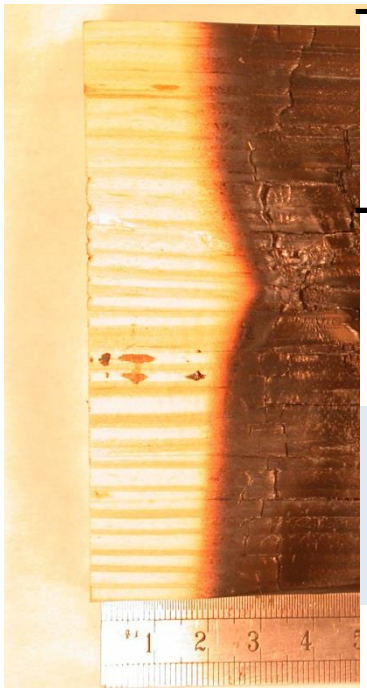


Fire Test (PS 1-09)

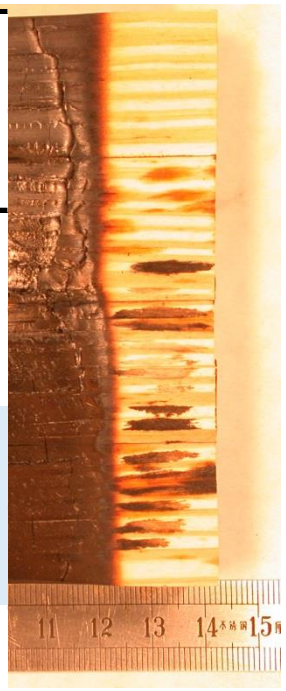


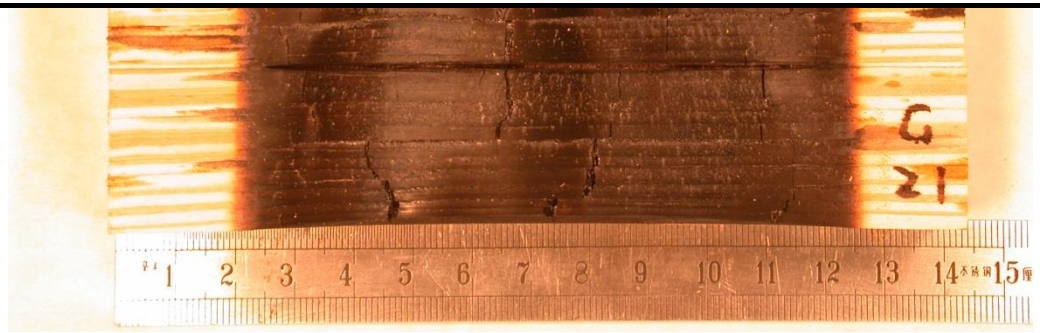
Bending Test

Results and Discussions



Sample ID	Weight (g) Before	Weight (g) After	Weight Loss (g)
P1	256.7	236.6	20.1
P2	266.8	248.0	18.8
G1	260.4	241.6	18.8
G2	265.0	246.3	19.2
M1	261.7	242.1	19.6
M2	271.8	252.8	19.0



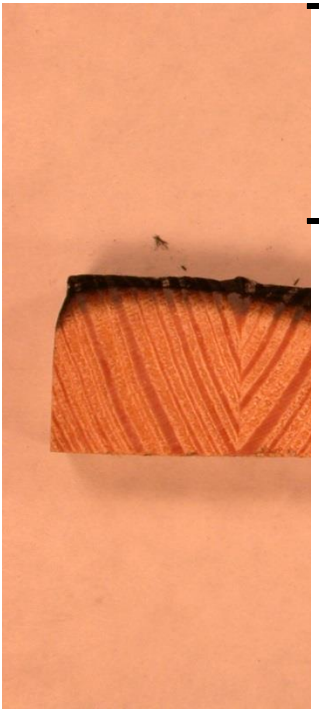


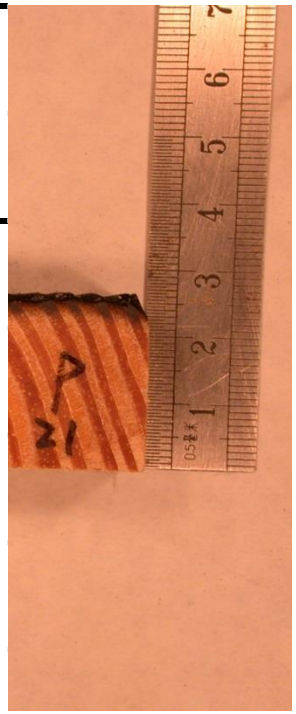
Results and Discussions

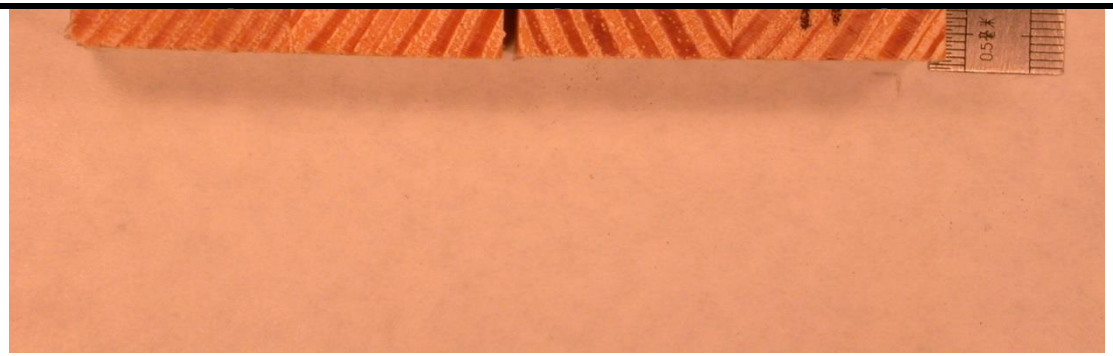
Sample ID	Thickness (mm)	Separation depth (mm)	Char Depth (mm)	Pyrolysis Depth (mm)
P1	27.3	/	7.3	2.6
P2	27.4	/	7.2	2.4
G1	26.9	12.1	6.7	2.5
G2	27.4	12.6	7.5	2.5
M1	27.1	/	7.0	2.4
M2	27.1	/	7.1	2.4

Results and Discussions

Control Group	Peak Load(N)	Fire Test Group	Peak Load(N)
P1C	1341.2	P1	349.1
P2C	1235.7	P2	445.9
G1C	1683.0	G1	282.8
G2C	1659.8	G2	216.1
M1C	1333.9	M1	375.2
M2C	1480.8	M2	416.6







Summary

- PRF and MF samples (no separation) performed better than those made with PU (with separations) during the fire test

- Char zone and pyrolysis zone thicknesses were constant regardless of adhesive type

- PU samples had lower peak load values compared to others after fire test

Future Work

- Determine the limiting thickness for fire test by applying PRF or MF edge gluing

- Verify findings in full-size CLT panels

Acknowledgements

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- Bryan Dick, Zach Miller, Mike Maltby, Guillermo Velarde

Thank You!

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Questions

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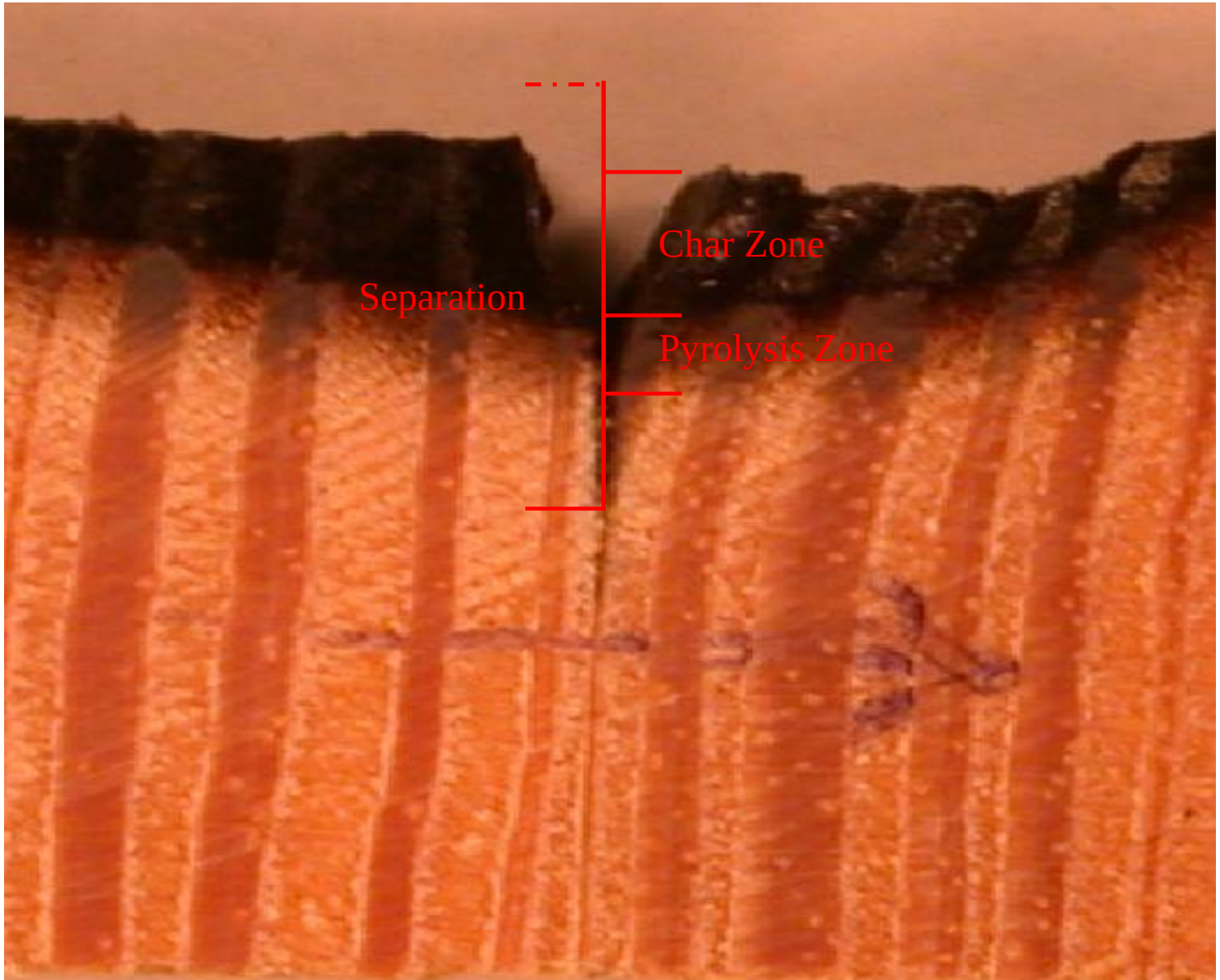
Additional Slides



Additional Slides

- Melamine formaldehyde: typically used for MDF and plywood manufacture, is not moisture resistant
- Phenol resorcinol formaldehyde: more expensive but has moisture resistant properties (a desirable durability quality for CLT above and beyond fire resistance)
- Polyurethane: reactive, one-part formaldehyde-free moisture reactive adhesive used in glulam beams (formaldehyde-free is also desirable for CLT)
- Emulsion polymer isocyanate: two-part, moisture resistant, used for I-joists and finger joints (glue containing isocyanate is not environmentally-friendly and two-part systems are not superior to one-part adhesives)
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- Adhesive #2 and 3 would be the most attractive adhesive system from a moisture durability perspective. From an environmentally-conscious consumer perspective, #3 wins hands-down.

Melamine-Formaldehyde

- Include MF (melamine-formaldehyde) and MUF (melamine-urea-formaldehyde)
- Similar to UF, MF is formed by a condensation of melamine to formaldehyde. The amino group in melamine reacts completely with formaldehyde groups leading to complete methylolation. Up to six formaldehyde molecules may be attached (see Pizzi 1994).
- Advantages
  - More durable than UF, lower formaldehyde emissions, high tack with low viscosity (important for fiberboard), cure over a wide range of pH
- Disadvantages
  - More expensive than UF, less durable than phenol formaldehyde

Resorcinol Resins

- Resorcinol resins may be a combination of resorcinol and PF resins. They are two-part systems that are mixed with a catalyst to cure at room temperature. They are primarily used in laminated beams, finger joints, and structural applications.
- Advantages
  - Very resistant to moisture, strong bonds, long-term durability
- Disadvantages
  - Can have long curing times, expensive, reddish-brown color

Isocyanates

- Primary reaction is isocyanate and water to form an amine and subsequently a poly urea
- Used in structural, exterior panels that are strong and moisture resistant
- Advantages
  - 100% solids, no formaldehyde, wets wood better than PF, does not introduce excess moisture, durable and strong bonds, foams
- Disadvantages
  - Much more expensive than formaldehyde based adhesives, sensitizing agent, foams, bonds metal