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Fire Performance of CLT Assemblies

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February 9th, 2011

Vancouver, BC

Outline

- Introduction: Wood buildings and fire
- Fire resistance
 - General Design Methodology (Prescriptive)
 - Testing-based
 - Calculation-based
- Flame spread
 - Requirements and CLT
- Current Research Programs
 - FPInnovations / IRC – National Research Council
 - Carleton University / FPInnovations

CLT Handbook

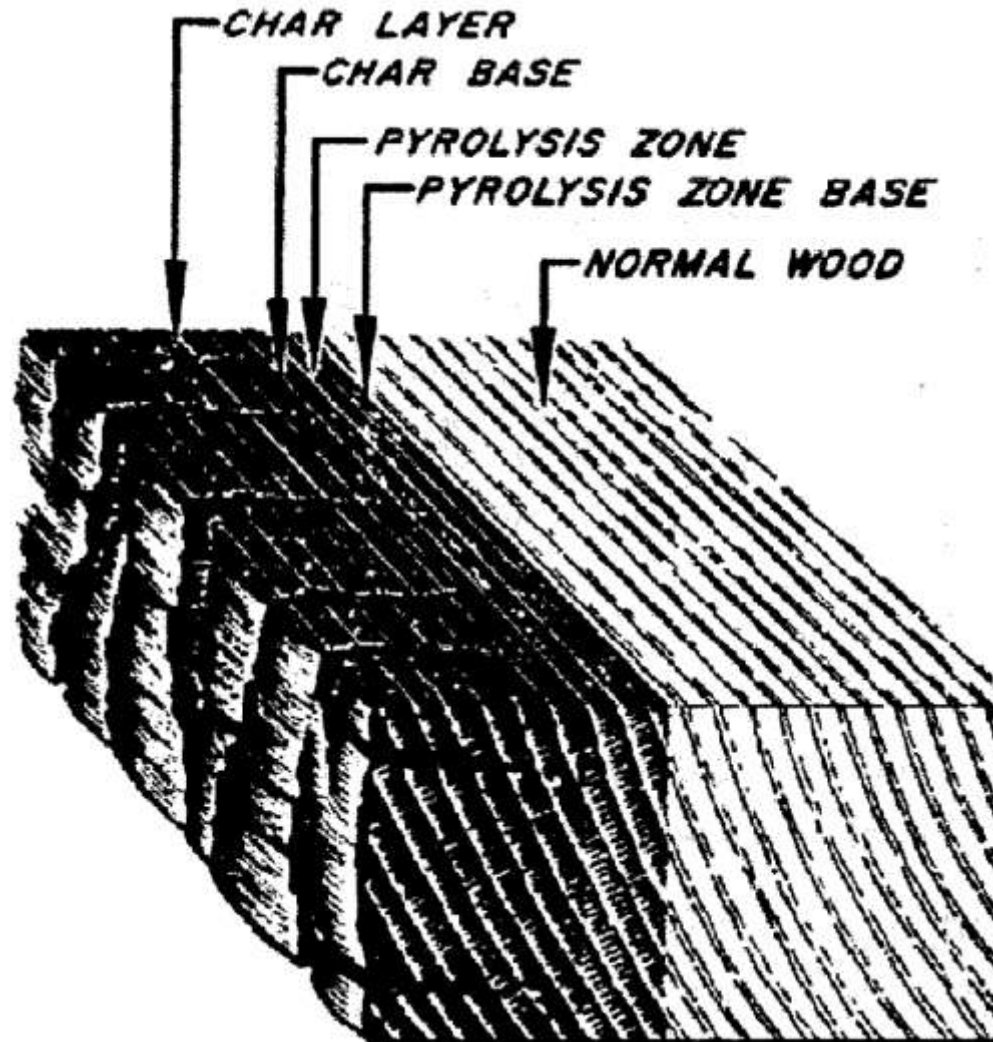
- Chapter 8 – Fire Performance of CLT Assemblies



Fire Safety and Wood Buildings

- Because wood burns, many people mistakenly assume that wood buildings behave poorly in fires.
- Large size wood members have the inherent ability to provide fire resistance because of the unique charring properties of wood.
 - Burn slowly and forms char layer
 - Non-charred wood retains significant strength
 - Wood is dimensionally stable under fire conditions

Response of Wood to Fire



How does this knowledge of how wood behaves in fire apply to CLT

- The charring of CLT can be treated as 1-D.
- Reduction or possibly elimination of concealed spaces (voids) in construction also could reduce fire risk.
- Appendix D, Section 2.4 - Minimum assembly thicknesses for load bearing and non-load bearing walls and floors

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Objectives of Providing Fire Resistance

- Early stages, safe evacuation of occupants (prevent spread of fire and smoke from fire compartment)
- Thereafter, prevent fire spread outside of compartment, provide safety for fire fighters and provide property protection (structural integrity of building)

Standard Test for Fire Resistance

- CAN/ULC S101 – Standard Methods of Fire Endurance Tests of Building Construction and Materials.
 - ASTM E119, ISO 834, etc.
 - Test method is referenced in building codes where a particular fire-resistance rating is required such as 45 min, 1, 1.5, 2 hrs.

CAN/ULC S101 – Floor Assembly Furnace



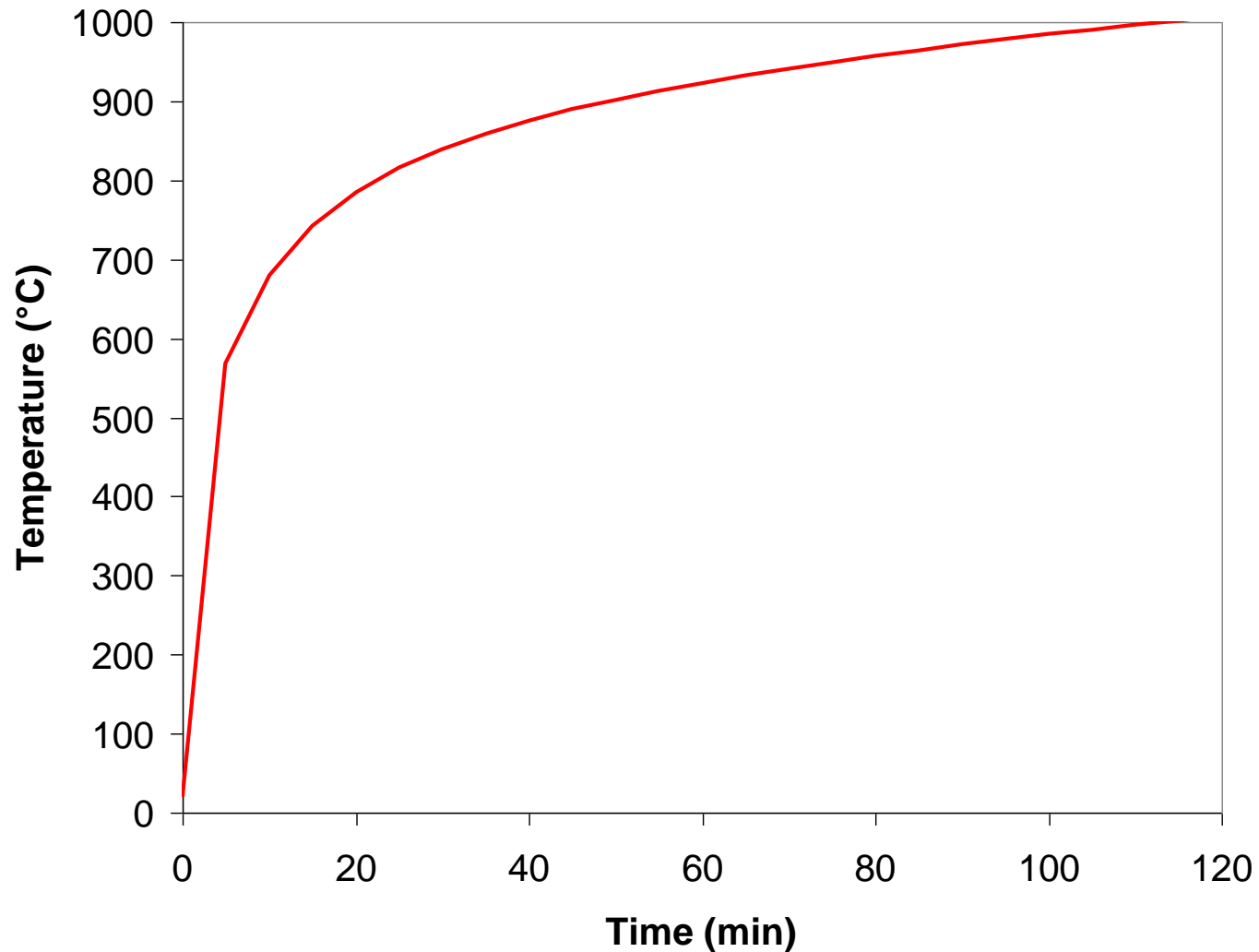
CAN/ULC S101 – Wall Assembly Furnace



CAN/ULC S101 – Floor Assembly Loading



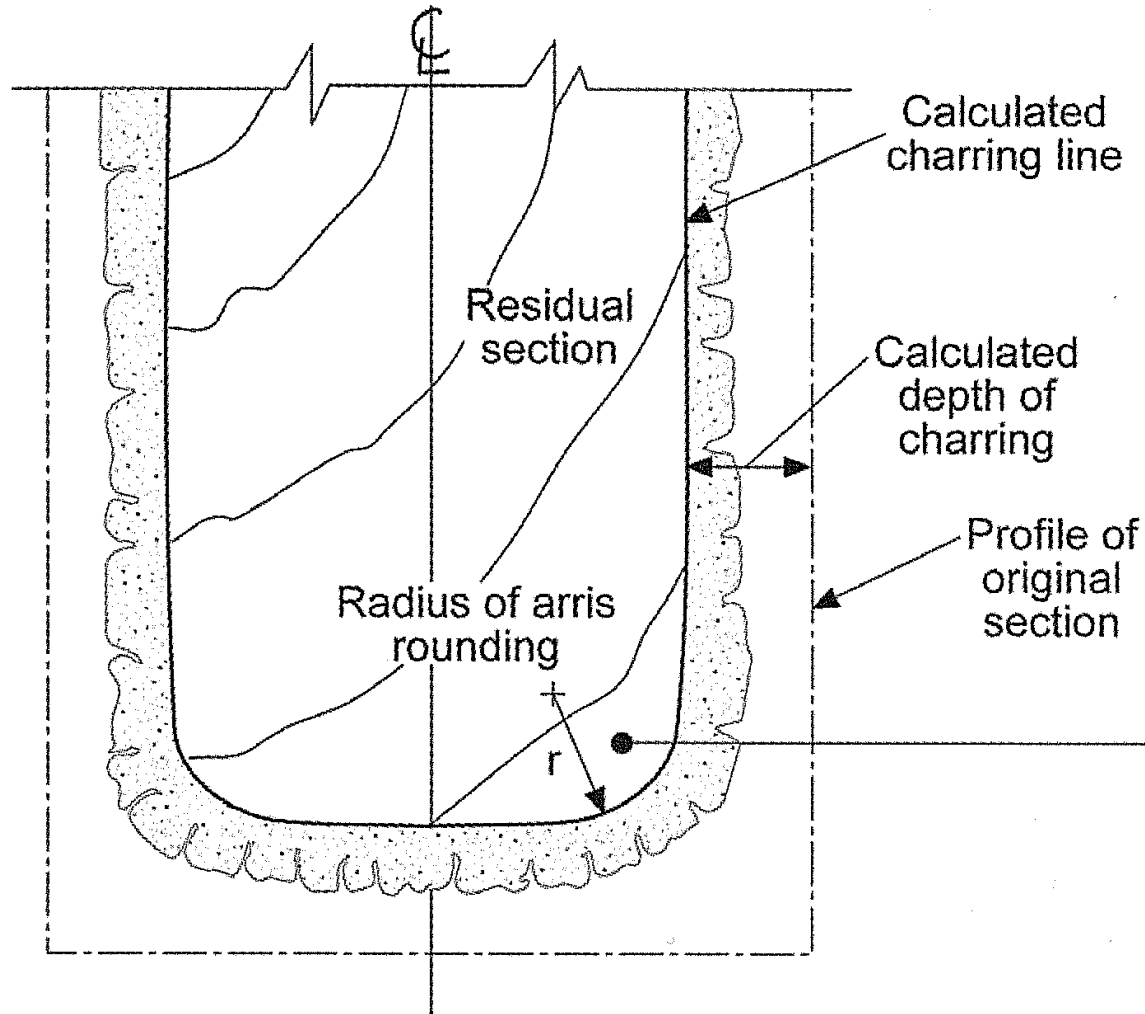
CAN/ULC S101 – Temperature Exposure



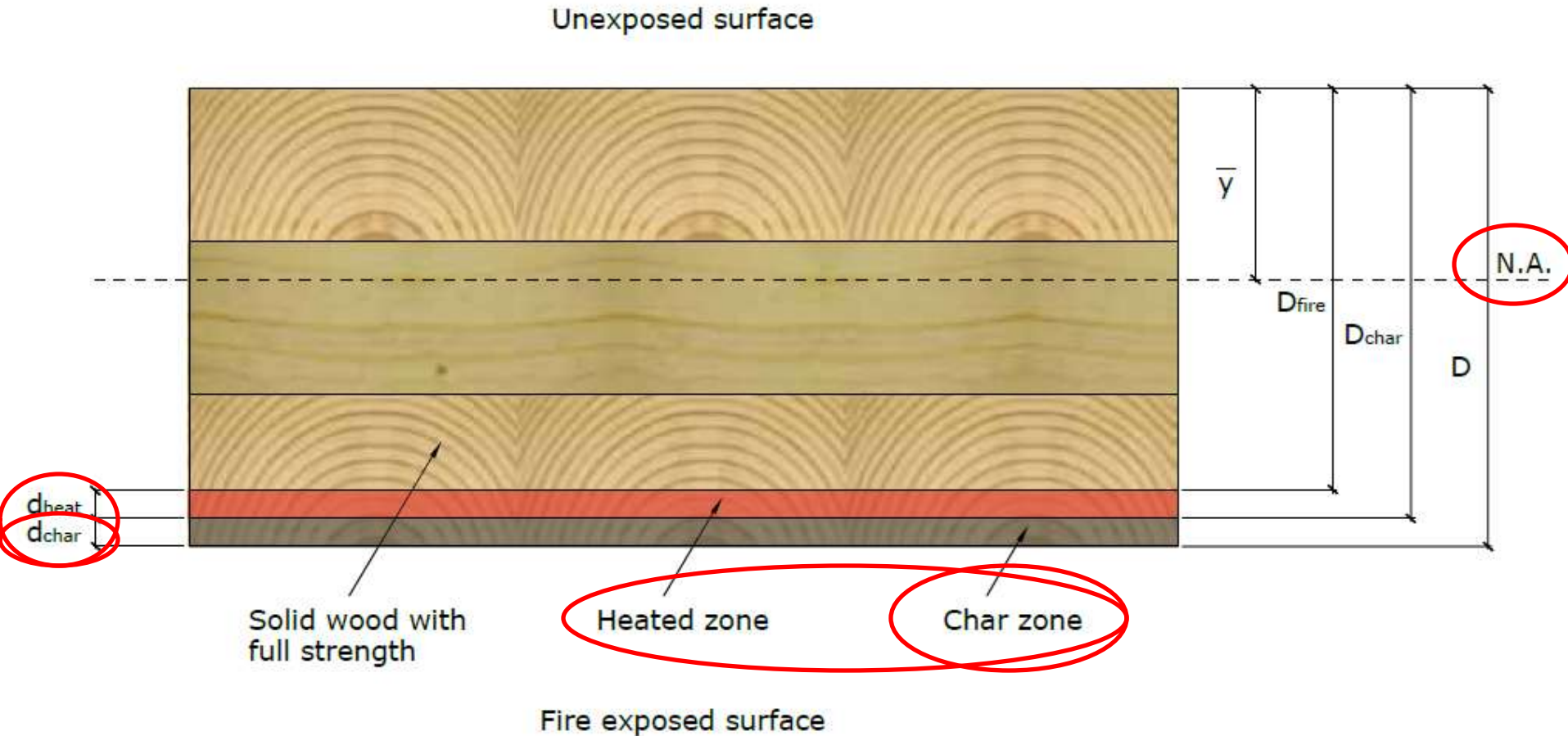
Standard Fire-resistance Test Failure Criteria

- Insulation Failure
 - Temperature rise of 140 ° C average or 180 ° C at any point on unexposed side.
- Integrity Failure
 - Passage of flame or gases hot enough to ignite cotton pads.
- Structural Failure
 - Inability to sustain the applied load at some point during the test.

Concept of Heavy Timber Design for Fire Resistance



Calculating the Fire Resistance of CLT



Step 5: Compare resistance of remaining cross-section to the applied load

Protection of Wood

- Test recently completed at US Forest Products Laboratory.
 - Tested Glulam and LVL members in tension with protection by 1 and 2 layers of 16 mm type X gypsum board
 - Tests found 1 layer of type X gypsum board provided an additional 30 minutes to the fire-resistance rating of the tension member.
 - Tests found 2 layers of type X gypsum board provided an additional 60 minutes to the fire-resistance rating of the tension member.
- Most likely will observe greater increases in FRR when gypsum board is applied to CLT

Overview

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Flame-Spread Requirements

- Flame-spread requirements in the building code specify maximums of 150, 75 or 25 flame-spread rating (FSR).
- Typical FSRs required for residential buildings
 - Residential Units
 - Maximum FSR of 150 for walls and ceiling
 - Corridors leading to an exit
 - Maximum FSR of 75 or
 - Maximum FSR of 150 on bottom half with a maximum FSR of 25 on the top half of walls or
 - Maximum FSR of 150 if the corridor is sprinklered.
 - Stairwells leading to an exit
 - Maximum FSR of 25

Flame-Spread Requirements

- CLT manufactured using Canadian softwood species will certainly have flame-spread rating less than 150.
 - NBCC Appendix D lists the flame spread rating for lumber as 150.
 - A review by Forintek published as Technote TEC-49E shows flame-spread ratings of lumber found in the literature vary greatly between 65 and 120 with the majority around 100.

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Current and Planned Research

- FPIinnovations
 - Medium-scale fire resistance tests looking at charring rates and behaviour of the panels.
- FPIinnovations / IRC – National Research Council
 - Focus on standard fire exposure for meeting prescriptive requirements in the national and provincial Building Codes.
- Carleton University / FPIinnovations
 - Focus on non-standard fire exposure for performance-based design and risk analysis

Current and Planned Research

- FPInnovations

- Medium-scale (vertical) fire resistance tests on 4' by 4' panels
- Verify the charring rates typically used for large wood elements applies to CLT
- Increase the understanding of how CLT assemblies (both with and without gypsum protection) behave in fire.



FPInnovations Research on Fire Performance of CLT

- Main conclusions drawn from medium-scale tests
 - The charring rate for unexposed CLT panels agrees well with that used in existing design codes for large wood beams and columns.
 - In order to avoid integrity failure, it is critical the assembly does not allow the passage of hot gases or air.
 - Falling off of char layers was observed as reported by others, however the degree of falling off and impact were less in these tests.
 - Solid wood is a great insulator

Current and Planned Research

- FPInnovations / IRC – National Research Council
 - Develop and validate generic methodology for calculating fire-resistance rating of CLT wall and floor panels using full-scale testing.
 - Support CLT demonstration projects in short term by including proposed assembly designs in our test program. (Generate test data to support fire resistance claims based on calculations)



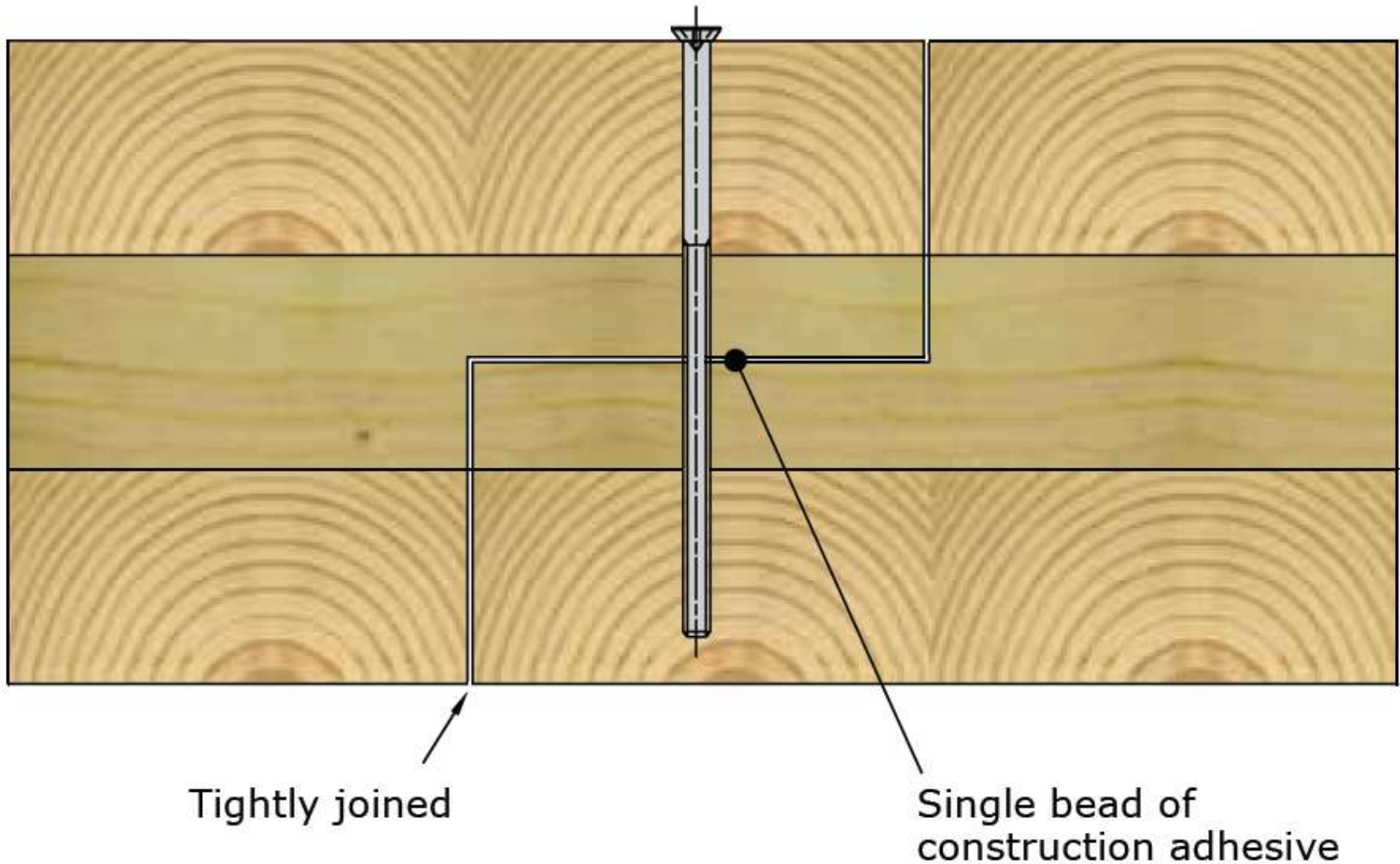
FPInnovations Research on Fire Performance of CLT

- Currently completed 2 of 8 full-scale tests completed
 - Floor assemblies
 - 3 ply CLT floor assembly, protected by 2 layers of 12.7 mm type x gypsum board
 - 5 ply CLT floor assembly, unprotected, with PUR adhesive
 - 5 ply CLT floor assembly, unprotected, with PRF adhesive
 - CLT/Concrete composite floor assembly
 - Wall assemblies
 - 3 ply CLT wall assembly, protected by 2 layers of 12.7 mm type x gypsum board
 - 5 ply CLT wall assembly, unprotected

FPInnovations Research Project on CLT

- CLT floor and wall assemblies tested
 - 3 ply (3 x 38 mm) 114 mm thick
 - SPF 1650 Fb MSR
 - Protected by two layers of 12.7 mm type x gypsum
- Floor
 - Applied load based on L/240 deflection
- Wall
 - Applied load limited by bearing strength

Panel Joint Details



FPIinnovations Research Project on CLT



FPIinnovations Research Project on CLT



Current and Planned Research

- Carleton University / FPInnovations
 - Using CUrik, evaluate the relative risk to occupants and property when using CLT construction vs. other traditional materials.
 - Create a model to predict the performance of CLT panels in “real” fires for input into the risk model.
 - Investigate the impact of CLT construction in various configurations on the design fires for input into the risk model.



Conclusions

- CLT assemblies can provide excellent fire resistance.
- A design methodology for the fire-resistance of CLT is provided in the Handbook.
- Research is ongoing in an effort to refine the proposed design. Future goal is to included design method within CSA O86 or NBCC.

Conclusions

- Where combustible construction is currently permitted to be used according to the prescriptive requirements in the NBCC, CLT is a viable option.
- The challenge moving forward is to provide the information needed (solutions) to design larger and taller buildings with CLT. This is possible using alternative solutions.



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