Design and Construction of Tall Wood Buildings: A Guide for Fire-Safety Design

World Conference on Timber Engineering
Quebec City, Canada

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BASc, Queen's University at Kingston, Civil Engineering

M Eng, UBC's short lived Fire Science program

25 years' experience in Equivalencies and Alternative Solutions

GHL Consultants Ltd

- Founded 20 years ago
- Building Code Consultants
- Fire Engineers
- Code reviews – both assisting clients and as Authorities

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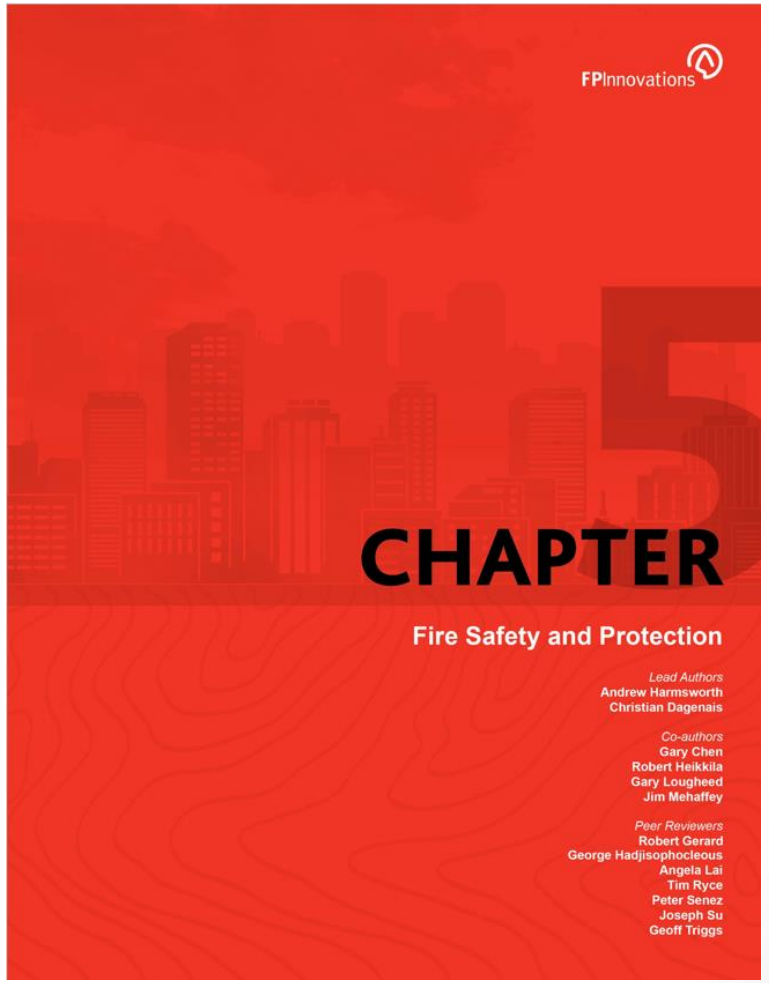
Outline

- Introduction
- Fire-Safe Alternative Solutions
- Achieving Equivalent Fire Performance with Encapsulation
- Fire Resistance of Wood Assemblies

1 Introduction

Tall Wood Guide - Fire Safety

- Guide is first to map out an alternative solution for Tall Wood on a national basis
- Michael Green and LMDG did some preliminary work in their Tall Wood Study



Been Done Before

- Objective is to show that it can be done

Kelly Douglas Building, Vancouver
9-Storey Heavy Timber -1905

312 ft. (95 m) Sitka Spruce
Canada (Picture Courtesy of FPInnovations)

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Tall Wood Guide

- Chapter 5 of the Tall Wood Guide is on Fire Safety and Protection.
- Peer Reviewed

- Lead Authors
  - *Andrew Harmsworth*
  - *Christian Dagenais*
- Co-authors
  - *Gary Chen*
  - *Robert Heikkila*
  - *Gary Lougheed*
  - *Jim Mehaffey*

- Peer Reviewers
  - *Robert Gerard*
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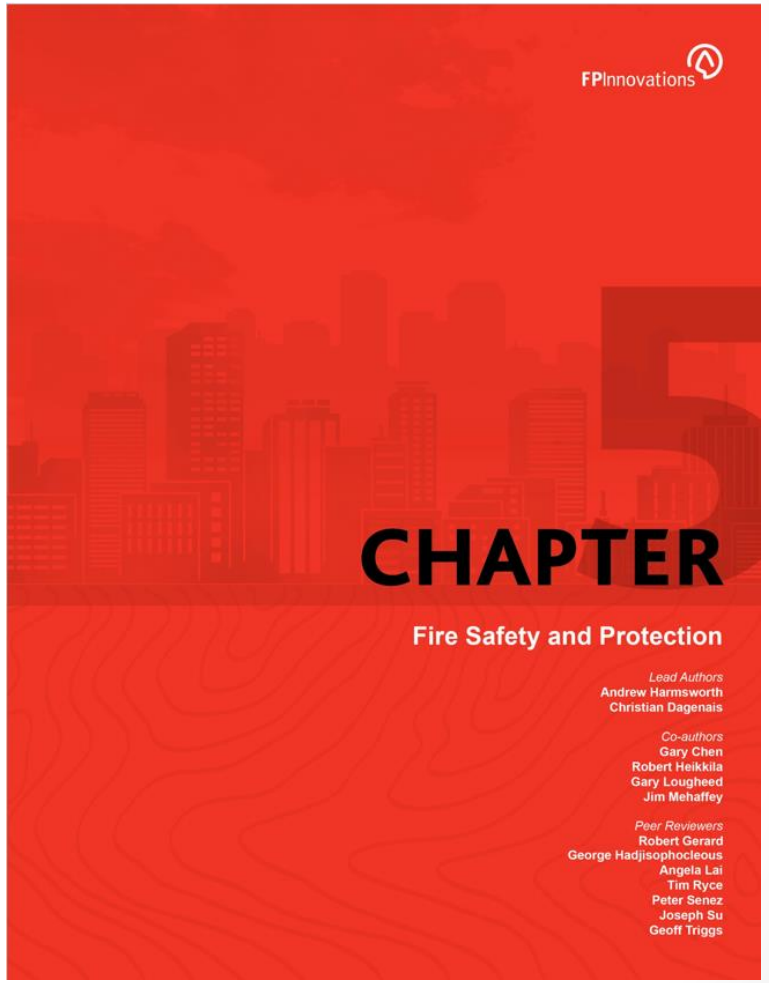

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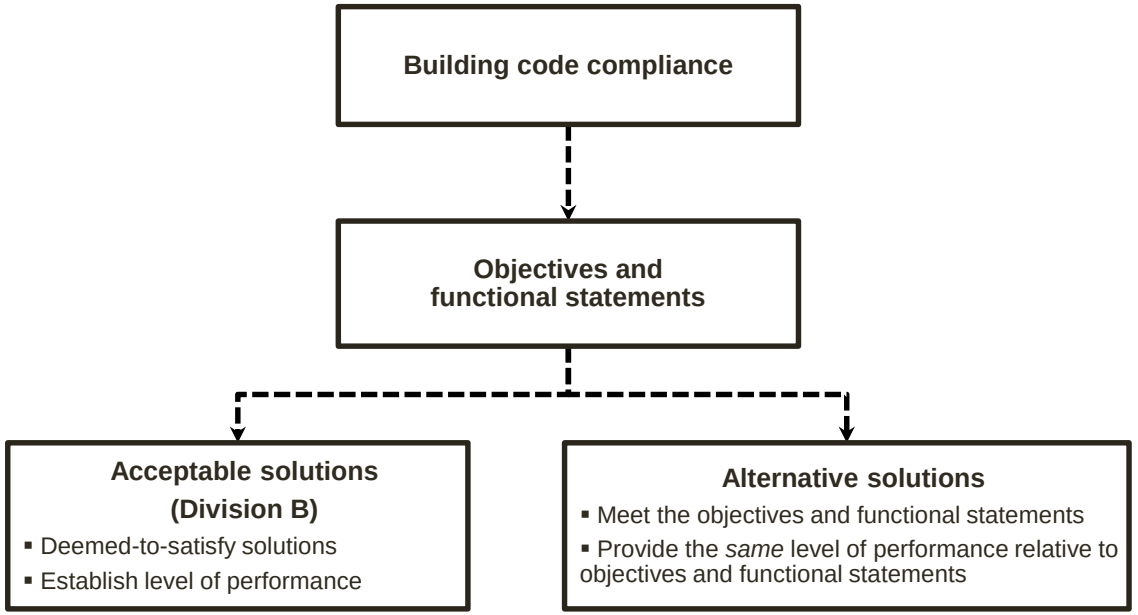
2
Fire-Safe Alternative Solution

Alternative Solutions for Fire Safety

- Canadian Codes are objective based
- Alternative Solution must demonstrate that is it as safe as what is directly permitted
- Benchmark for high building is concrete or steel building, 2h fire rated assemblies, and sprinklered



Code Provides Objectives

Objective OS1 Fire Safety from 3.2.2

- Intent 1:
- To limit the probability that combustible construction materials within a storey of a building will be involved in a fire, which could lead to the growth of fire, which could lead to the spread of fire within the storey **during the time required to achieve occupant safety and for emergency responders to perform their duties,** which could lead to harm to persons.

- Other *Provisions of the Acceptable Solutions* are similarly worded.

Why is ‘non-combustible prescribed’

- Circa 1900, in absence fire alarm noncombustible buildings were safer
- Building were more subject to our construction errors
- Protection was not as reliable

Construction Type no longer relevant

- With fire alarms, no significant difference in life safety between non-combustible and combustible construction types of same fire rating.
- Added fireblocking
- Added monitoring of fire alarm systems
- Added sprinklers

Emotion prevails but let's apply science

- Evaluation of alternative solutions should be based on science not emotion
- Level of safety need to balance risks
- Buildings are subject to risks:

Code compliance ≠ no risk.

Code compliance = risks at acceptable level.

Entering a building is just like getting into a car, there is an acceptable level of risk.

Benchmark

- To develop an alternative solution need a benchmark – accepted building conforming to the code
- Evaluate the performance of the ‘alternative’

- Assume Benchmark is a concrete or steel building of same size

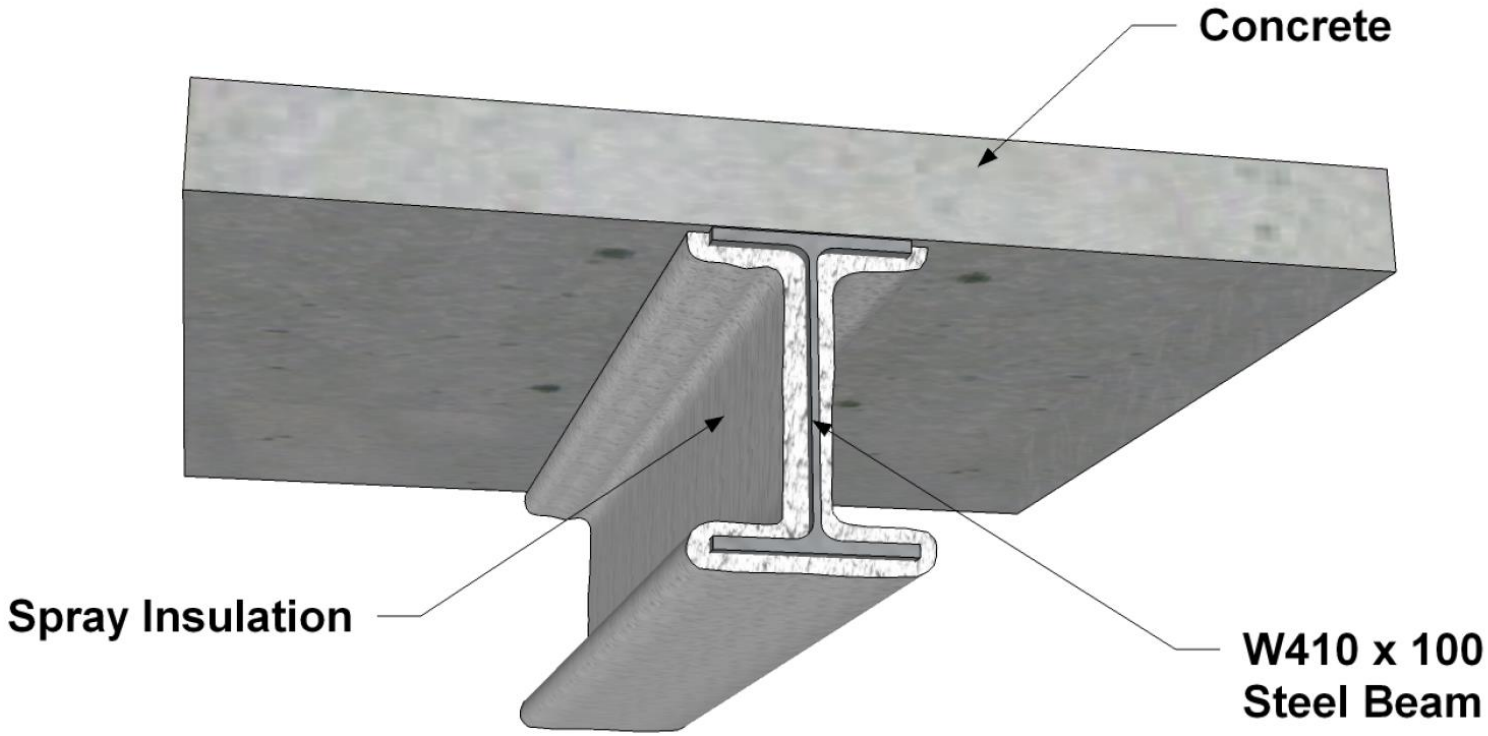
- Perhaps Benchmark should be a 3 storey unsprinklered wood frame building.

- OR – a large house.

3

Achieving Equivalent Fire Performance with Encapsulation

Fire Resistance - Encapsulation



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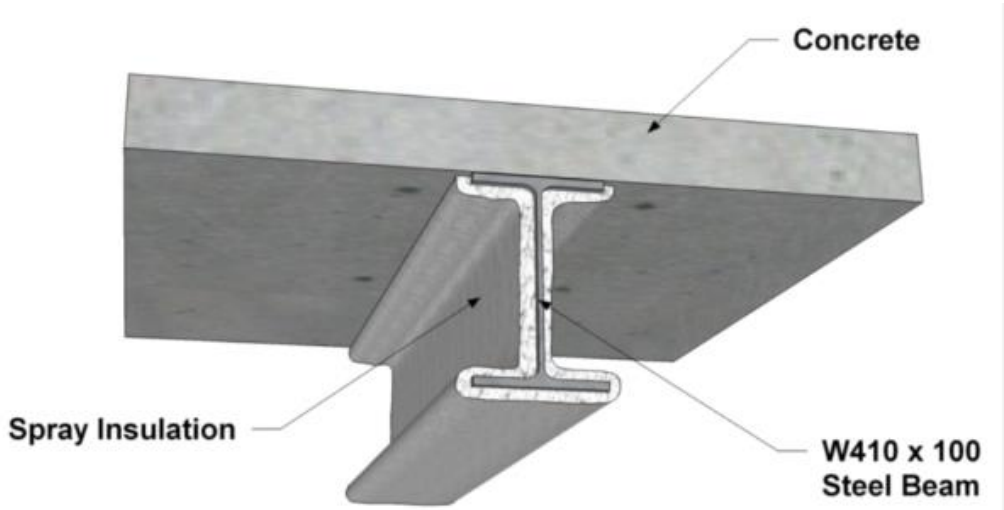
Fire Resistance

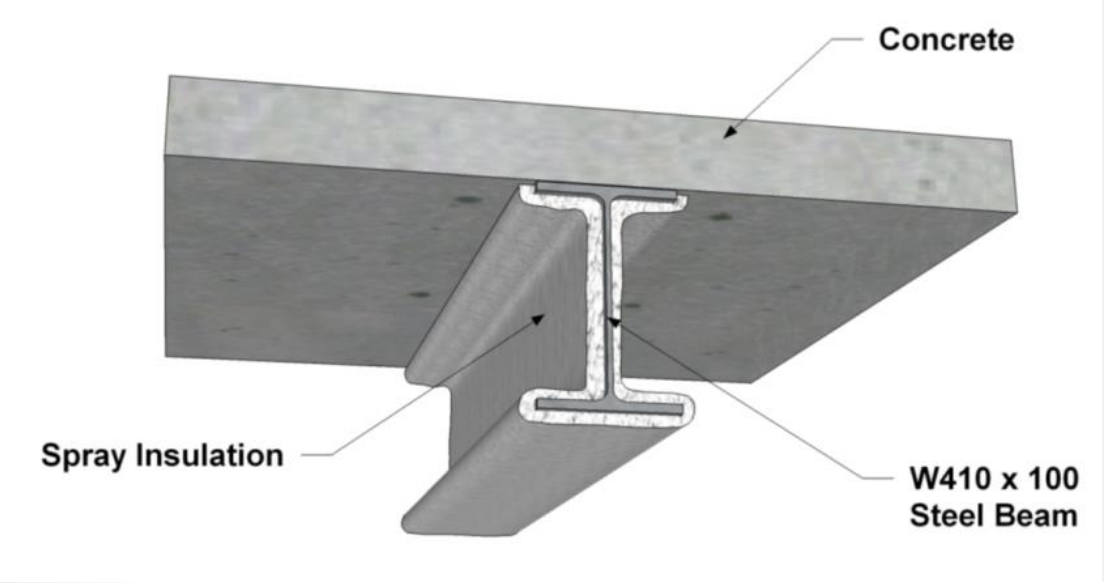
- Steel is encapsulated for thermal protection
- Steel is encapsulated: limit to 538°C (~60% strength)
- Complete encapsulation would maintain 100% strength

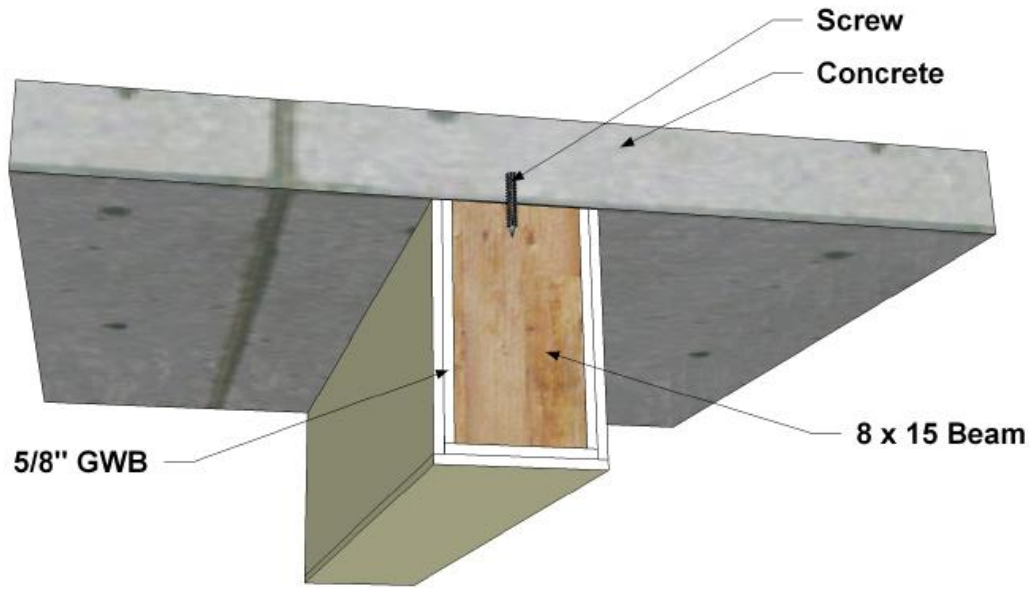


Mass Timber

- Charring can provide inherent fire rating
- Zero loss of strength below char layer
- Wood is Combustible

Encapsulation





For Strength

For Combustibility

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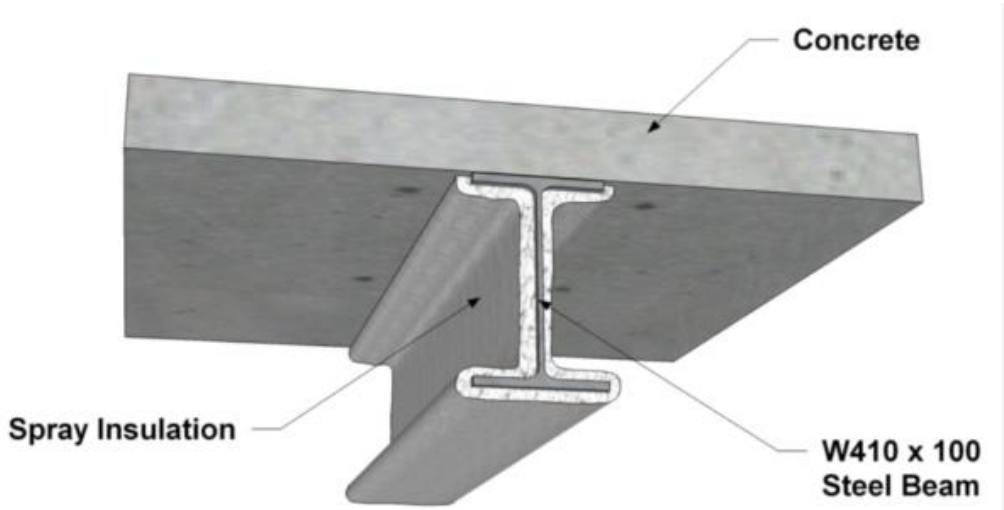
Complete Encapsulation

- Wood not affected by the fire for expected duration (2h).
- Wood does not contribute to the fire for expected duration.
- 4 layers of ½in GWB.
- Makes the point that it CAN BE DONE.

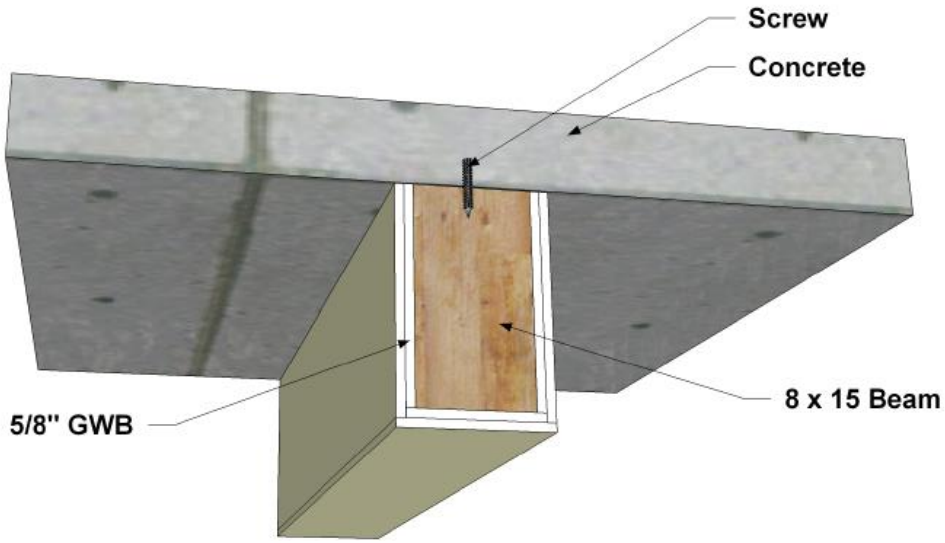
Limited Encapsulation of Steel

- Encapsulated: limit to 538°C
- (~60% strength)
- Complete encapsulation would maintain 100% strength



Limited Encapsulation of Wood

- 1 to 2 layers of GWB
- Prevent wood from contributing to fire severity for ‘time to achieve evacuation and FF response
- Prevent possibility of ‘re-flashover’



Fire Resistance

- Start with full encapsulation
- Peel off layers
- Code indicates some exposed wood panelling is acceptable

My Opinion

- “Burnout with all systems failed” is not appropriate metric

IMHO This at 2h is acceptable

This at 2h is not

My Opinion

- “Burnout with all systems failed” is not appropriate metric
- Continued charring is acceptable
- Re-flashover is not

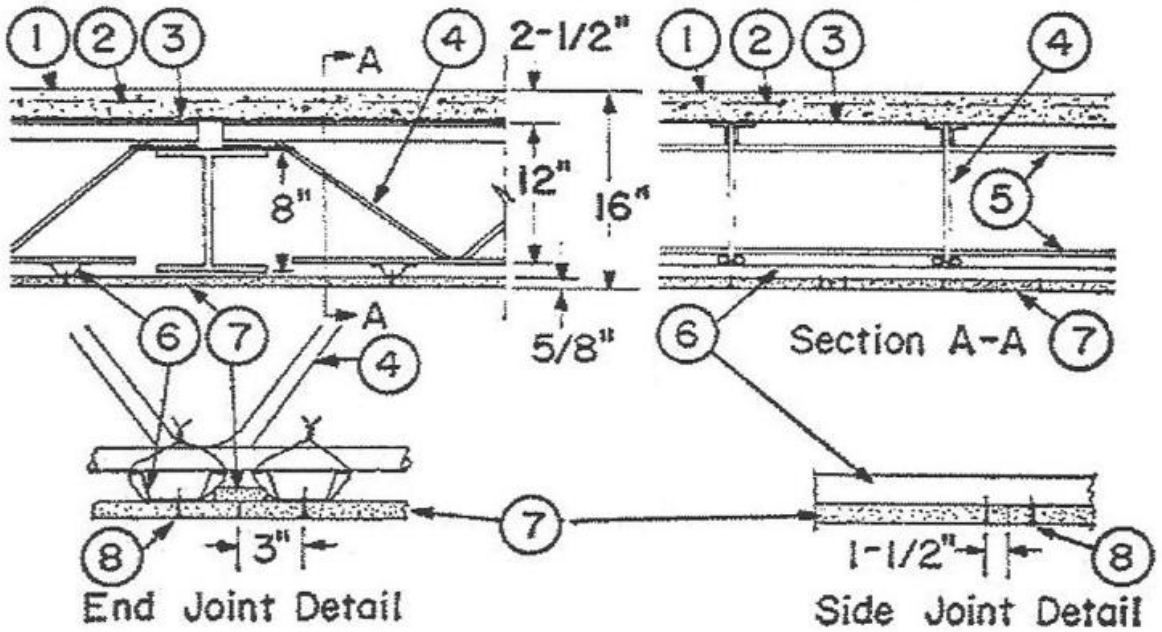
Alternate Approaches

- Encapsulation of all mass timber

- Partial encapsulation with some walls exposed with backup water supply – *See my paper on Reliability of Sprinkler Systems During and After a Seismic Event and Application to Tall Wood Buildings*

Benchmark - Noncombustible

Restrained Assembly Rating — 3 Hr.
Unrestrained Assembly Rating — 3 Hr.
Unrestrained Beam Rating — 3 Hr.
Load Restricted for Canadian Applications — See Guide BXUV7



Beam — W8x35, min size.

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2h FRR

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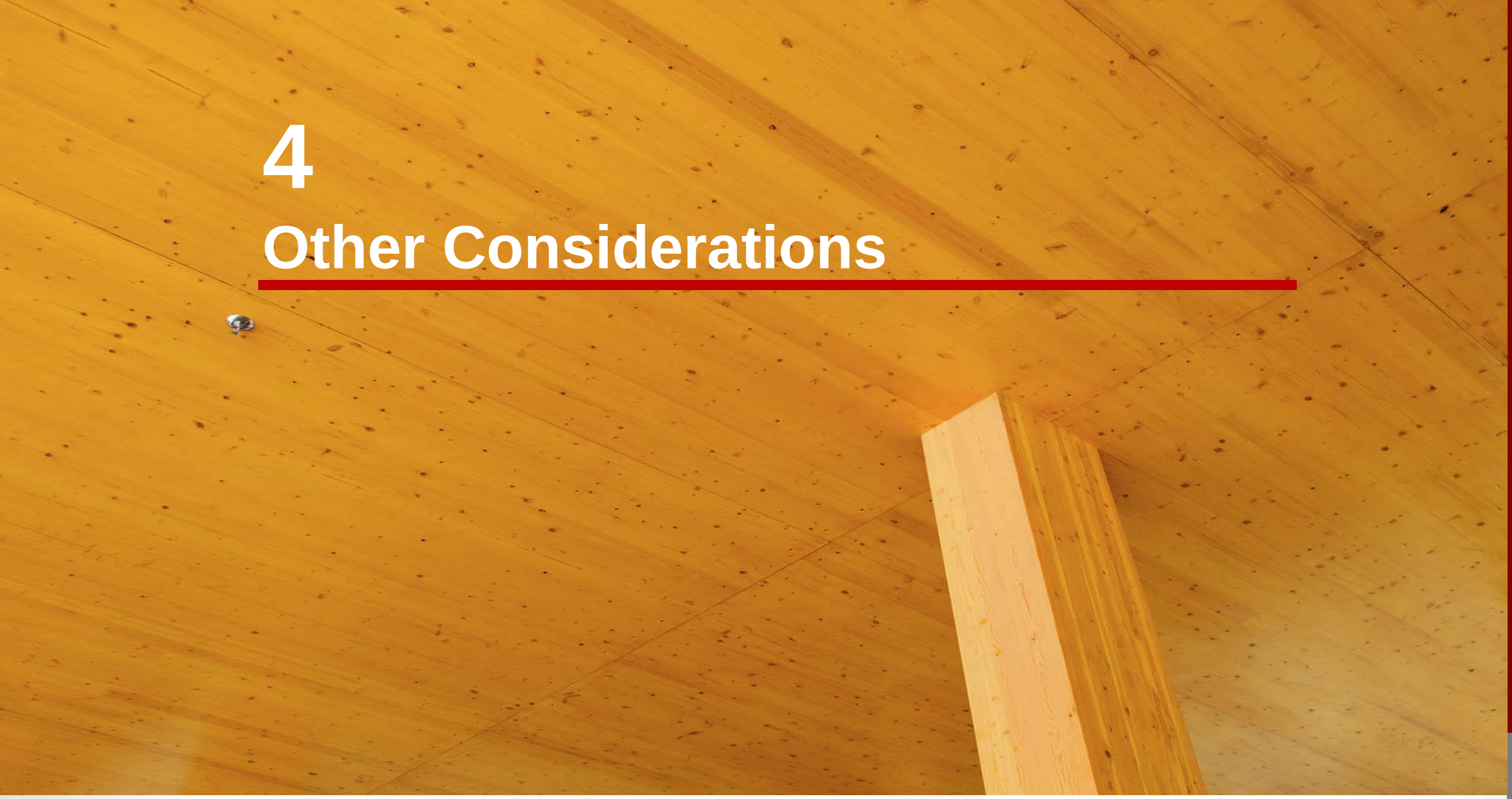
This, especially if wrapped in 2 layers of GWB

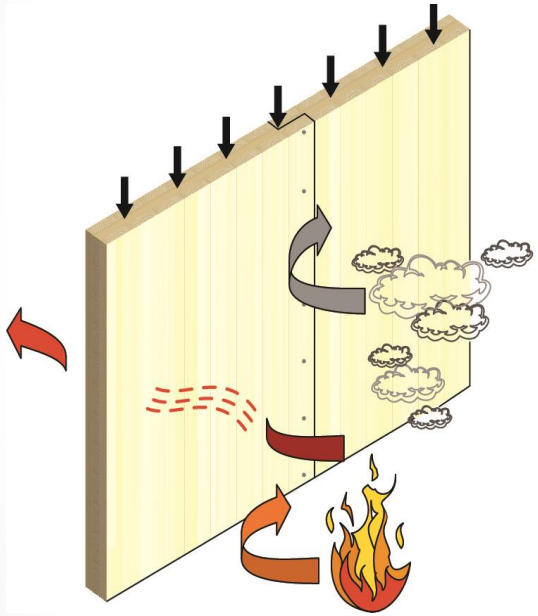


4
Other Considerations

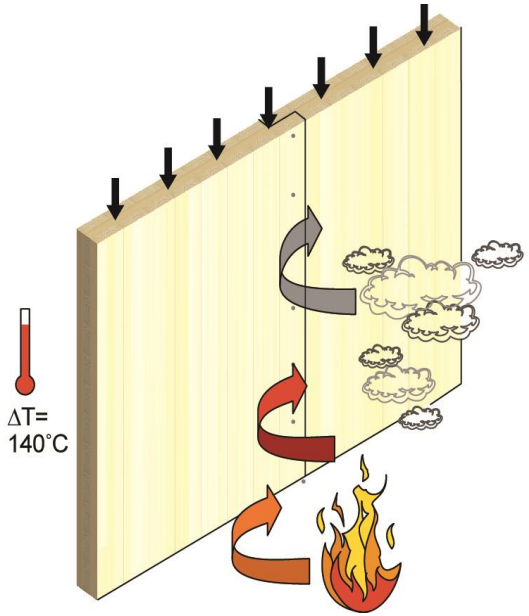
Other Considerations

- The Tall Wood Guide also addresses:
  - Fire Resistance Rating
  - Firestopping
  - Protection of concealed spaces
  - Spatial separation and exposure protection
  - High building considerations
  - Construction fire safety

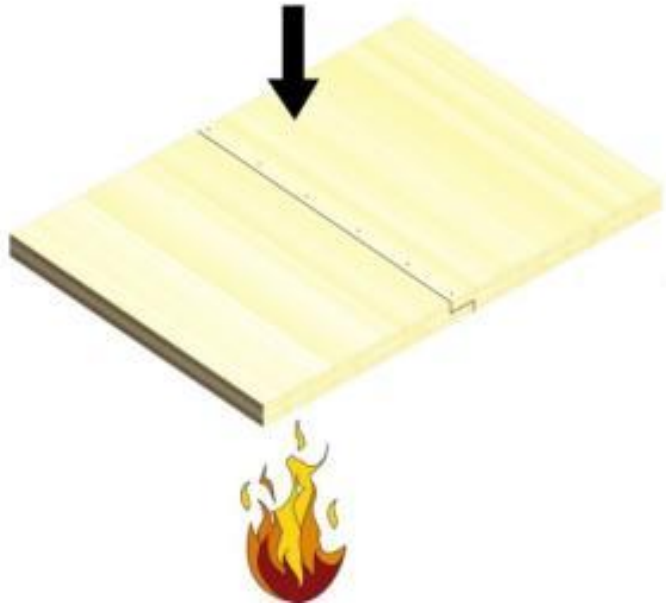
Fire Resistance



Integrity



Insulation



Structural Resistance

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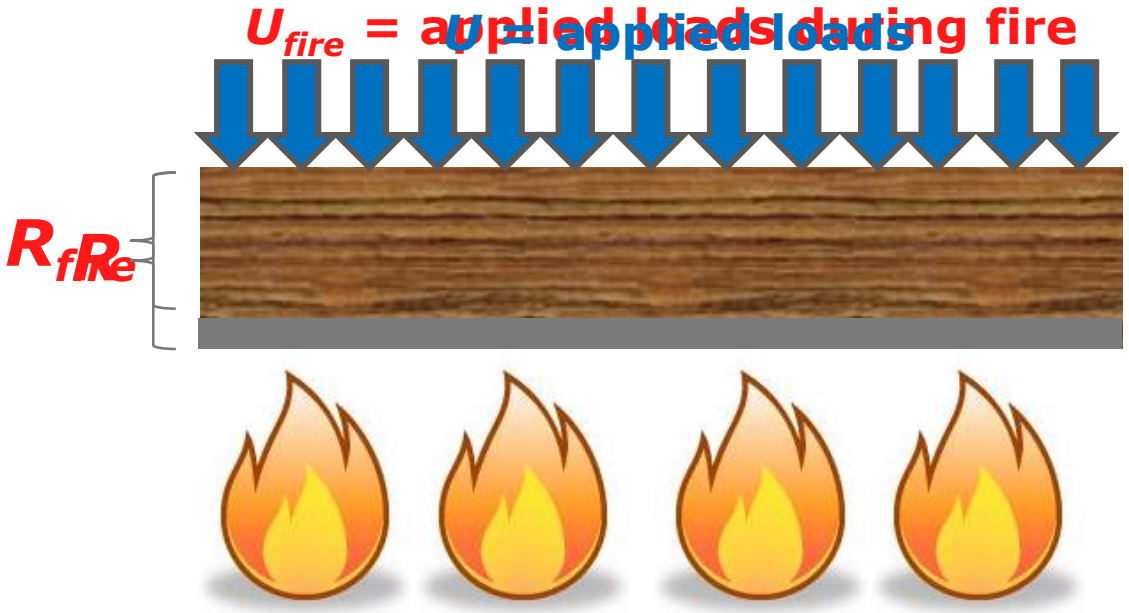
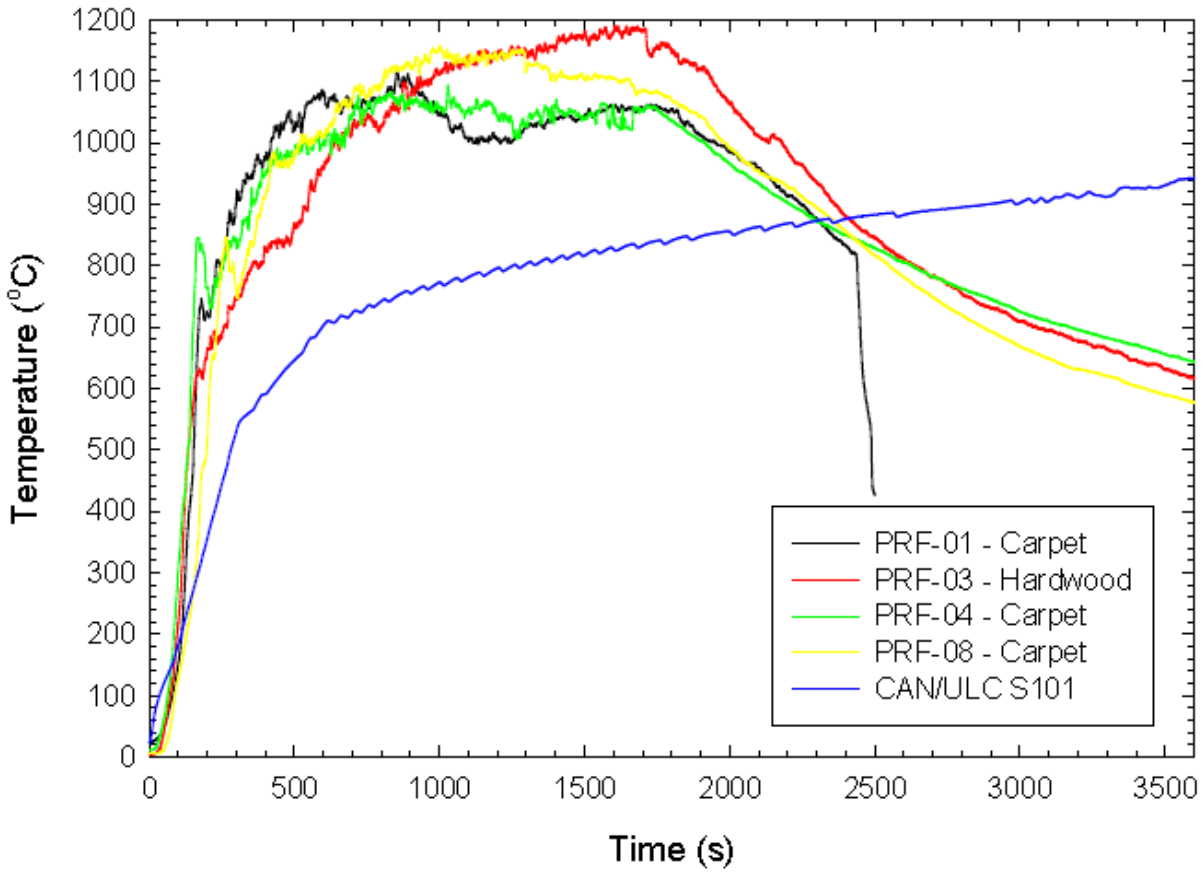
Limit State Design – for Fire

$$U_{fire} \leq \Phi_f R_{fire} \qquad (1)$$

where U_{fire} = the design action from the applied load at the time of the fire;
Φ_{fire} = the strength reduction factor for the timber material; and
R_{fire} = the nominal load capacity at the time of the fire, accounting for charring of wood members



Standard Fire vs. Design Fire



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Connections

2h Fire Rated Connection
The Landing, Vancouver

Fire-resistance test conducted on concealed plate
(credit: L. Peng (Peng, Hadjisophocleous, Mehaffey, & Mohammad, 2010))

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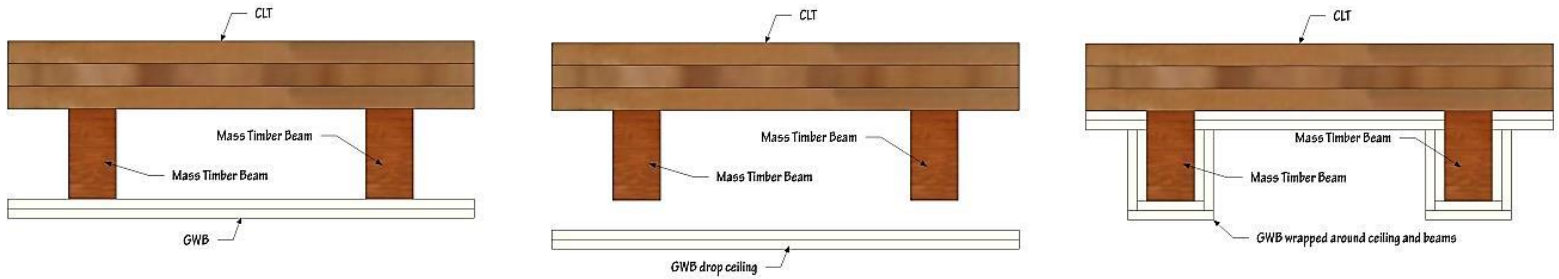
Protected Connections for Enhanced Fire Performance

Treatment of Concealed Spaces



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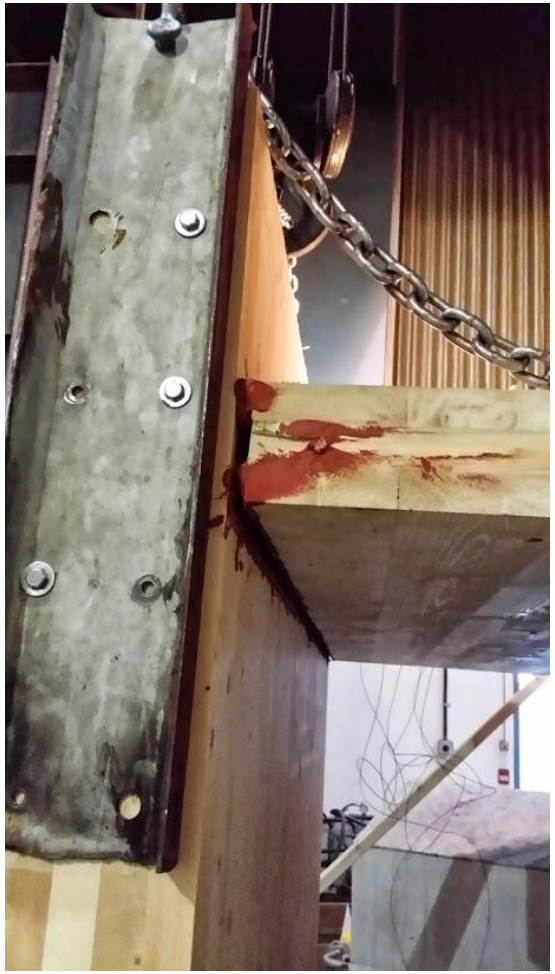
Firestopping - Joints



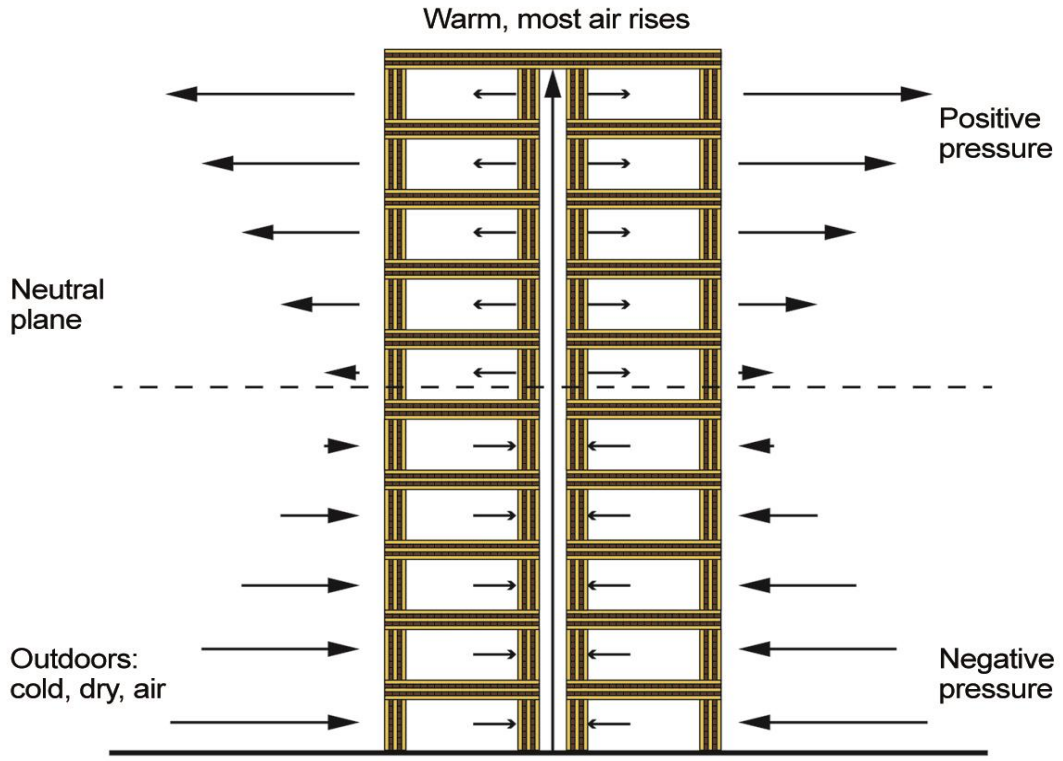
Results to come

Firestopping - Penetrations

FII/ FPI Firestop Test 2013/02/04

High Building Provisions

- Smoke Control
- Fire Department Response



Sprinkler Systems

Construction Fires

Laminated 2x6 elevator shaft

5 Conclusion

Future Editions

- First edition needed to capture all the issues
- Next edition needs to:
  - Edit out some issues
  - Look more at the solutions
  - Consider newer materials
  - Look at where appropriately protected light timber may be acceptable – if it is fully encapsulated it does not need to be mass timber
  - Address quality control
  - Firefighting assumptions

Acknowledgments

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- Lead Authors
  - *Andrew Harmsworth*
  - *Christian Dagenais*
- Co-authors
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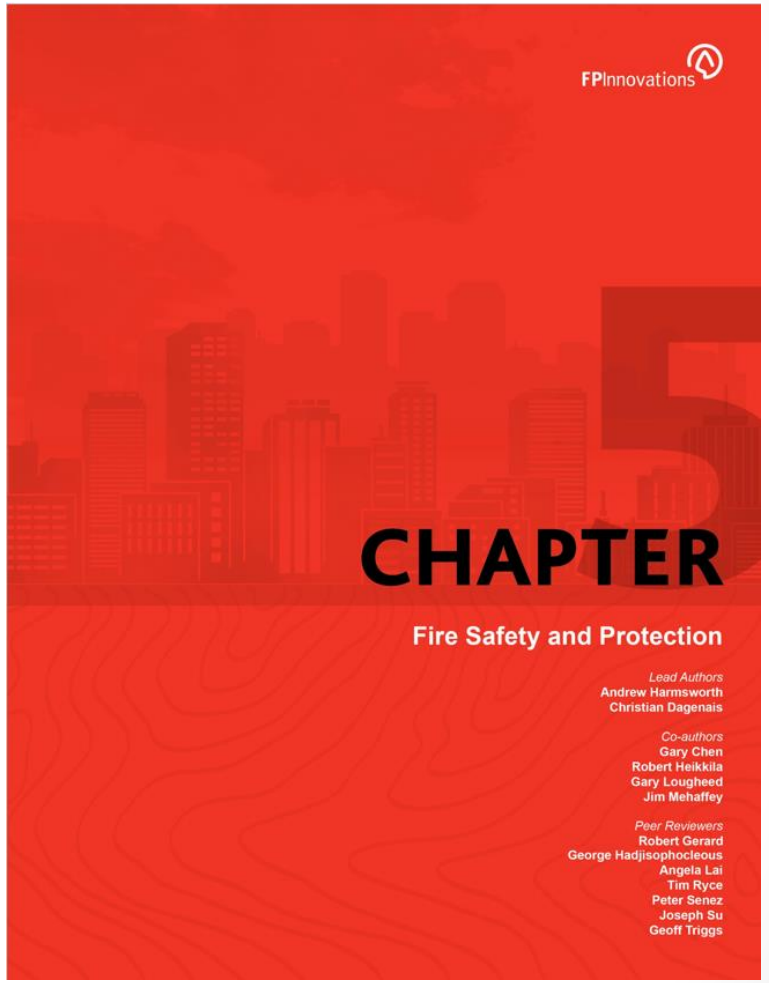

Thank You

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