

# Tall Wood

The Next 20 Years, The Next 20 Storeys

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## What Building Officials Need to Know

A copy of this presentation is available at:

[http://www.ghl.ca/shared/Tall\\_Wood\\_Presentation \(BOABC Nov 2013\).pdf](http://www.ghl.ca/shared/Tall_Wood_Presentation_(BOABC_Nov_2013).pdf)

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Email: [ah@ghl.ca](mailto:ah@ghl.ca)

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
- No system design – won't sell you things you don't need

# About GHL

- “Code Consulting” firm
- Prefer “Fire Engineering”
  - Focus on Part 3
  - Fire hazard analysis
  - Fire risk analysis
  - Structural fire resistance
  - Heat transfer
  - Smoke control design

# GHL Staff

- 6 Engineers – 4 with Master's Degrees in Fire Science
- 1 Architect
- 2 former Building Officials
- 3 BCQ qualified Technologists  
(Qualified as Building Officials)

# Building Code Committee Work

- APEG Building Codes Committee (Khash Vorell / Andrew Harmsworth)
- BC Appeal Board (Frankie Victor)

# Research Work

- BC Wood First Advisory Committee to Forestry Investment Innovations
- CAN 086 Task Group on Fire (Andrew Harmsworth)
- NEWBuildS Research Network (Andrew Harmsworth, Board of Directors) – 40 Master's and PhD Students
- Fire Risk Assessment for Alternative Solutions (Gary Chen)
- Effectiveness of Sprinkler Systems after an Earthquake.



# Research Work

- 6 Storey Group C (Residential) – Code Change (Andrew Harmsworth / Gary Chen, 2009)
- Group D (Office) Studies – 6 Storey Frame and 8 Storey Heavy Timber (HT)
- MSc Studies on Effects of Fire as a Structural Load (Gary Chen) - Current
- Lead Author, Tall Wood Guide with FP Innovations

# 6 Storey Wood - 1871



Wikipedia



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# 9 Storey Heavy Timber - 1905



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# Today



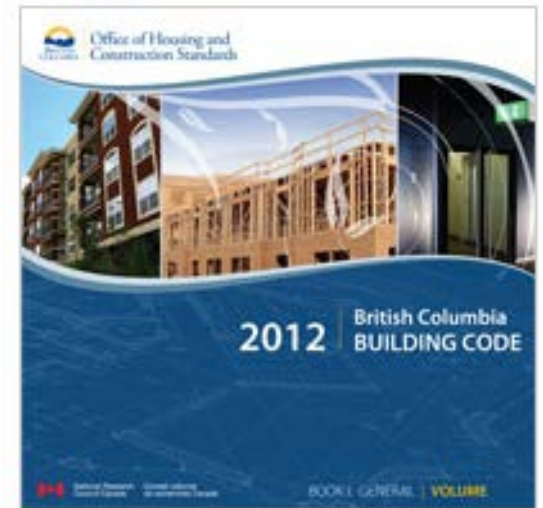
# We Used to Know How to Do It



# What Happened

- Greater concern with fire safety.
- National Building Code of 1941.
- Initially prefaces with the idea that it was a 'Guide'.
- Over time it became a restrictive document.

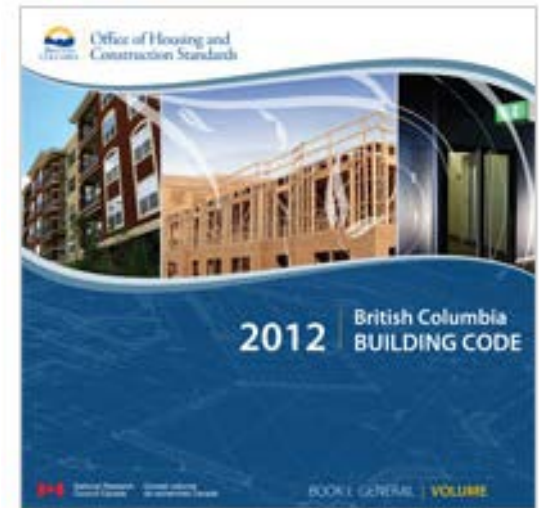
# The Building Code



It is a consensus document:

- It regulates construction of buildings.
- Traditionally written by NRCC (Constitution).
- The Province adopts it on the public's behalf.
- Code measures are public interest decisions.

# Risk



Buildings are subject to risks:

- Code compliance  $\neq$  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.



# Codes and Mass Timber

1905 Pre-NBCC

1941 NBCC

2015 NBCC  
(Proposed)

1953...2010  
NBCC

1941, 2015 NBCC

2010  
NBCC



Vancouver



Québec City

**Building Code Compliance**

**Acceptable Solutions**

**Alternative Solutions**



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Courtesy FPInnovations  
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# History and Background

## Use of Combustible Construction

- Up to early 1900's
  - Regulated by insurance industry
  - 5 and 6 storey wood frame was common
  - 8 and 9 storey HT common
- NBCC 1941, introduced height and area limits
- NBCC 1965, 3 storey height limit
- BCBC 1973 (NBCC 1970), 3 storey
- BCBC 1992 (NBCC 1990), 4 storey
- BCBC 2006 (April 4, 2009), 6 storey height limit

# Thoughts on Codes

- Code should not care what material you use.
- All materials and design methods should be required to meet the same performance level.
- Code should be based on science, not emotion.
- Designers and Owners should be able to choose the best material for the job.

# New Concerns

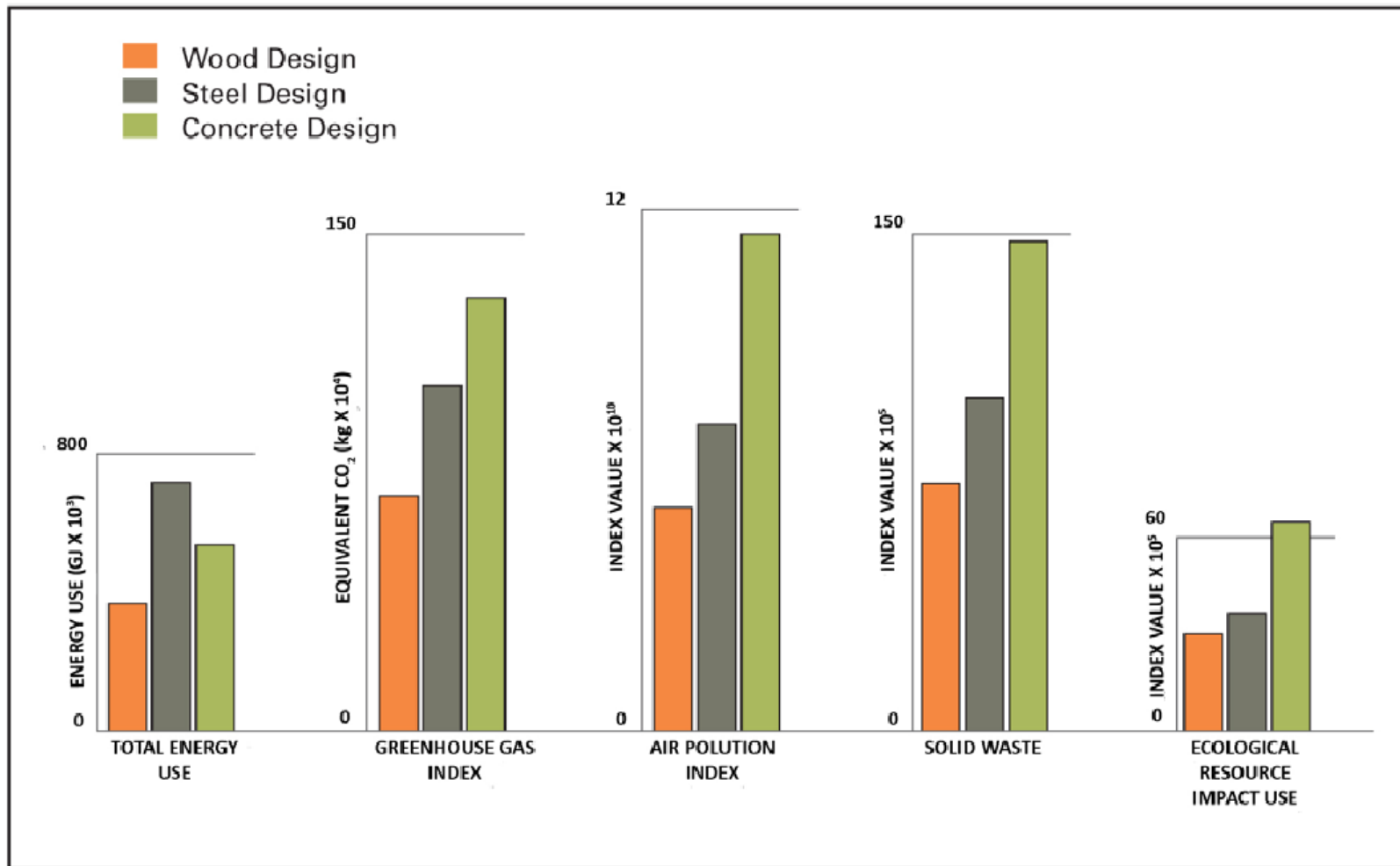
The Code should not prevent materials and methods that address concerns not addressed by the Code.

# Why Wood?

Greenhouse gas concerns:

- Steel and concrete production produces large quantities of CO<sub>2</sub>.
- Wood production produces less CO<sub>2</sub>.
- Wood buildings sequester CO<sub>2</sub>.

# Environmental Impact of Structural Typologies



Courtesy CWC

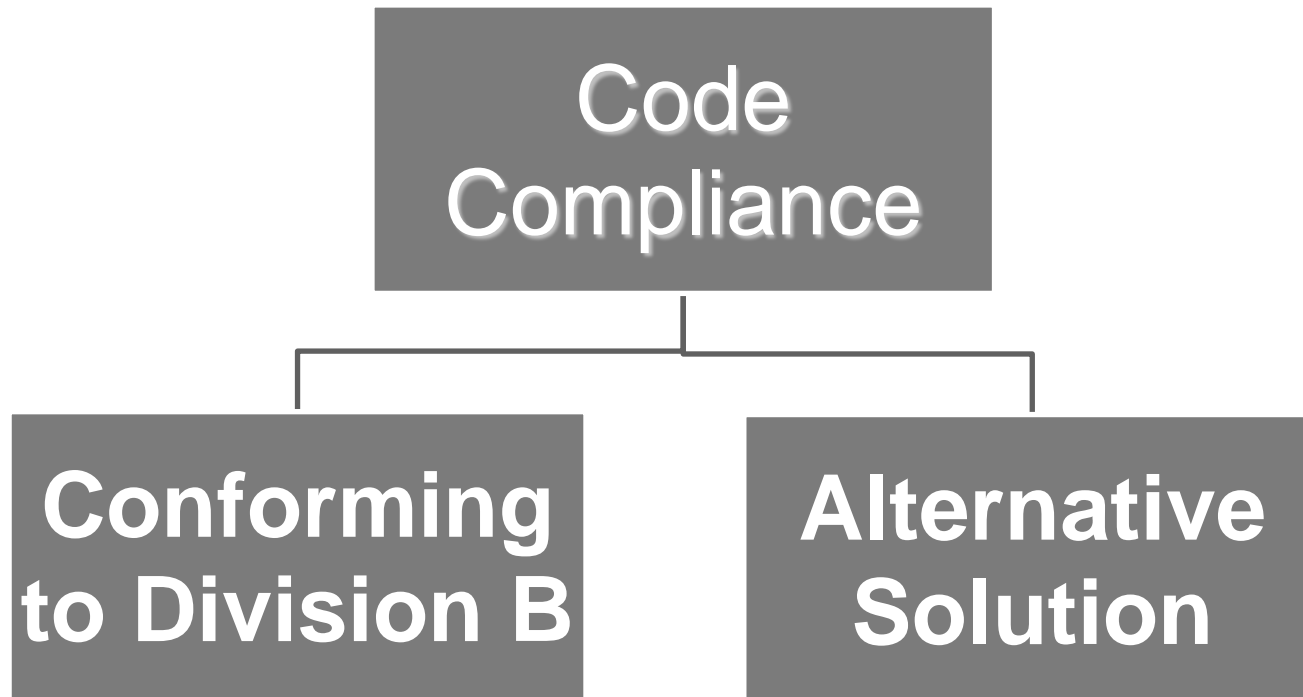


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# 2005 – Objective Based

- Objective-based Code a fundamental change.
- Code provides solutions.
- Establishes objectives and functional statements.

# Objective Based Code





# Risk

- Probability of Failure x Consequence of Failure
- Generally with fire:
  - Probability is very small
  - Consequence is very large
- Approach to address risk includes:
  - Minimize the probability
  - Minimize the consequence
  - Minimize both the probability and the consequence

# Fundamental

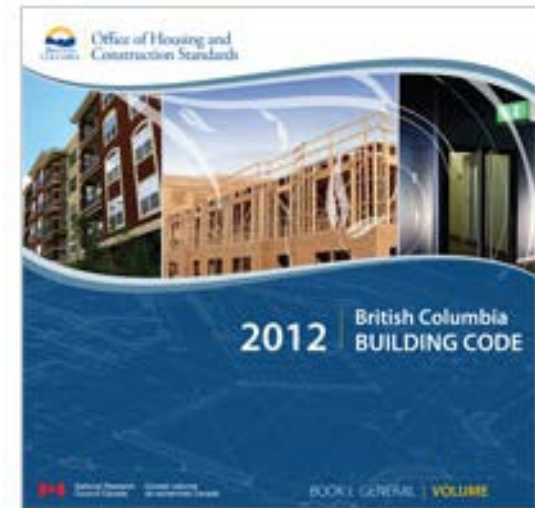
Division B is only one solution.

There can be other solutions.

# Level of Performance

Limitation is that you must provide at least the level of performance that the Division B Solution provides.

# BC 6 Storey Residential



GHL prepared the risk analysis.

Essentially an 'Alternative Solution' that was incorporated in the Code.

GHL argued that risks were equivalent to existing allowable building areas and heights if appropriate provisions were made.

# Peer Review and Consultation

GHL's study on risks Peer Reviewed.

Public consultation.

Peer review.

# Where Are We Now?

BC Code allows 6 Storey Residential, limited area.

Quebec interim changes.

NBC 2015 proposed changes to allow 6 storey wood frame published for comment.

# GHL Experience - 6 Storey

Complex, requires good engineering.

Design team, Contractor's qualifications very important.

Definitely practical and safe.







# Construction Fires





Laminated 2x6 elevator shaft





# Mass Timber Terminology

Consensus is developing to use the term Mass Timber.

(Massive lost out – too late)

Avoids confusion with the specified sizes for Heavy Timber in Division B.

# Mass Timber Fire Resistance

Two methods:

- Encapsulation
- Char

# Tall Wood Guide

FPInnovations project funded by NRCan

- 400 Pages.
- 70 on Fire
- Fire Section first to provide comprehensive review of fire issues in tall wood buildings.
- Still a lot of work, but a team of authors and reviewers conclude it can be done.

# Approach Chosen

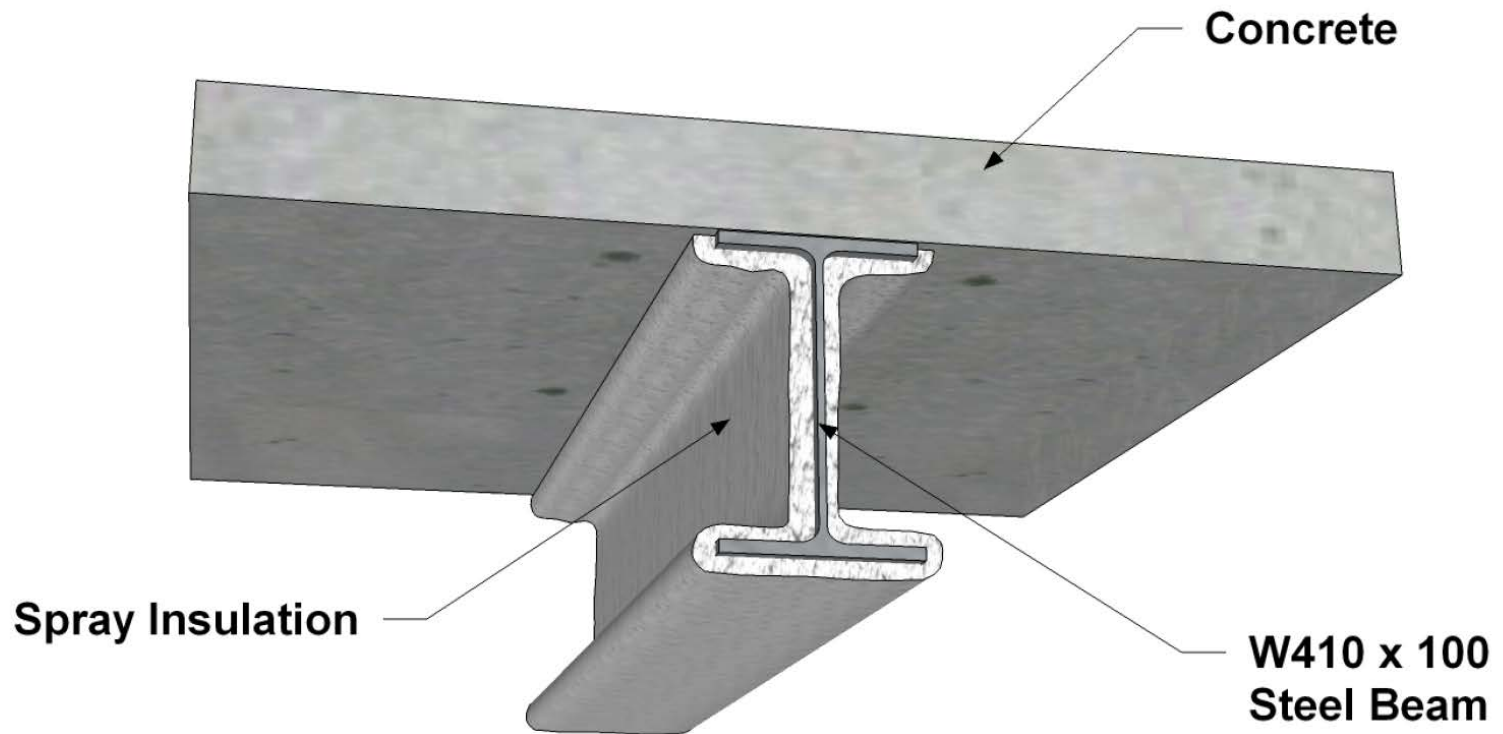
- Intent was to demonstrate that it CAN BE DONE.
- Nationally acceptable Risk Tolerance.
- Took a conservative approach.
- Recommends that an approach of encapsulation of combustibles:



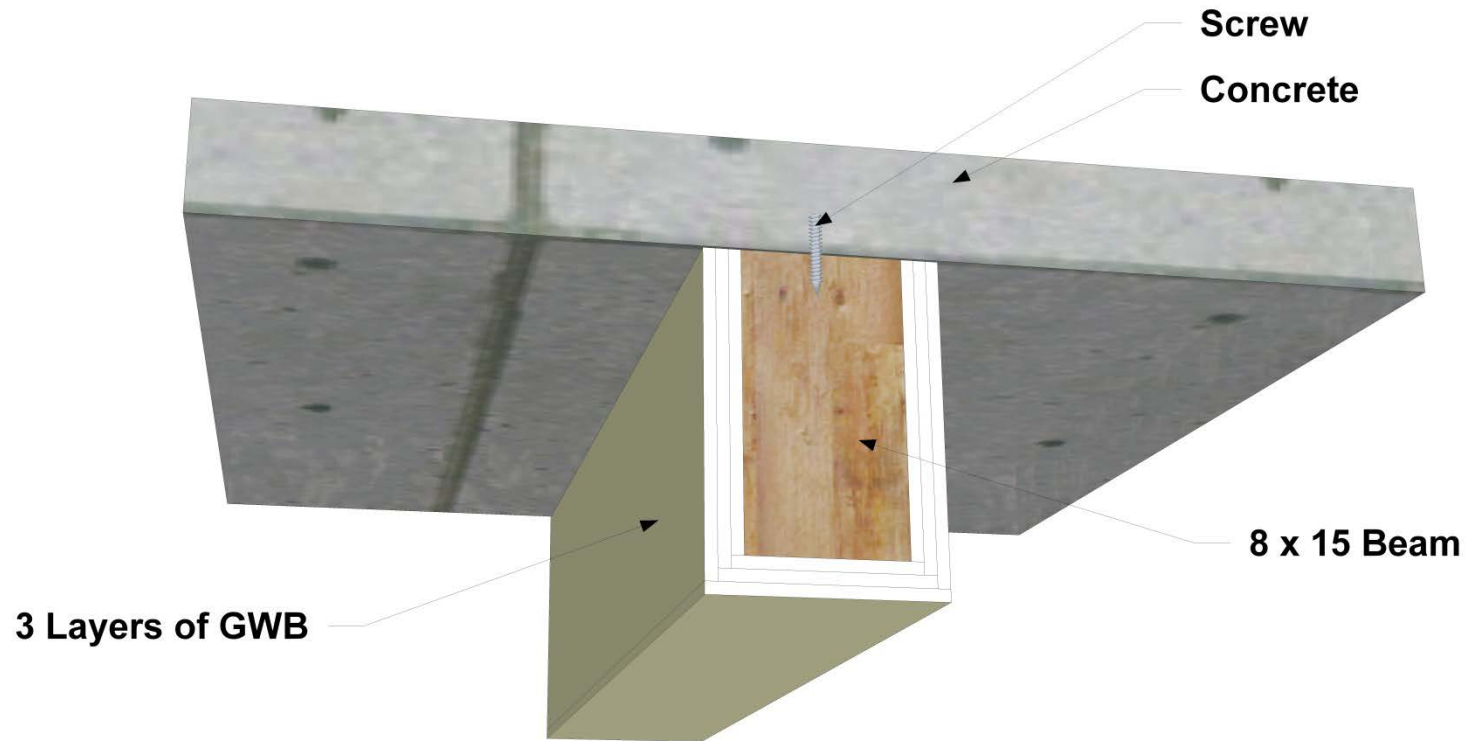
# Possible Approaches -

- Full Performance based assessment
  - Lack of performance criteria / inconsistent benchmarks
  - Time consuming
- Extend permitted combustible construction based on Comparative Risk Analysis
  - WIDC
  - BC 6 Storey
- Equivalent Component Performance
  - Protect components for equivalent performance

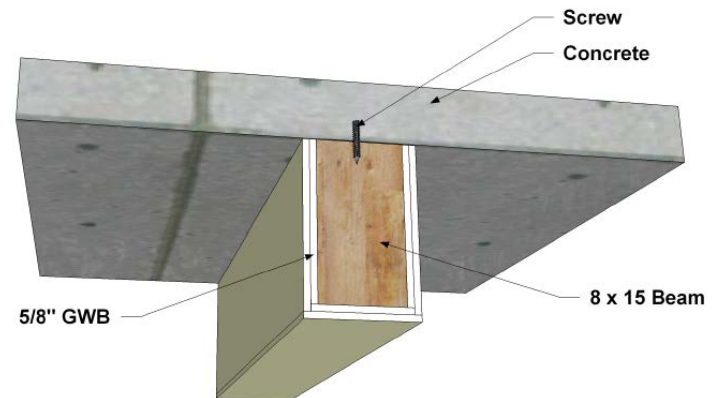
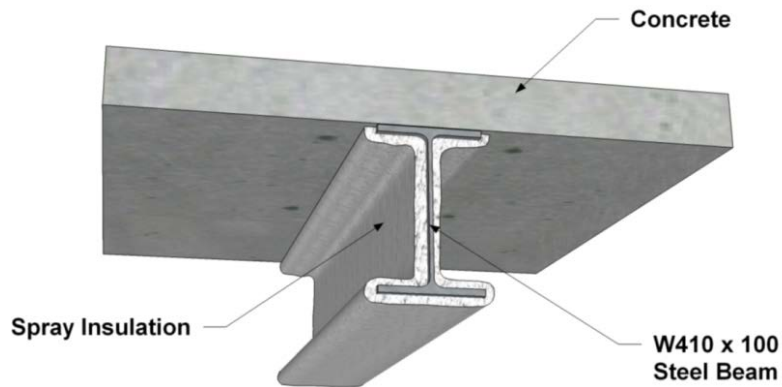
# Encapsulation



# Encapsulation



# What is the Difference



# Complete Encapsulation

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

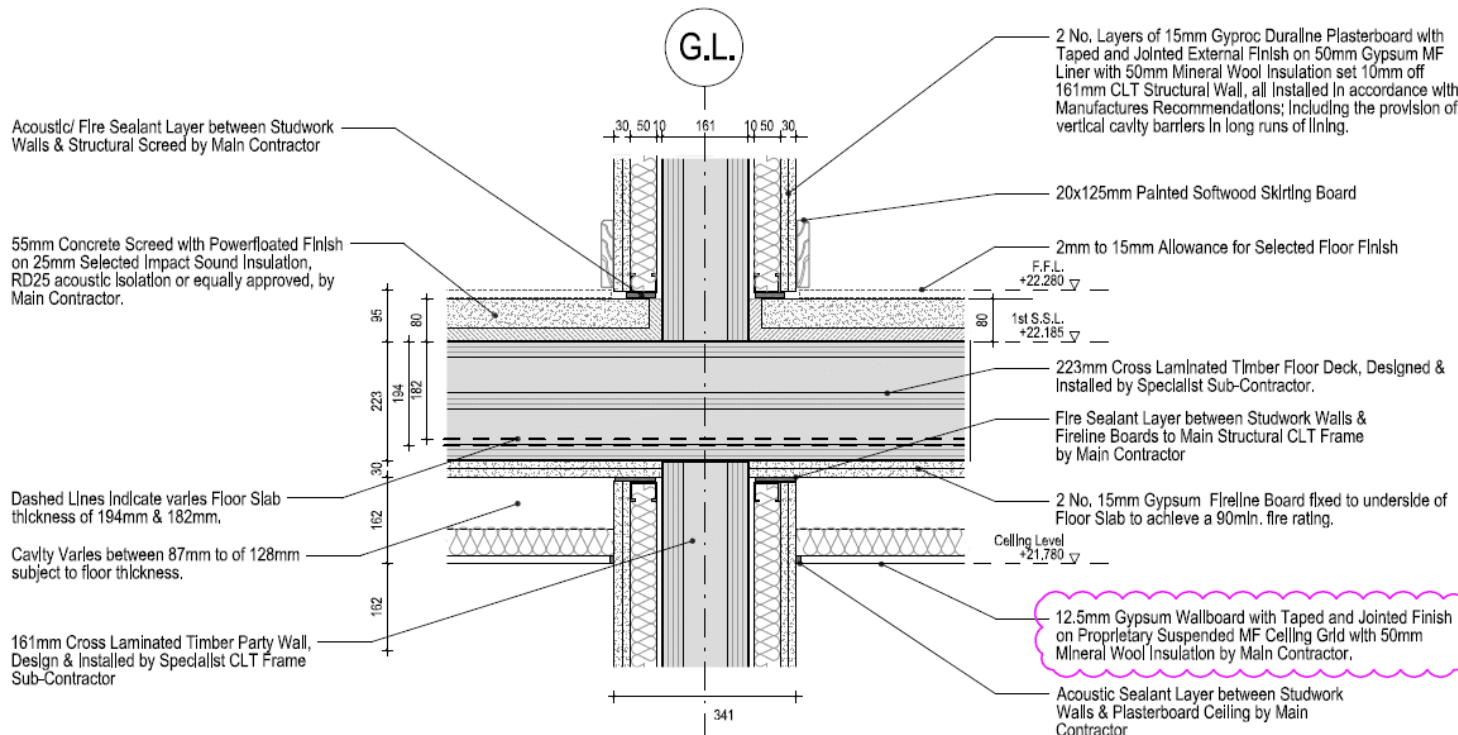
# Fire Resistance Rating of Gypsum Board Membranes

Gypsum Board Members	Fire Resistance Rating
One layer of 12.7mm (½in) GWB	15min
One layer of 15.9mm (⅝in) GWB	30min
Two layers of 12.7mm (½in) GWB	40min
Two layers of 15.9mm (⅝in) GWB	60min
Three layers of 15.9mm (⅝in) GWB	90min
Four layers of 15.9mm (⅝in) GWB	120min

# UK Early Example – Bridport House



## Fire / Acoustic



D002  
176-A-C-400-11

Junction of 1st-4th Floor & Party Wall

Scale 1:10

CLT Symposium Moncton  
Philipp Zumbrunn  
12 October 2011



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# Peel Off the Layers

Then, suggested we peel off the layers.

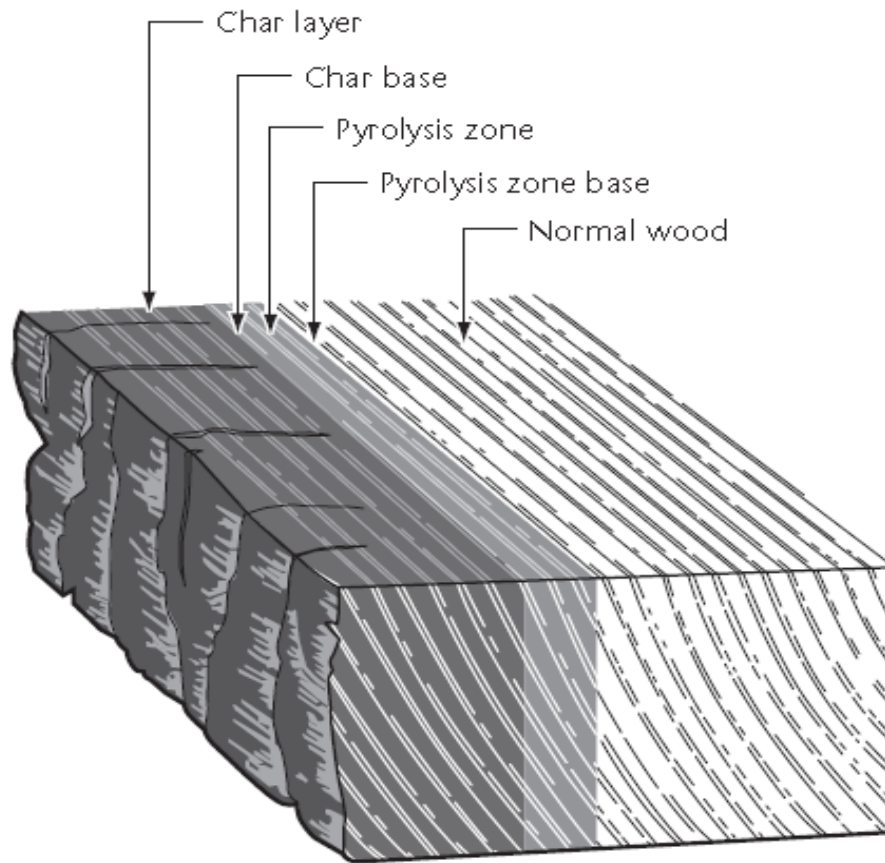


# Char → Fire Resistance



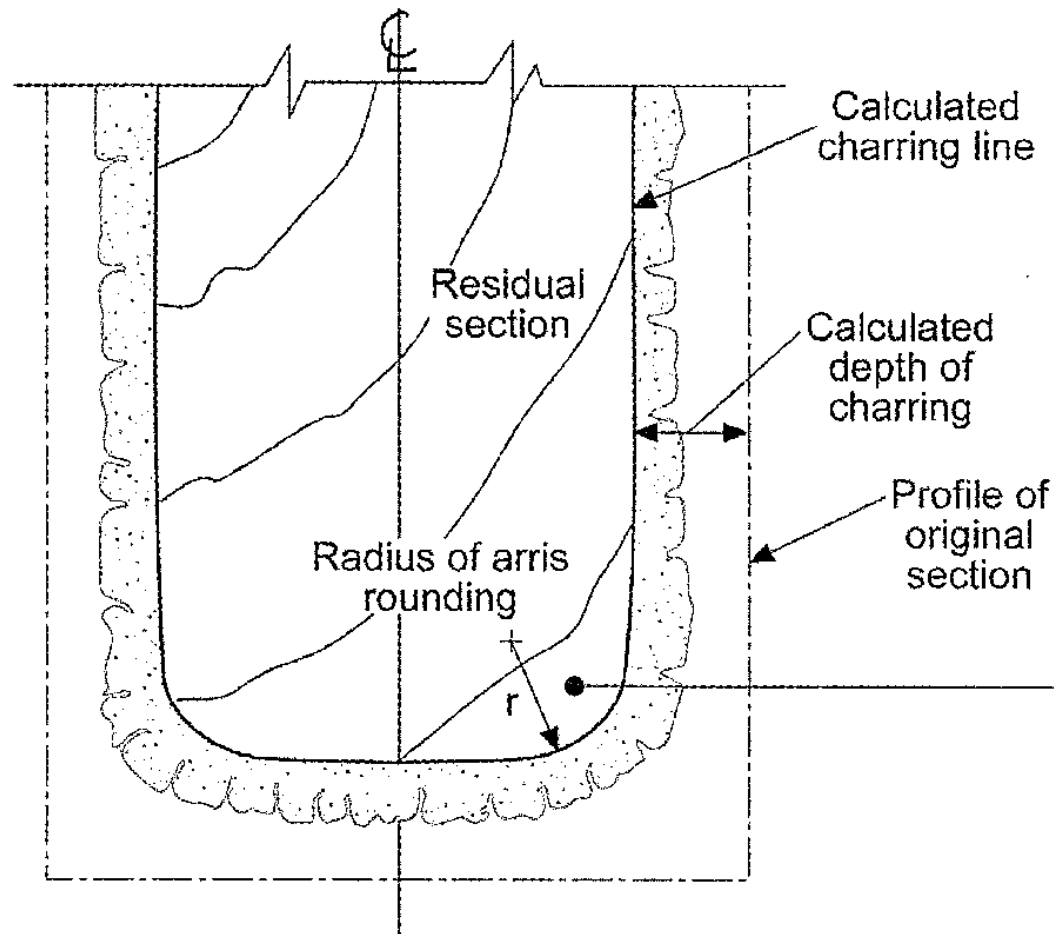


# Char Layer – Small-Scale Flame Test





# Concept of Mass Timber Design for Fire Resistance



# Size of Members

Upsize of members for fire.

But this refers to critical collapse loads only.

Often performance governs (vibration, deflection).

Members may not need to increase in size.

# What has greater risk?

# 2h Noncombustible

BXUV.G512 - Fire Resistance Ratings - ANSI/UL 263

<http://database.ul.com/cgi-bin/ulweb/LISEXT/1FRAME/FireResistanceWizard.html>

## Fire Resistance Ratings - ANSI/UL 263

See General Information for Fire Resistance Ratings - ANSI/UL 263

Design No. G512

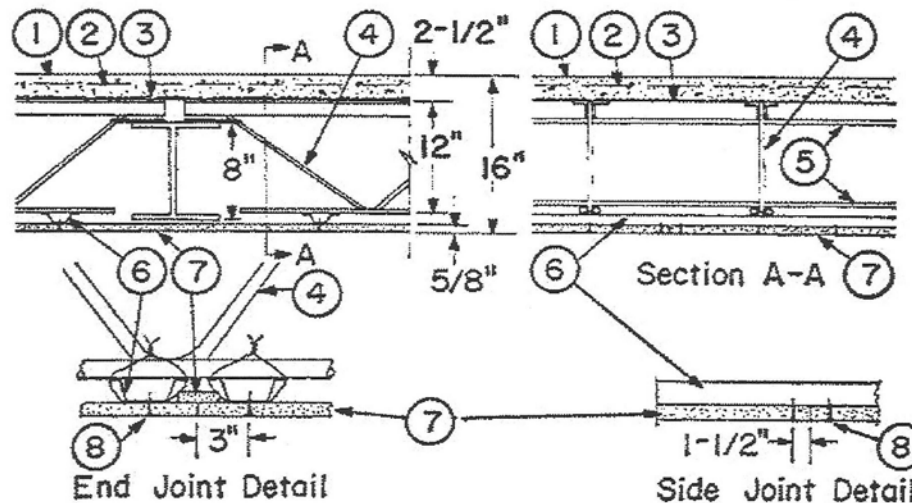
February 18, 2010

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.

1 of 4

4/27/11 1:26 PM



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This, especially if wrapped in 2 layers of GWB





# Comparison

Code refers to comparison of level of performance of the Alternative Solution.

Useful to look at an acceptable solution for Earth Sciences Building compared to the proposed solution.

# Risk Analysis

- Another approach.
- UBC Earth Sciences Building.

# 5 Storey A-2 Occupancy UBC Earth Sciences Building

Acceptable solution for A-2 occupancies:

- 1h noncombustible construction
- Alternative solution to address 1h mass timber



# Approach

Risk Analysis

Pre-Flashover

Post-Flashover

# Pre - Flashover

95% sprinkler reliability.

Only necessary to address 5% probability.

Low occupant load, extra fire separations.











# Peer Reviewed

GHl was the proponent.

Gage-Babcock & Associates Ltd was the reviewer.

All large UBC buildings done by peer review.

# Mass Timber vs Steel

## Wood

- Expensive to protect.
- Highly reliable.
- Reproducible results.
- Contributes Fire Load

## Steel

- Cheap to protect.
- How reliable?
- How reproducible are the results?
- Burns Out

# Concrete

## Concrete

Agreed generally more fire safe than mass timber.

Are fire rating designs and cover still applicable?

Is 1/2in of cover acceptable per IBC?

Spalling is unpredictable.

Concrete – how do you repair it - \$30B loss in NZ

# Firefighting Considerations

- If Sprinklered – no difference from sprinklered nc building
- Encapsulation == encapsulated steel
- Performance in the first half hour will be the same as concrete or steel building of the same design.
- Evacuation the same.
- Difference may be cleanup, as mass timber may continue to burn and char.
- Difference – If the sprinklers fail, longer cleanup





# Connections

Not specifically addressed for Steel or Concrete

Especially intumescent – problems noted



# We Used to Know How to Do It



# Protected Connections for Enhanced Fire Performance



b) Connection covered with wood paneling



# Protected Connections for Enhanced Fire Performance



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



# Intumescent Paint

Most Tested on Steel Beams – no movement or cracking

Effectiveness on connections, steel or wood is not known



# Issues

A few issues that came up worth discussing.

Performance targets not clear.

Why 2h FRR?

Why does ULC S101 only require 1 test?

Is criteria set by residential 1h compartment rating?



# Sprinkler Reliability

To what degree can we rely on sprinklers?

Consensus of authors:

- On site water supply needed.

Addresses – seismic concerns:

- Fire after 2h?

US data confirms that sprinklers are 90% reliable; Canadian data, if monitored and supervised, reliability is much higher.

In my opinion, a fully sprinklered 2h combustible building can meet risk fully exposed, but not politically saleable in most areas.

# Seismic

*"An internal report of the City of Vancouver concludes that, at present, an M-7 earthquake would render the Greater Vancouver Water District supply system completely dysfunctional with 1000 water main breaks and 1000 service breaks." (Robertson 2000)*

**Conclusion: - We need an on site water supply**

# Design Fire

Is the standard fire acceptable, or do we need to look at real fires?

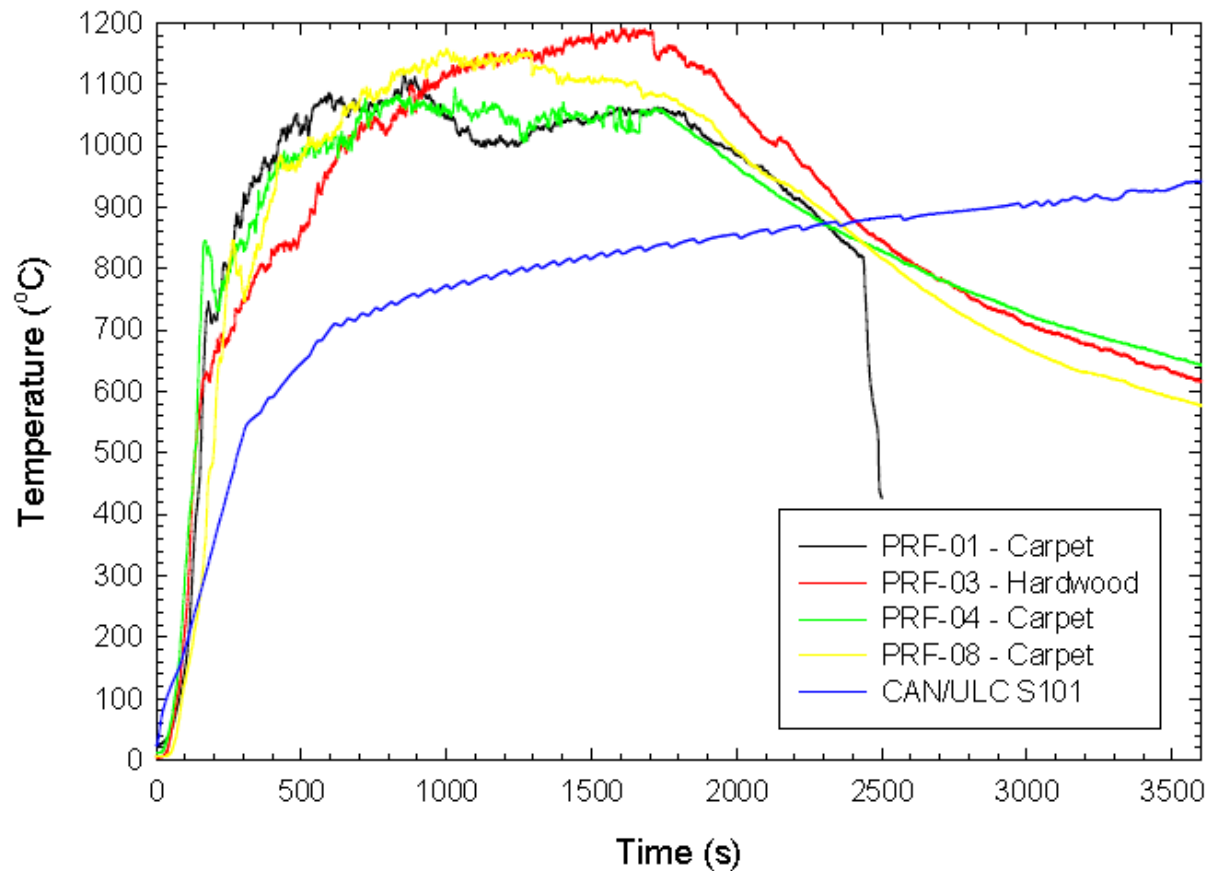
## Conclusion:

- Office, Residential Occupancies – standard fire is acceptable.
- High hazard, should probably assess real fires.

*Note if using reduced load, must use 'natural fire'.*



# Standard Fire vs. Design Fire Scenarios



# Void Spaces

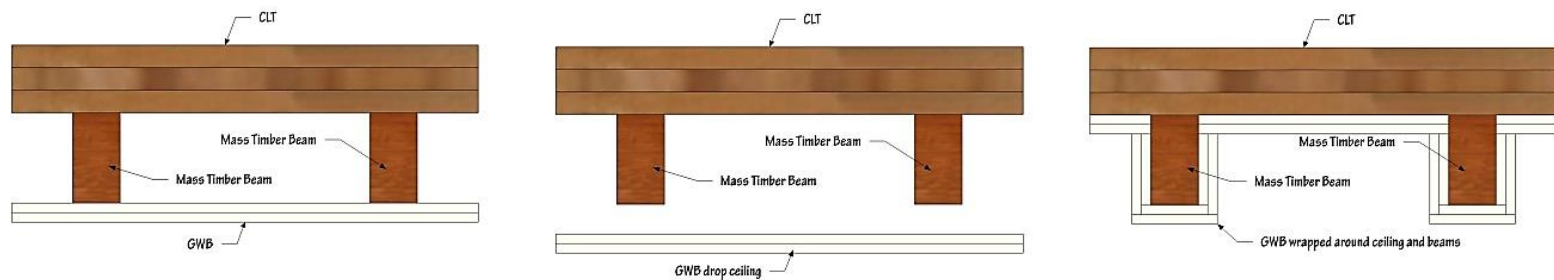
Limited but they will occur.

How big a void space is acceptable?

Unsprinklered (NFPA 13 provisions applicable).

- Sprinklered?

# Approaches to Encapsulation Creating Concealed Spaces





# Mass Timber within Occupied Spaces

Mass Timber typically FSR 40 to 50

- Wall and ceiling finishes up to 25 mm in thickness;
- Floor finishes of any thickness;
- Solid wood partitions that are not a part of floor to floor separations or exit separations;
- Light wood framing in partitions that are not a part of floor to floor separations or exit separations.



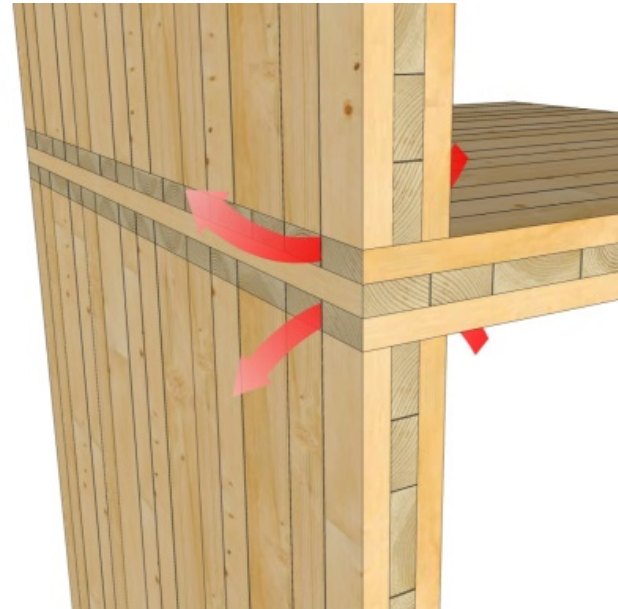
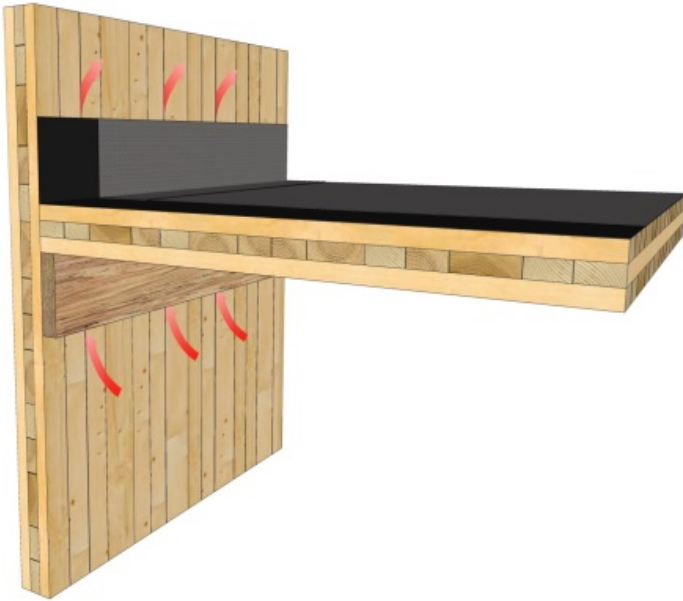
# Firestopping

Don't see a lot of issues.

Some public testing being done for WIDC.

But, be careful:

# CLT Smoke Leakage Paths



# Fire Tests not so bad



Results to come



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# Exterior Cladding

Unlikely to be fully exposed.

Code has a nice performance Standard for this, just needs to be applied to the whole wall assembly.

# Cladding





# What Was Accomplished

Various reports out there on tall wood.

Limited review of fire issues, many said very little.

Green/Kharsh/Triggs – some more detail and a lot of effort on detailing to address approach – good first step but needed a lot more detail.

First full summary of all the fire issues.

# European Example

8 Storey Residential in London.

Eurban / CarbonEng, A Design Build Contractor with CLT.

Courtesy of Philipp Zumbrunnen.

# Bridport House



CLT Symposium Moncton

Philipp Zumbrunn

12 October 2011

# Bridport House / Facts

- 7 weeks design period
- 10 weeks fabrication prior to start on site
- 12 weeks installation
- CLT Panels 1576m<sup>3</sup>
- Steel Elements 1520kg
- 30 CLT deliveries



# Bridport House / The Installation



Day 40



# Developments in Canada

NEWBuildS - Network for Engineered Wood-based Building Systems.

CAN/CSA O86 Task Group on Wood Fire Ratings.

NRC/CWC Research consortium on higher wood buildings.

FP Innovations CLT Development.

National Code Process.



# NEWBuildS

NEWBuildS - Network for Engineered Wood-Based Building Systems:

- History of the Code studies
- Fire Tests of CLT rooms
- Hybrid Construction (Steel/Wood and Concrete/Wood)

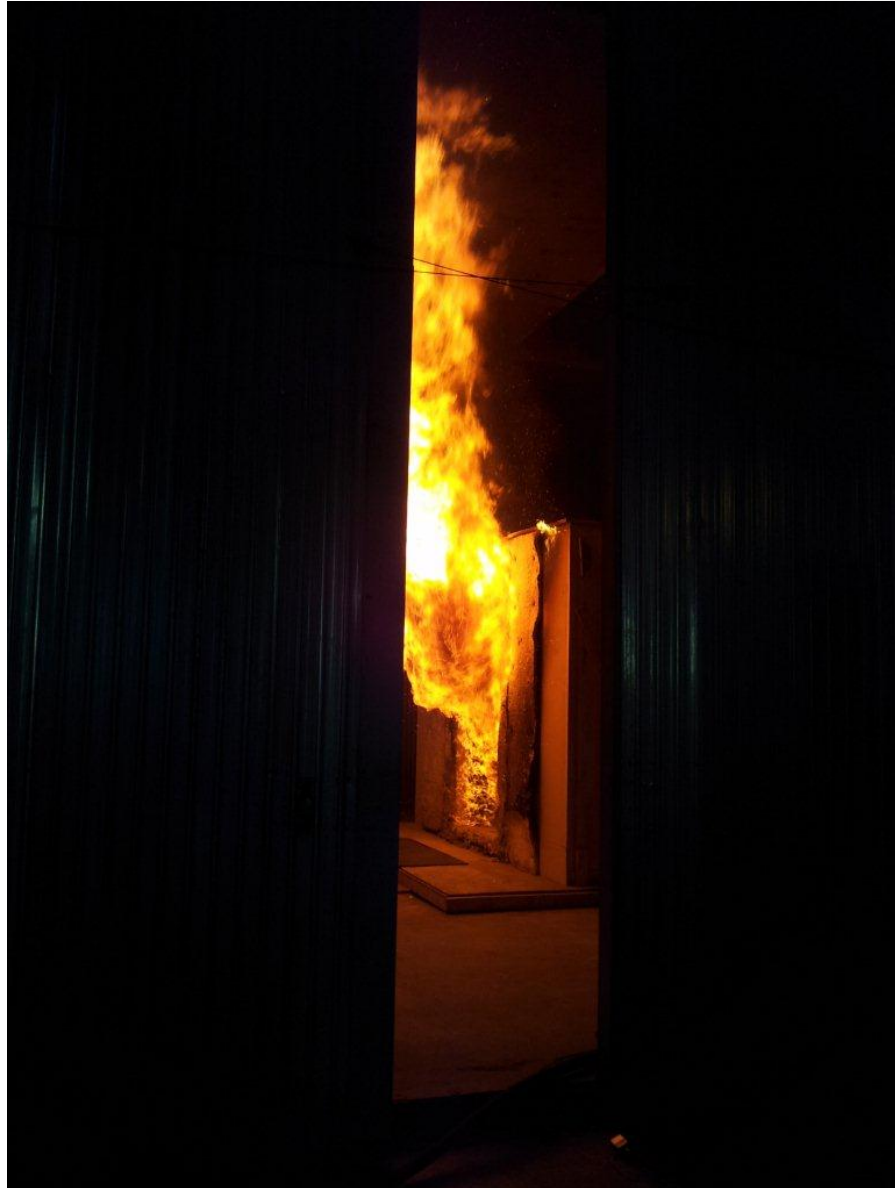
# NEWBuildS



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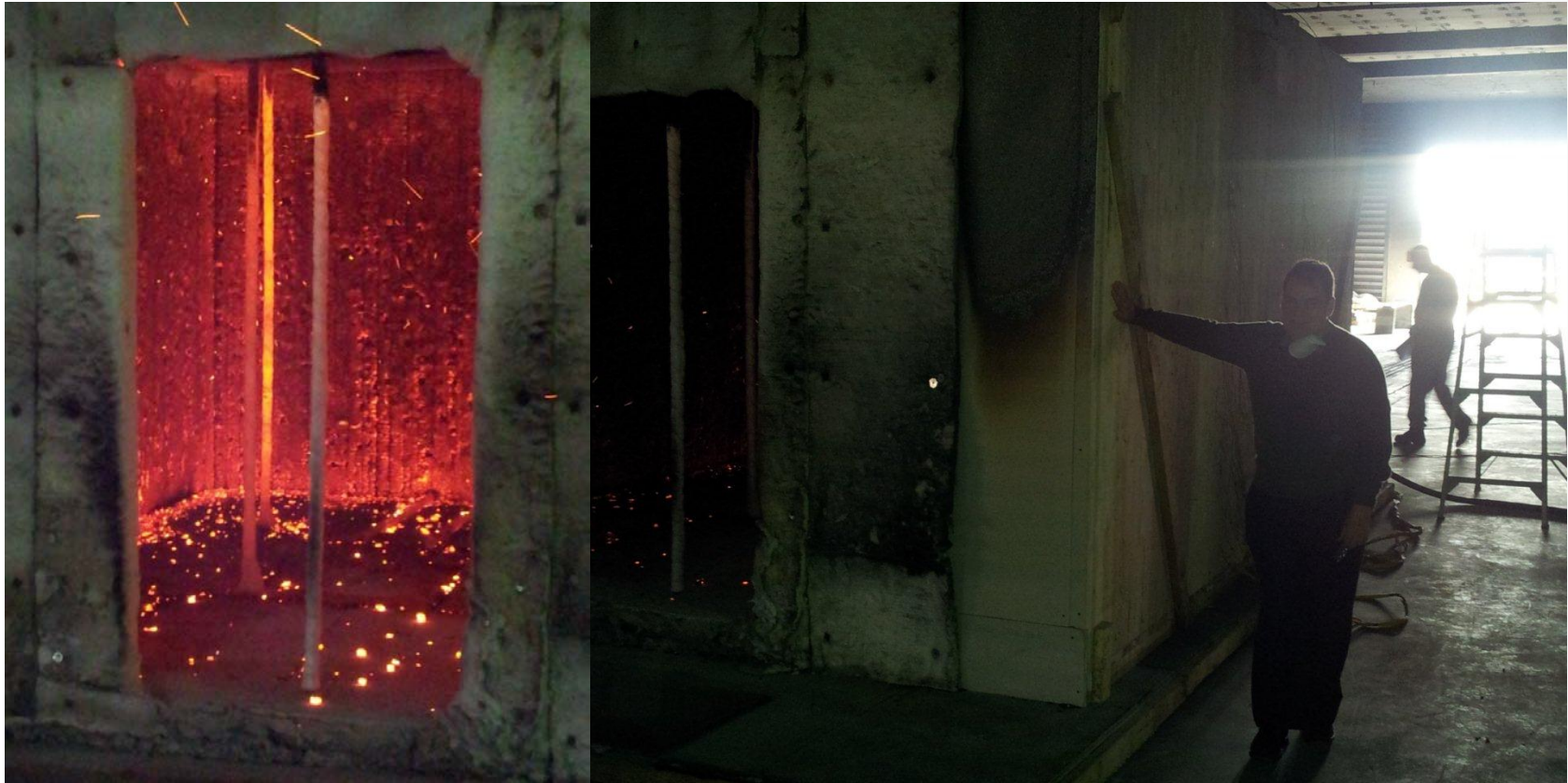
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# NEWBuildS



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# NRC/CWC Research Consortium

Research consortium on higher wood buildings:

- Looking at 6 storey combustible frame construction.
- Learned group similar to Code Committee.
- Comparative performance testing (fire and sound).



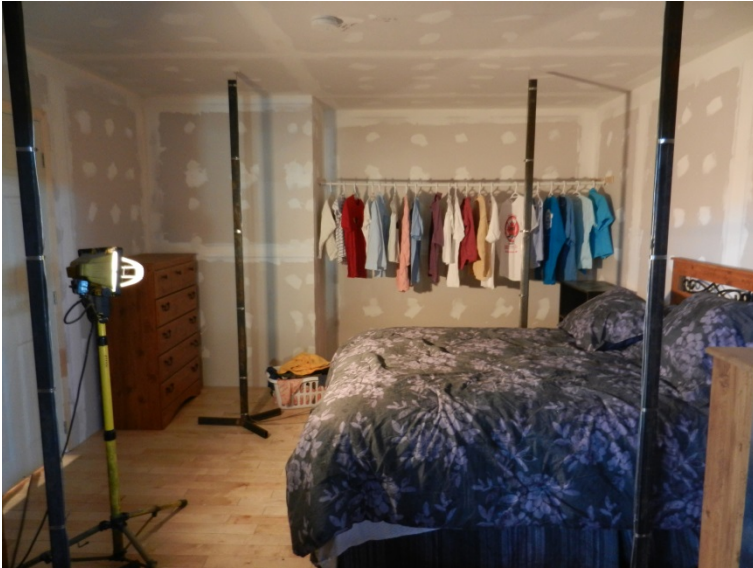
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Fire Test Fuel





# NRC/CWC Research Consortium



LWF Start of Test



CLT Start of Test

# NRC/CWC Research Consortium



LWF Fire Test



CLT Fire Test



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LWF



CLT



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# NRC/CWC Research Consortium



Steel



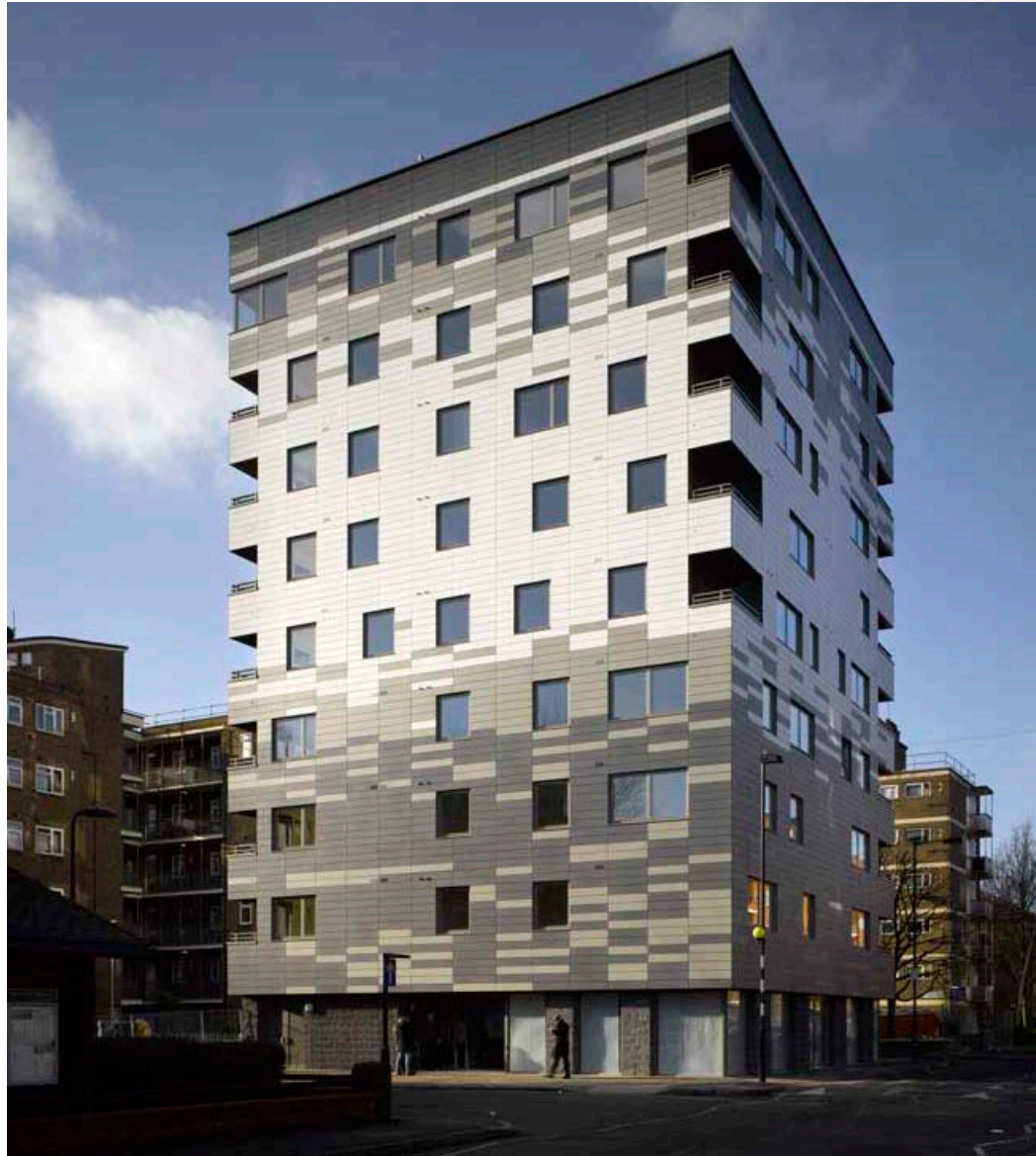
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# The Future

My opinion:

- 6 storey is probably the practical limit for wood frame.
- 8 storey with prefab quality control.
- No significant limit on area for wood frame.
- Structures will set limit on height for Heavy Timber.
- Hybrid buildings of unlimited height and area.



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# Wood Construction

Courtesy FPInnovations

Early 1900's



Late 1900's



Early 2000s



Future Concepts





# Conceptually, How High Can We Go With Wood?

Courtesy FPInnovations



16-Storey in Italy



20-Storey Austria



UBC-RJC 20-Storey



20-Storey Norway

FPInnovations



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Green-Karsh 30-storey ~ 80m



36 storey ~ (95 m)  
Switzerland



312 ft. (95 m) Sitka Spruce  
Canada

# Useful Links

- GHL CONSULTANTS LTD: [www.ghl.ca](http://www.ghl.ca)  
Tall Wood Presentation: [http://www.ghl.ca/shared/Tall Wood Presentation.pdf](http://www.ghl.ca/shared/Tall_Wood_Presentation.pdf)
- Woodworks! National:  
[www.woodworks.org/index.php?option=com\\_content&view=featured&Itemid=112](http://www.woodworks.org/index.php?option=com_content&view=featured&Itemid=112)
- Woodworks! Alberta:  
[www.wood-works.org/index.php?option=com\\_sobipro&sid=61:Wood-WORKS-Alberta&Itemid=228](http://www.wood-works.org/index.php?option=com_sobipro&sid=61:Wood-WORKS-Alberta&Itemid=228)
- Woodworks! BC:  
[www.wood-works.org/index.php?option=com\\_sobipro&sid=61:Wood-WORKS-Alberta&Itemid=228](http://www.wood-works.org/index.php?option=com_sobipro&sid=61:Wood-WORKS-Alberta&Itemid=228)
- Canadian Wood Council: Mid-Rise Construction in BC:  
[http://www.cwc.ca/documents/case\\_studies/Mid-Rise-Construction-in-BC.pdf](http://www.cwc.ca/documents/case_studies/Mid-Rise-Construction-in-BC.pdf)
- [44](#)
- Canadian Wood Council: Innovating with Wood:  
[http://www.cwc.ca/documents/case\\_studies/Four%20demonstration%20Case%20Study\\_May\\_30.pdf](http://www.cwc.ca/documents/case_studies/Four%20demonstration%20Case%20Study_May_30.pdf)
- Technical Guide for the Design and Construction of Tall Wood Buildings in Canada:  
[http://ghl.ca/shared/Tall Wood Building Technical Guide.pdf](http://ghl.ca/shared/Tall_Wood_Building_Technical_Guide.pdf)

# Questions?



# Thank you

A copy of this presentation is available at:

[http://www.ghl.ca/shared/Tall\\_Wood\\_Presentation.pdf](http://www.ghl.ca/shared/Tall_Wood_Presentation.pdf)

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