Tall Wood

The Next 20 Years, The Next 20 Storeys

Fire Safety and Building Codes

A copy of this presentation is available at:
http://www.ghl.ca/shared/Tall_Wood_Presentation (ON Woodworks Nov 2013).pdf

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Canadian Wood Council / Conseil canadien du bois

Wood Solutions Fair

WOODWORKS! Project of the Canadian Wood Council

The Engineering Institute of Canada / L'Institut canadien des ingénieurs

Continuing Education AIA

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Principal, **GHL** Consultants Ltd

Email: 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

Kelly Douglas Building, Vancouver

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Today

Wikipedia

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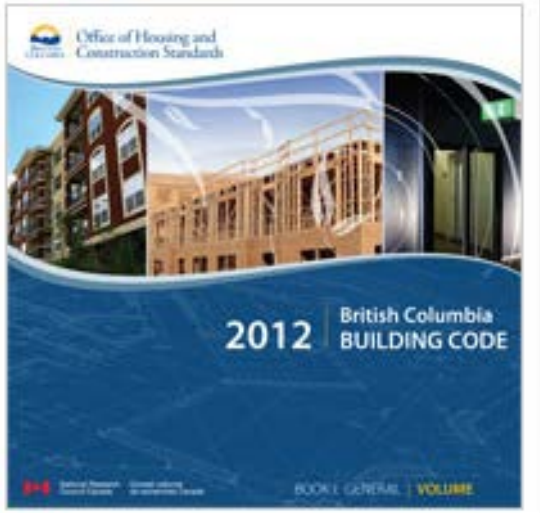
We Used to Know How to Do It

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.

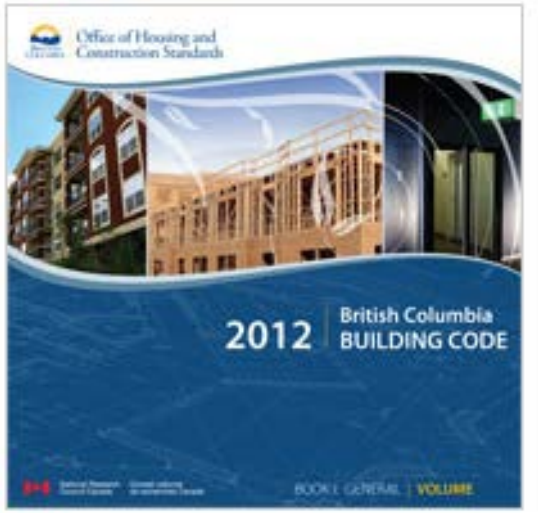
The Building Code



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 ≠ no risk.
- Code compliance = risks at acceptable level.

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History and Background

Use of Combustible Construction

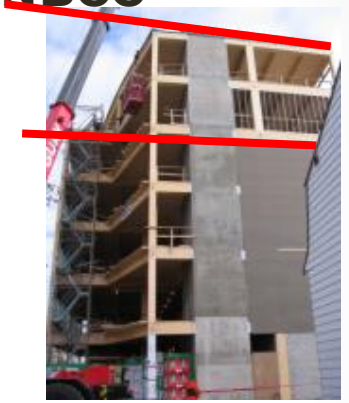
- Up to early 1900's
  - Regulated by insurance industry
  - 5 and 6 storey wood frame was common
  - 8 and 9 storey HT common
- NBCC 1941, introduced height and area limits
- NBCC 1965, 3 storey height limit
- BCBC 1973 (NBCC 1970), 3 storey
- BCBC 1992 (NBCC 1990), 4 storey
- BCBC 2006 (April 4, 2009),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

Codes and Mass Timber

Vancouver

1941, 2015 NBCC

2010 NBCC



Québec City

Building Code Compliance

- **Acceptable Solutions**
- **Alternative Solutions**

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Courtesy FPInnovations

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

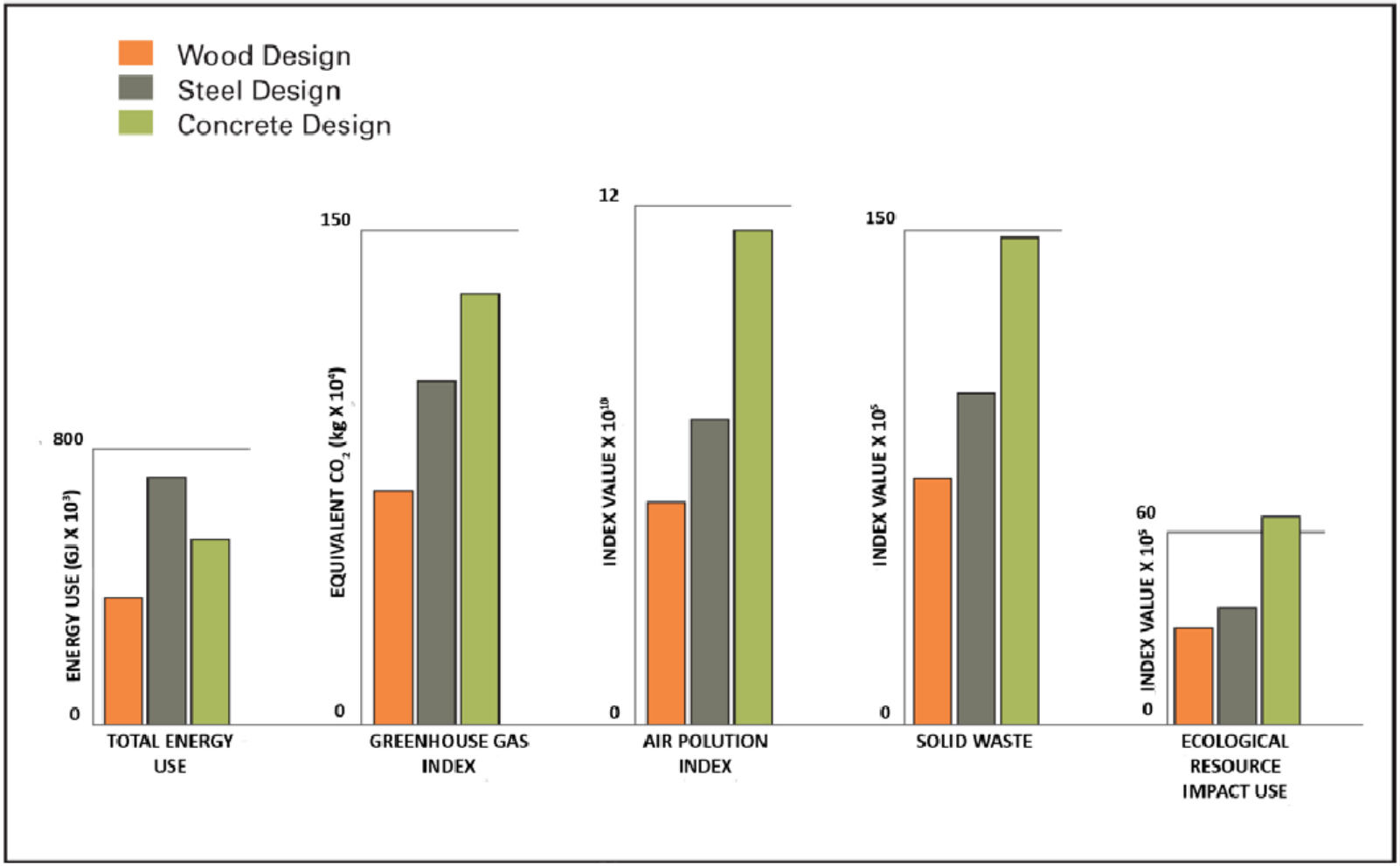
The Code should not prevent materials and methods that address concerns not addressed by the Code.

Why Wood?

Greenhouse gas concerns:

- Steel and concrete production produces large quantities of CO_2.
- Wood production produces less CO_2.
- Wood buildings sequester CO_2.

Environmental Impact of Structural Typologies



Courtesy CWC

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1941 to 1997

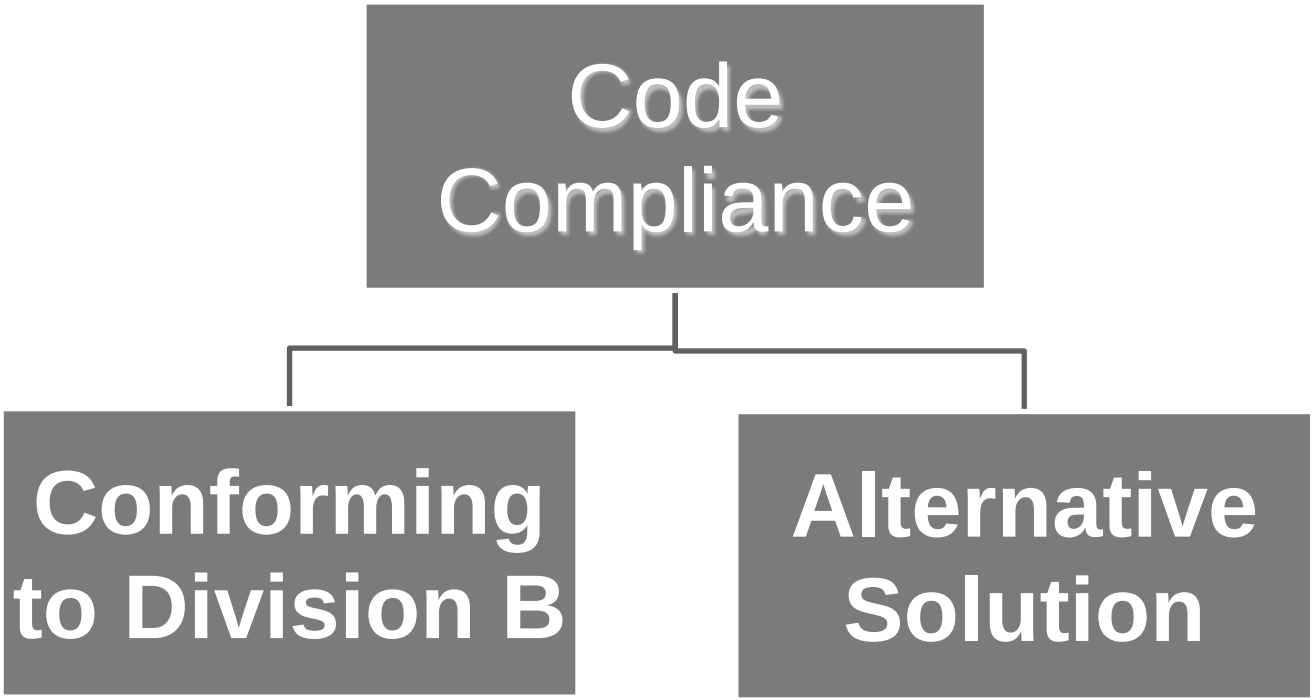
Requirements:

- Prescriptive based Code.
- Code says how you must do it.

2005 – Objective Based

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

Objective Based Code



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Objective Based Code

- Objectives
- Functional Statements
- Define the risk factors the Code is tying to regulate
- Examples
  - **OS1.2** To limit the probability that as a result of the design or construction of the building, a person in or adjacent to the building will be exposed to an unacceptable risk of injury due to fire or explosion impacting areas beyond its point of origin.
  - **OP1.2** To limit…. an unacceptable risk of damage to building due to…

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

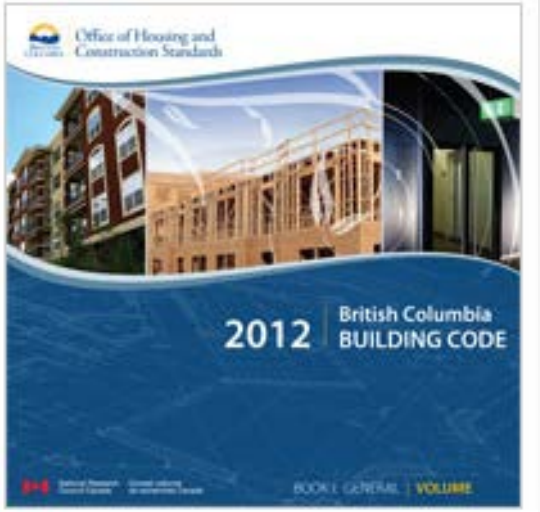
Division B is only one solution.

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.

Code Approach To Risks



Code's general approach:

- Limit building size based on use (occupancy).
- Fire separations, firewalls, fireblocking, firestopping.
- Sprinklers and standpipes.
- Fire alarm systems.
- Fire Department provisions.
- Exit and egress systems.

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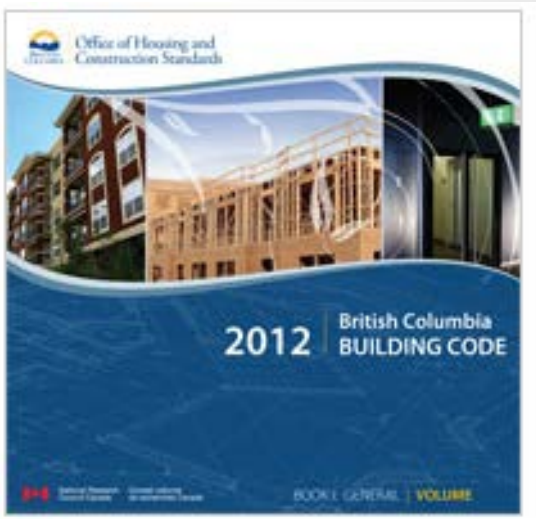
A Few Words on 6 Storey Wood Frame Construction

A dozen projects now complete in BC by GHL.

Numerous under construction.

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.

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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.

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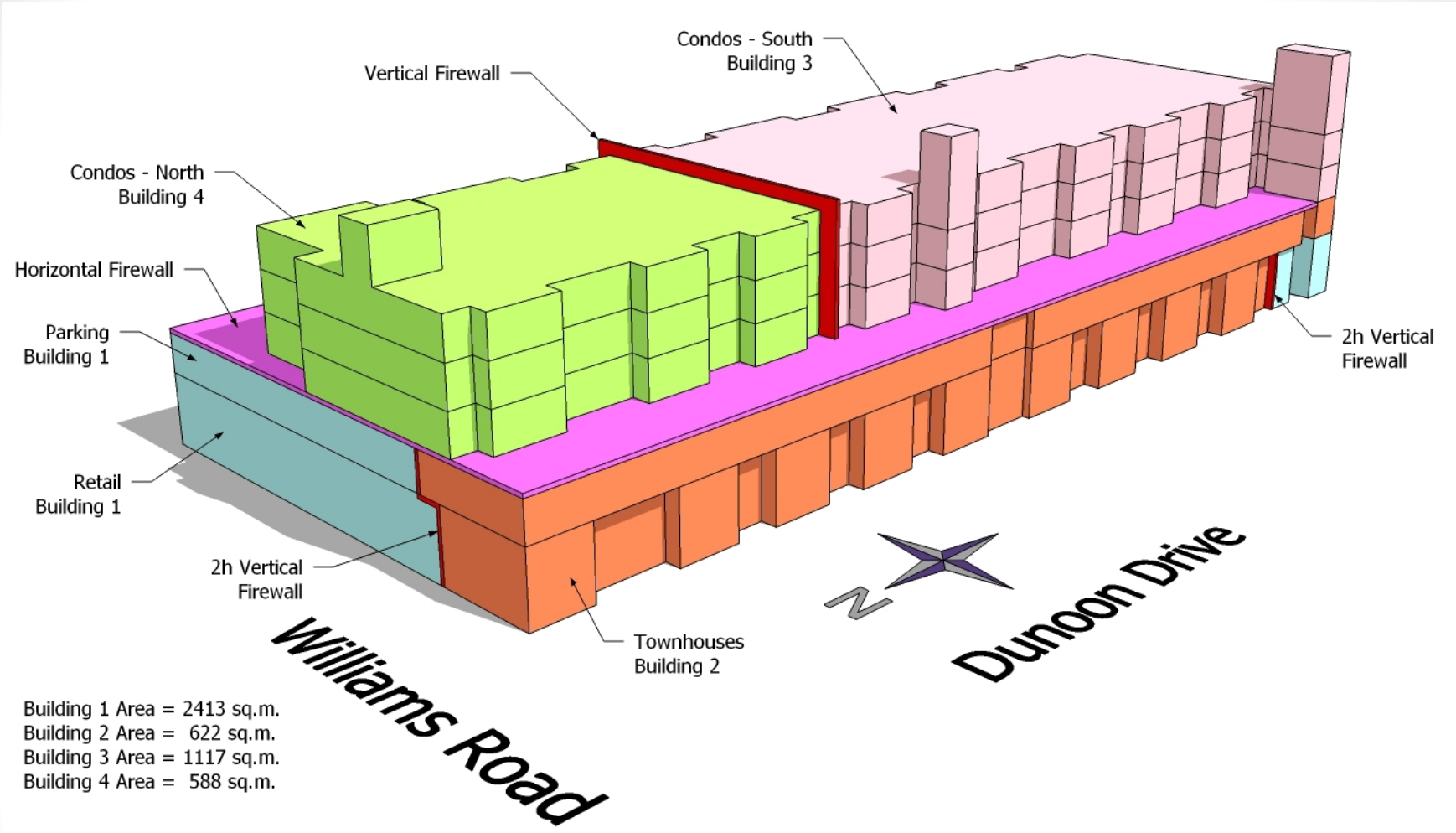

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Construction Fires

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Laminated 2x6 elevator shaft

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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.
- 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.

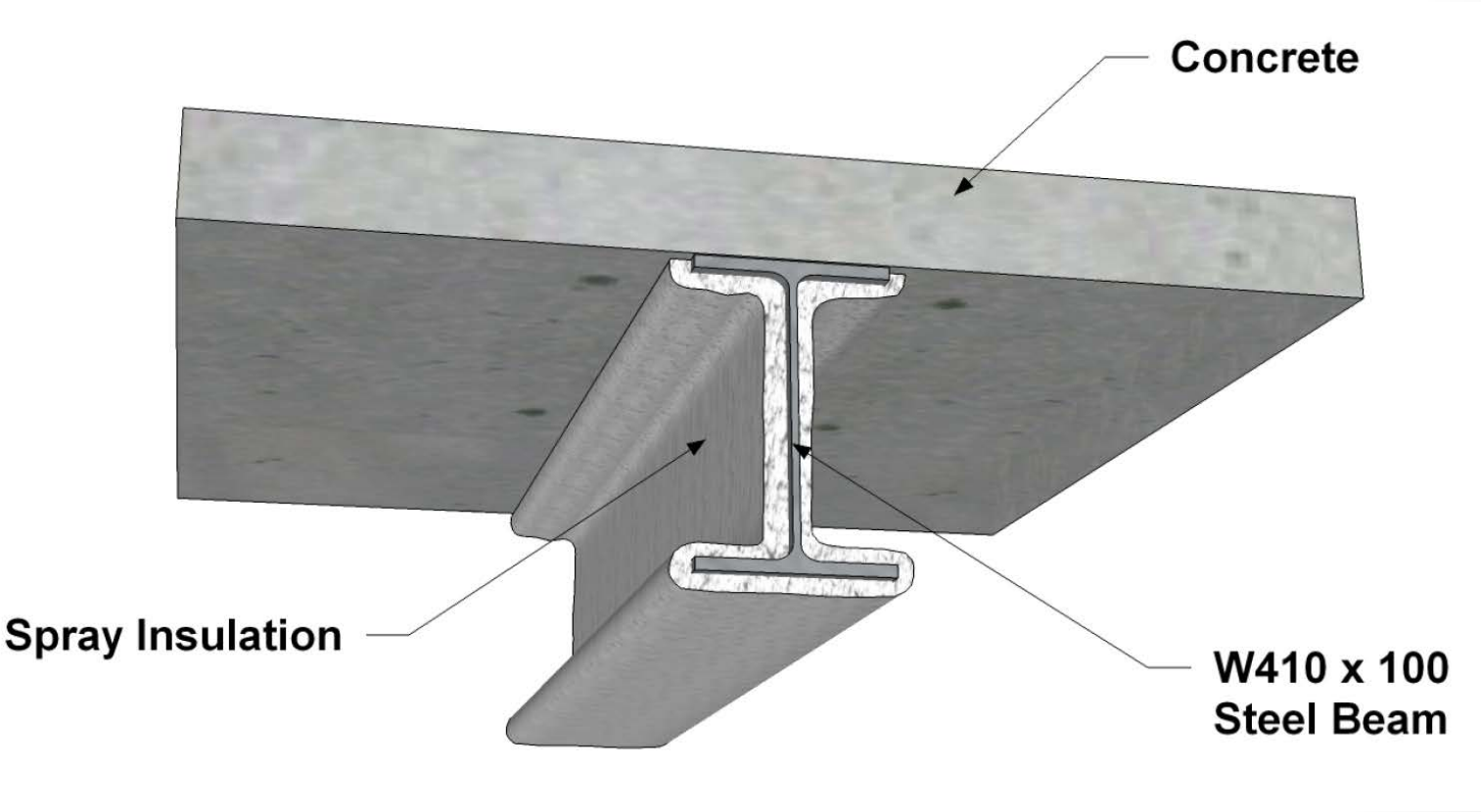
Approach Chosen

- 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



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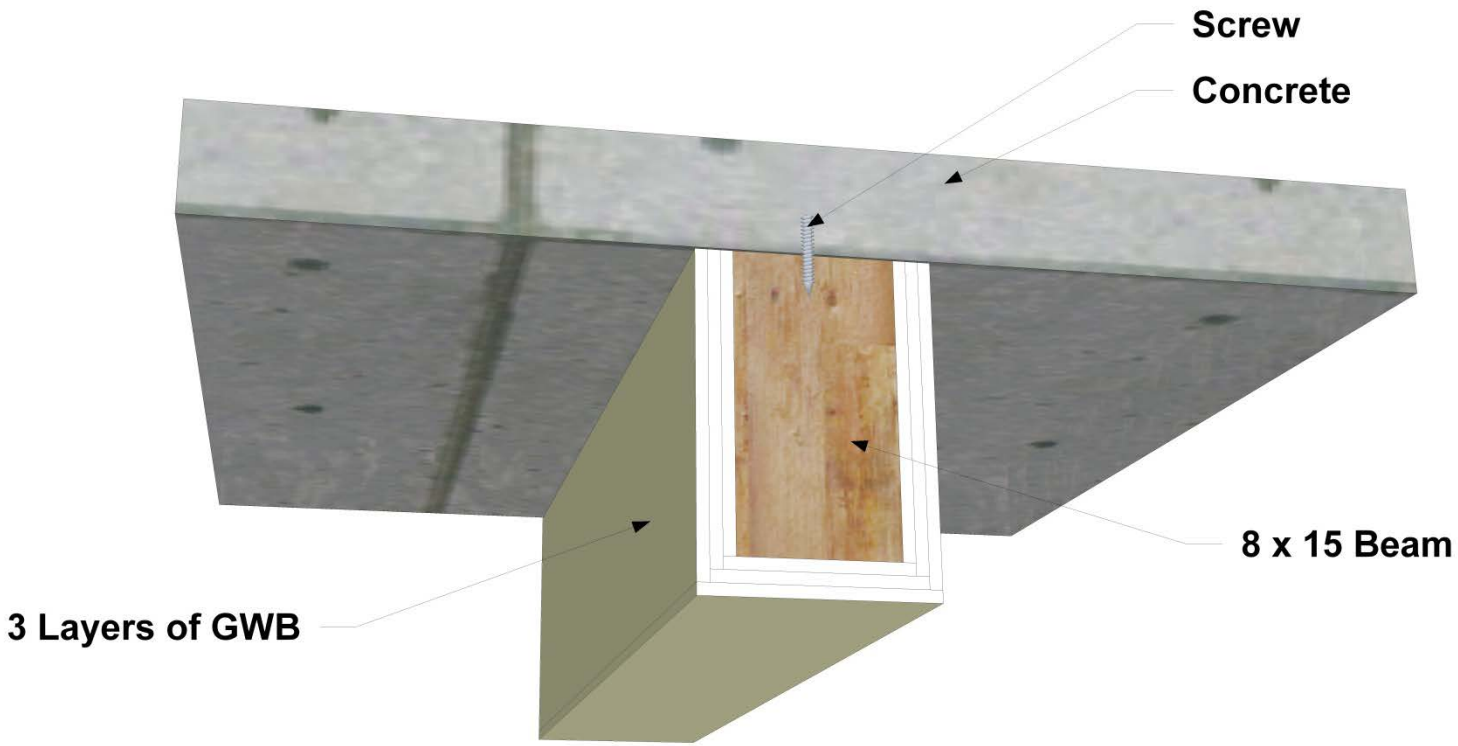
Encapsulation



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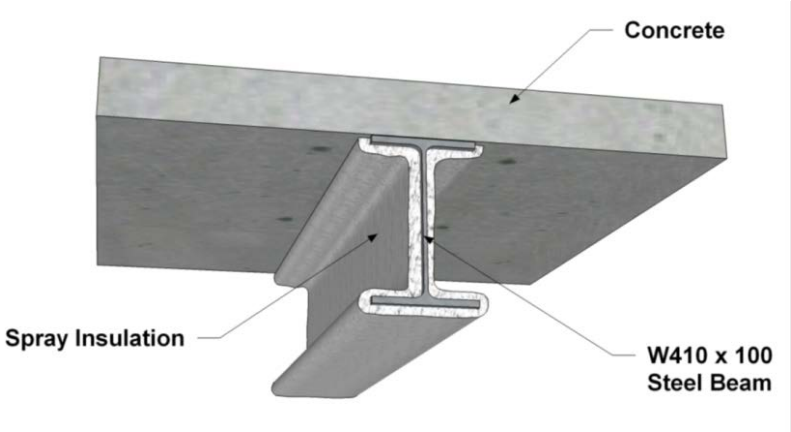
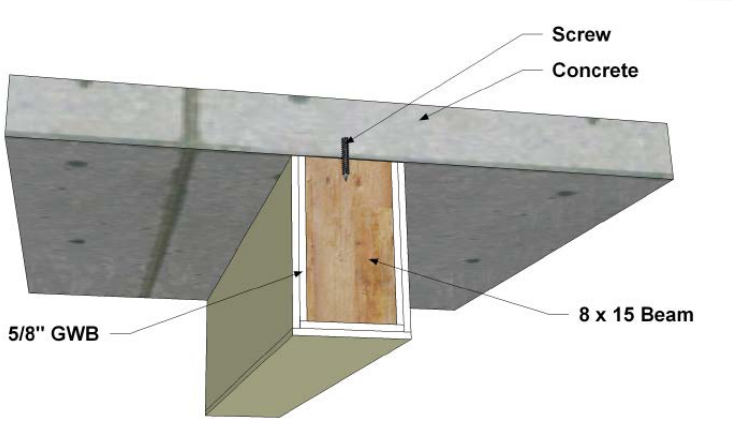
What is the Difference





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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

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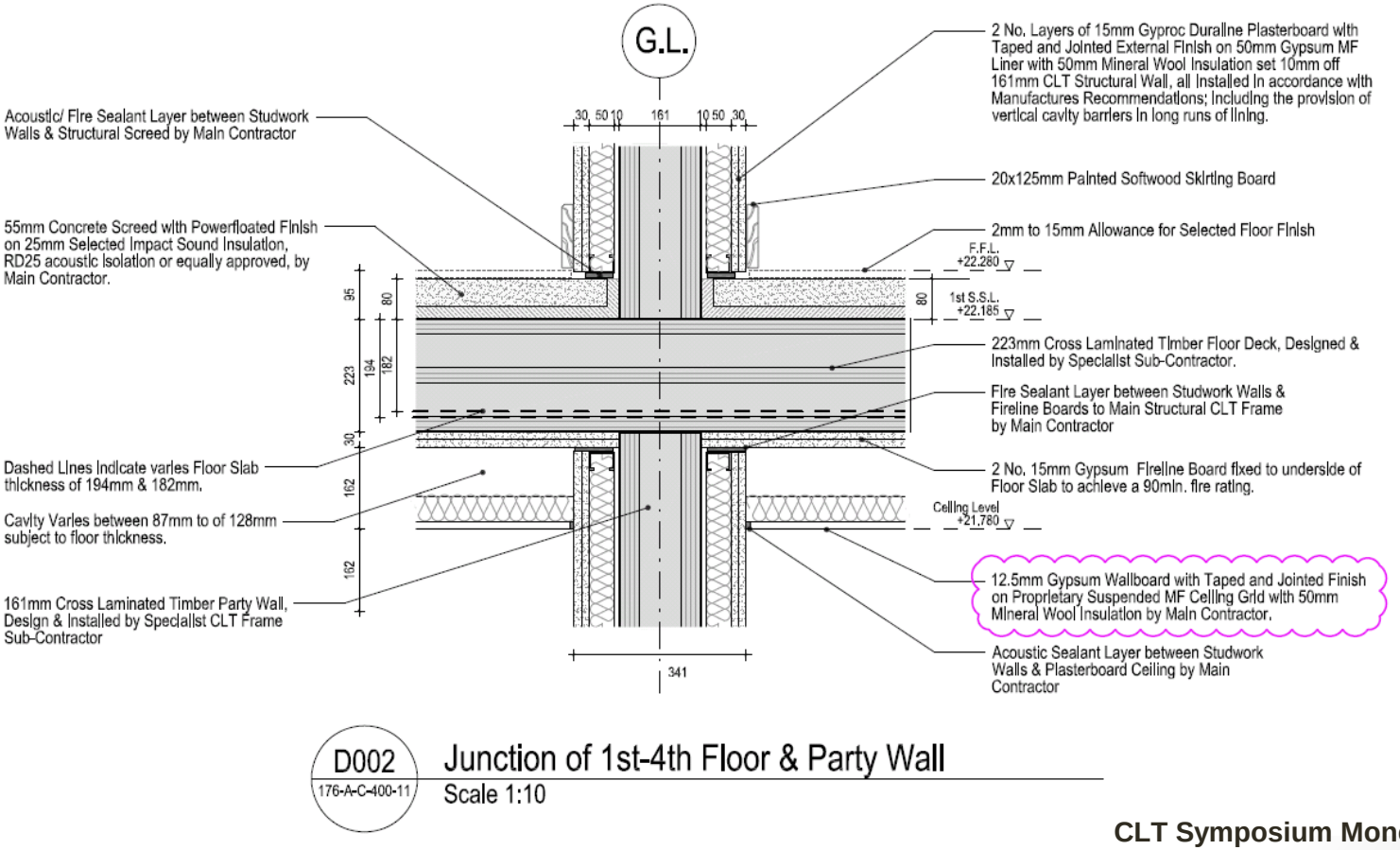
UK Early Example – Bridport House

Fire / Acoustic



D002 (176-A-C-400-11) Junction of 1st-4th Floor & Party Wall
Scale 1:10

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Peel Off the Layers

Then, suggested we peel off the layers.

What Happens to Wood

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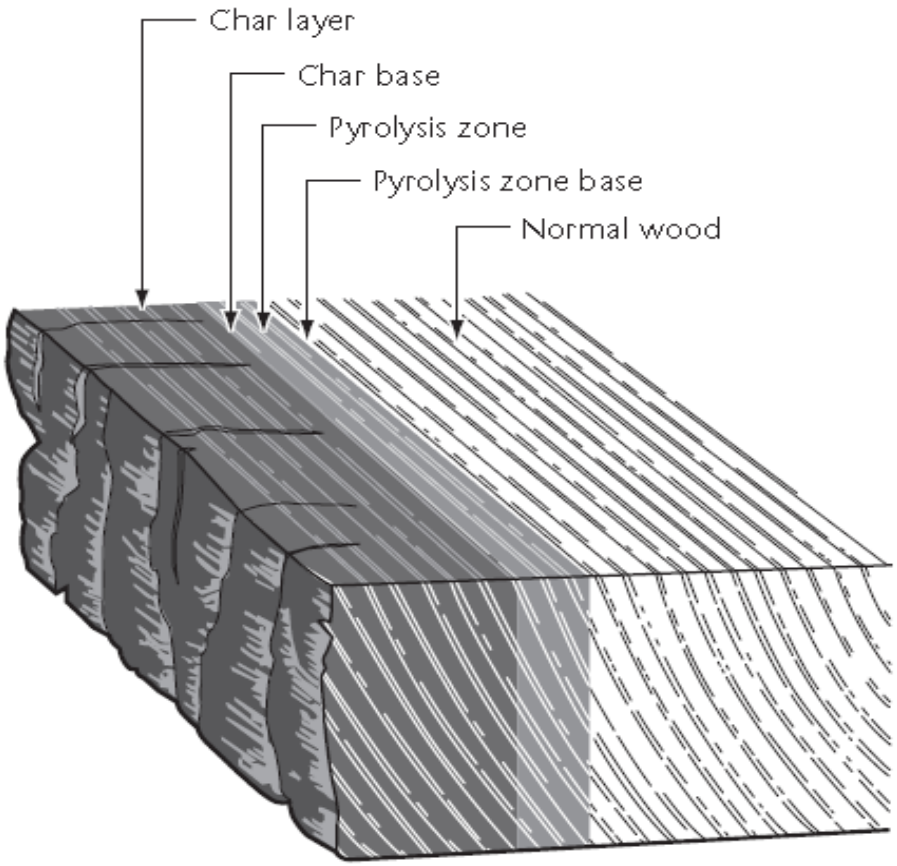
Char Layer – Small-Scale Flame Test



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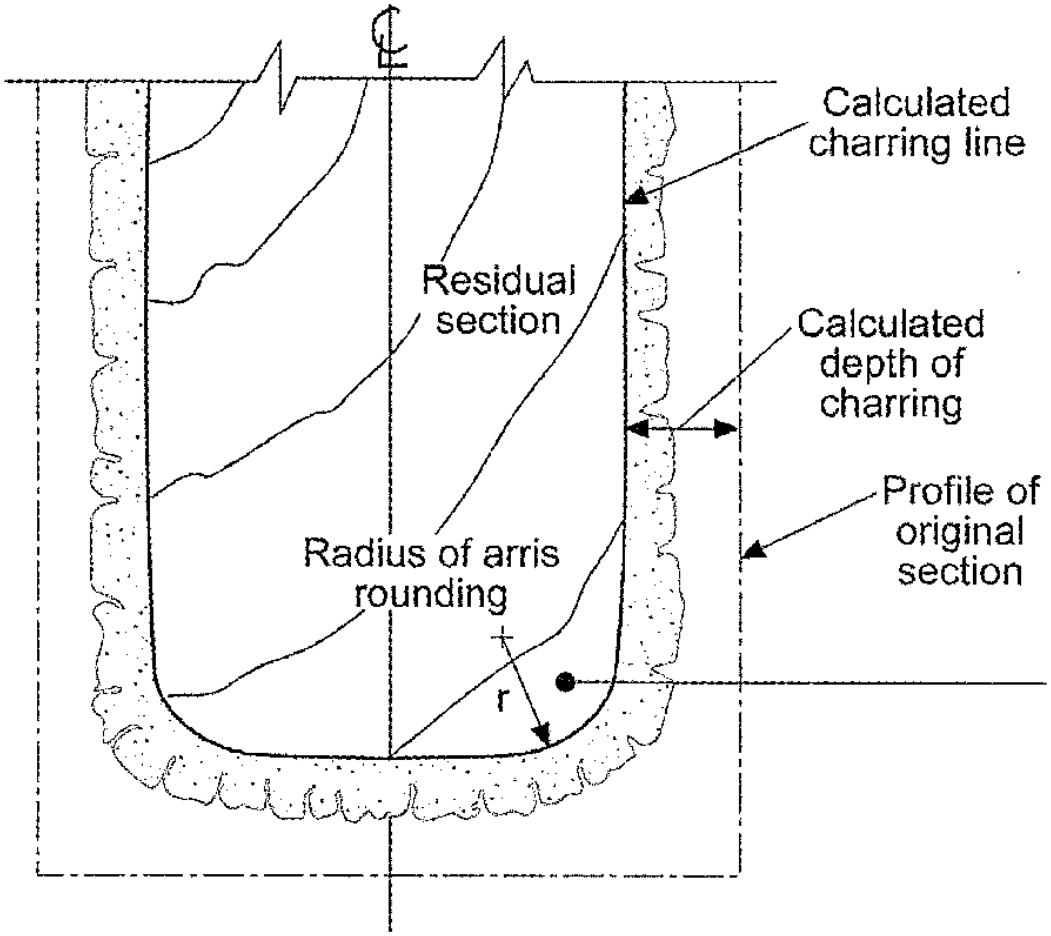
Concept of Mass Timber Design for Fire Resistance



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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

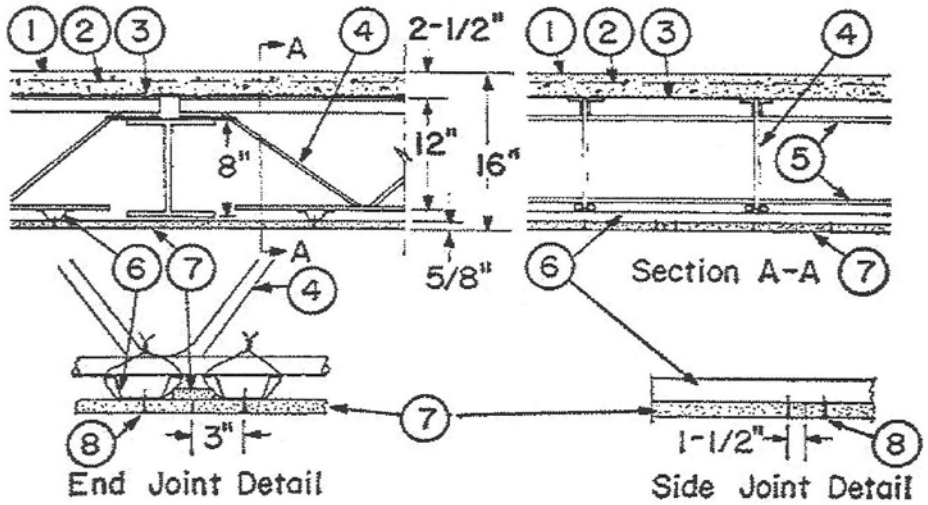
Fire Resistance Ratings - ANSI/UL 263

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.

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This, especially if wrapped in 2 layers of GWB

Risk Analysis

- Another approach.
- More feasible with a knowledgeable authority.
- UBC Earth Sciences Building.

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.

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

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Approach

Risk Analysis

Pre-Flashover

Post-Flashover

Pre - Flashover

95% sprinkler reliability.

Only necessary to address 5% probability.

Low occupant load, extra fire separations.

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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.

Steel

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

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

- Enhanced sprinkler system or encapsulation.
- Performance in the first 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.

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We Used to Know How to Do It

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Protected Connections for Enhanced Fire Performance

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

Protected Connections for Enhanced Fire Performance

b) Connection covered with wood paneling

Connections

Not specifically addressed for Steel or Concrete

Especially intumescent – problems noted

We Used to Know How to Do It

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

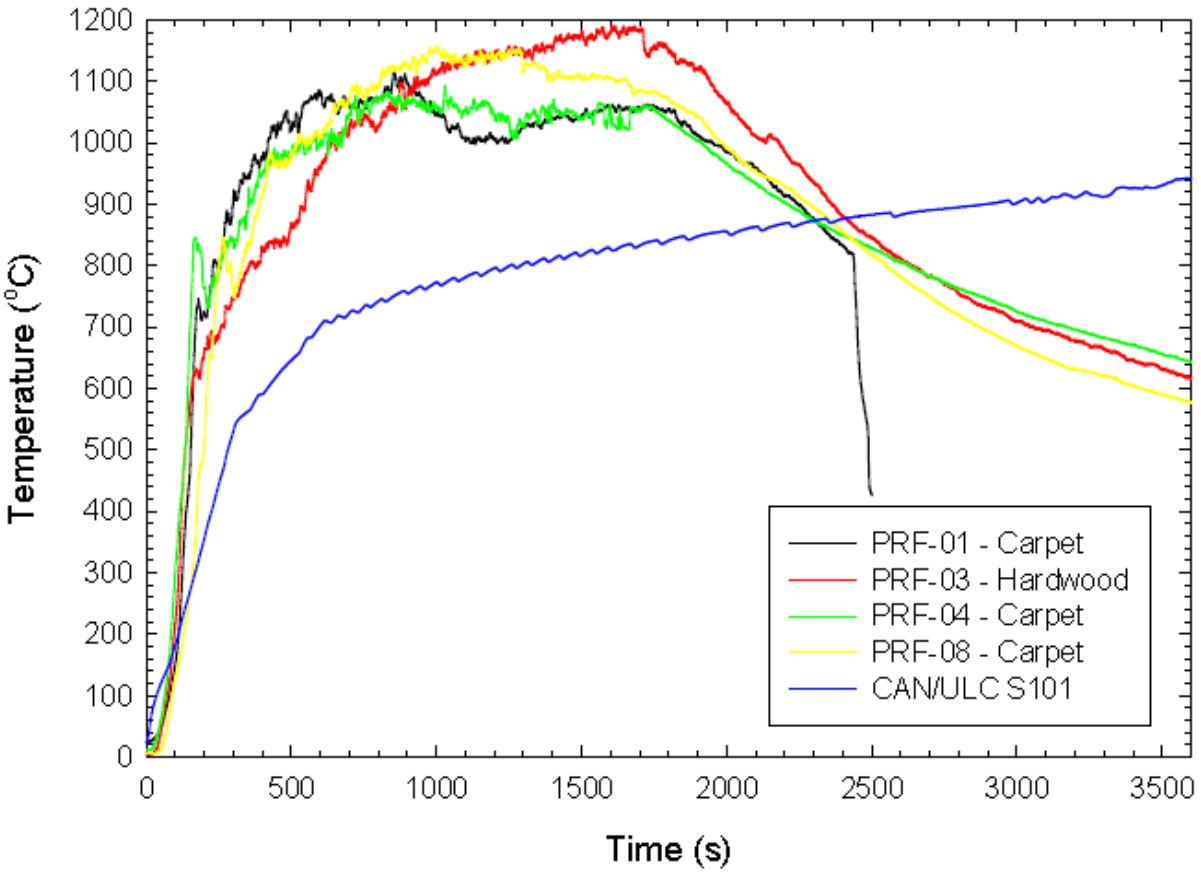
Is the standard fire acceptable, or do we need to look at real fires?

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



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Void Spaces

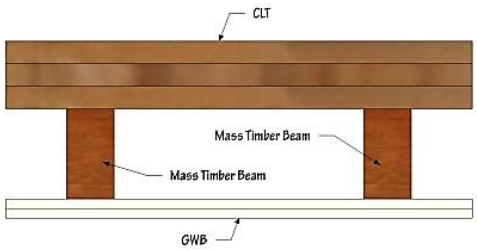
Limited but they will occur.

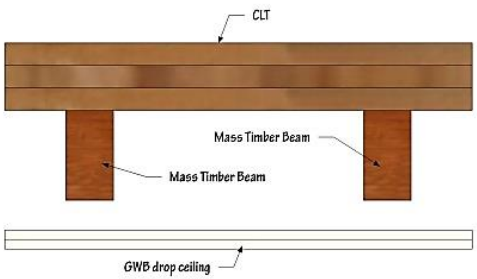
How big a void space is acceptable?

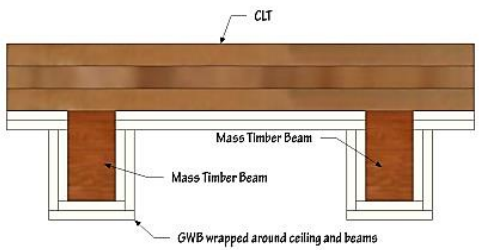
Unsprinklered (NFPA 13 provisions applicable).

- Sprinklered?

Approaches to Encapsulation Creating Concealed Spaces







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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.

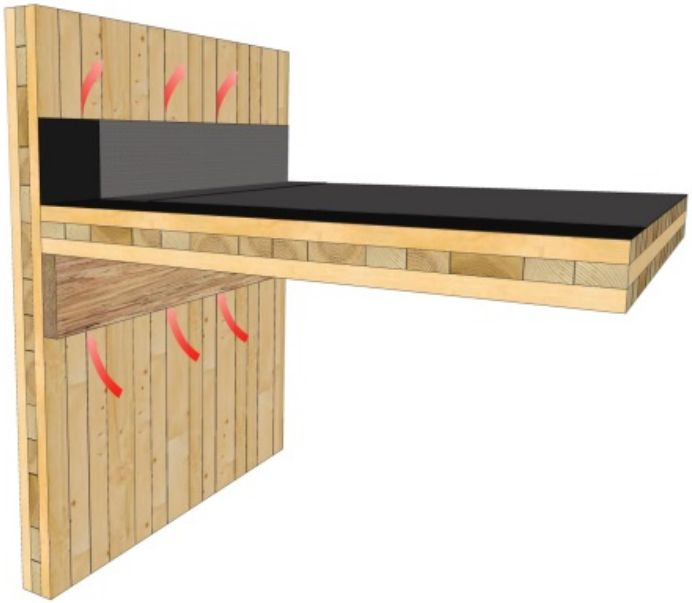
Firestopping

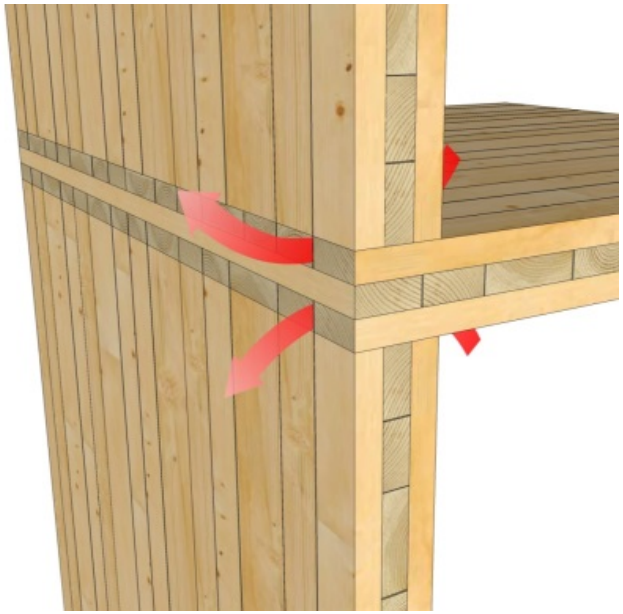
Don’t see a lot of issues.

Some public testing being done for WIDC.

But, be careful:

CLT Smoke Leakage Paths





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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

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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

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Bridport House / Facts

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

Bridport House / The Installation

Day 40

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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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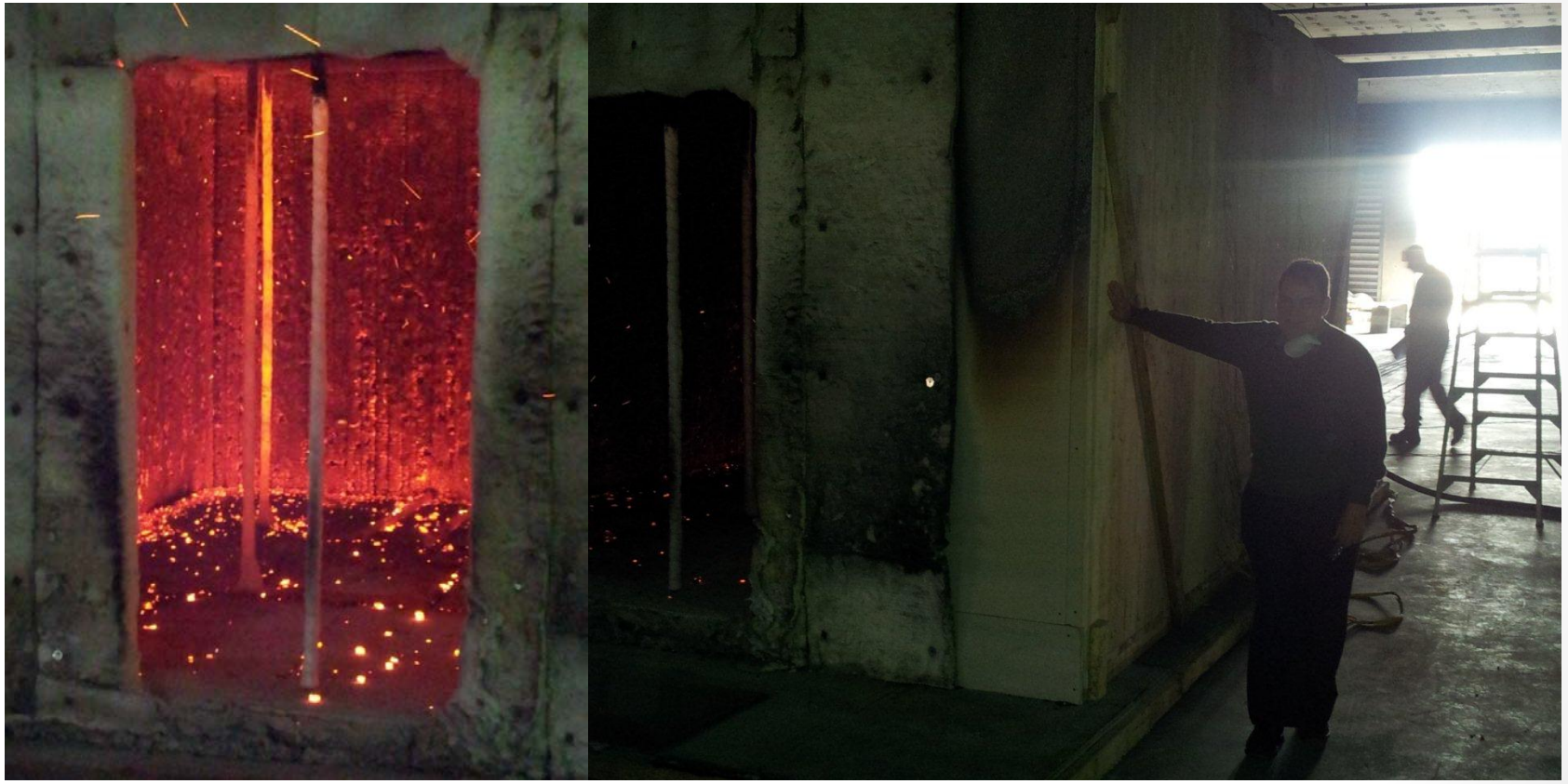
NEWBuildS



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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).

NRC/CWC Research Consortium

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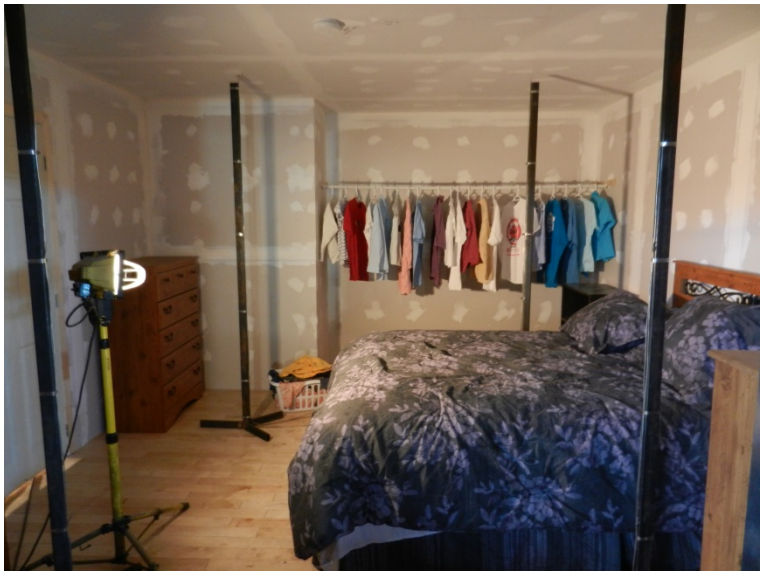
NRC/CWC Research Consortium



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

NRC/CWC Research Consortium

LWF End of Test

CLT End of Test

Fire Modelling

Tells us fire characteristics:

- Temperature / heat flux.
- Smoke movement.
- Duration.
- Cannot model effects of charring.

Typical Application of Fire Models in Alternative Solutions

Tenability Analysis

- Smoke layer height
- Tenability within the smoke layer
  - Visibility
  - Toxicity
  - Heat exposure
- Travel distance to exit
- Interconnected floor space design

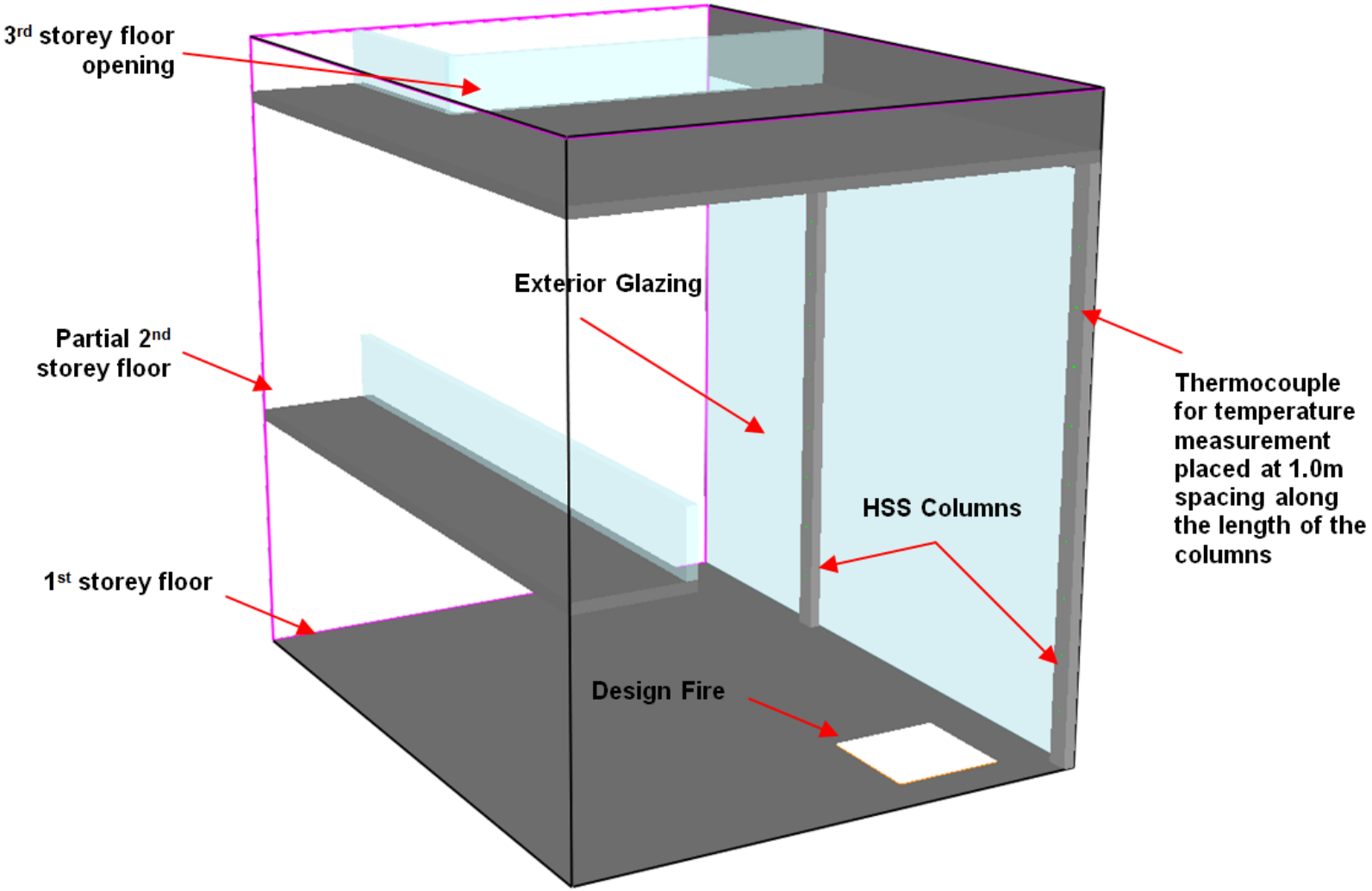
Compartment Temperature Analysis

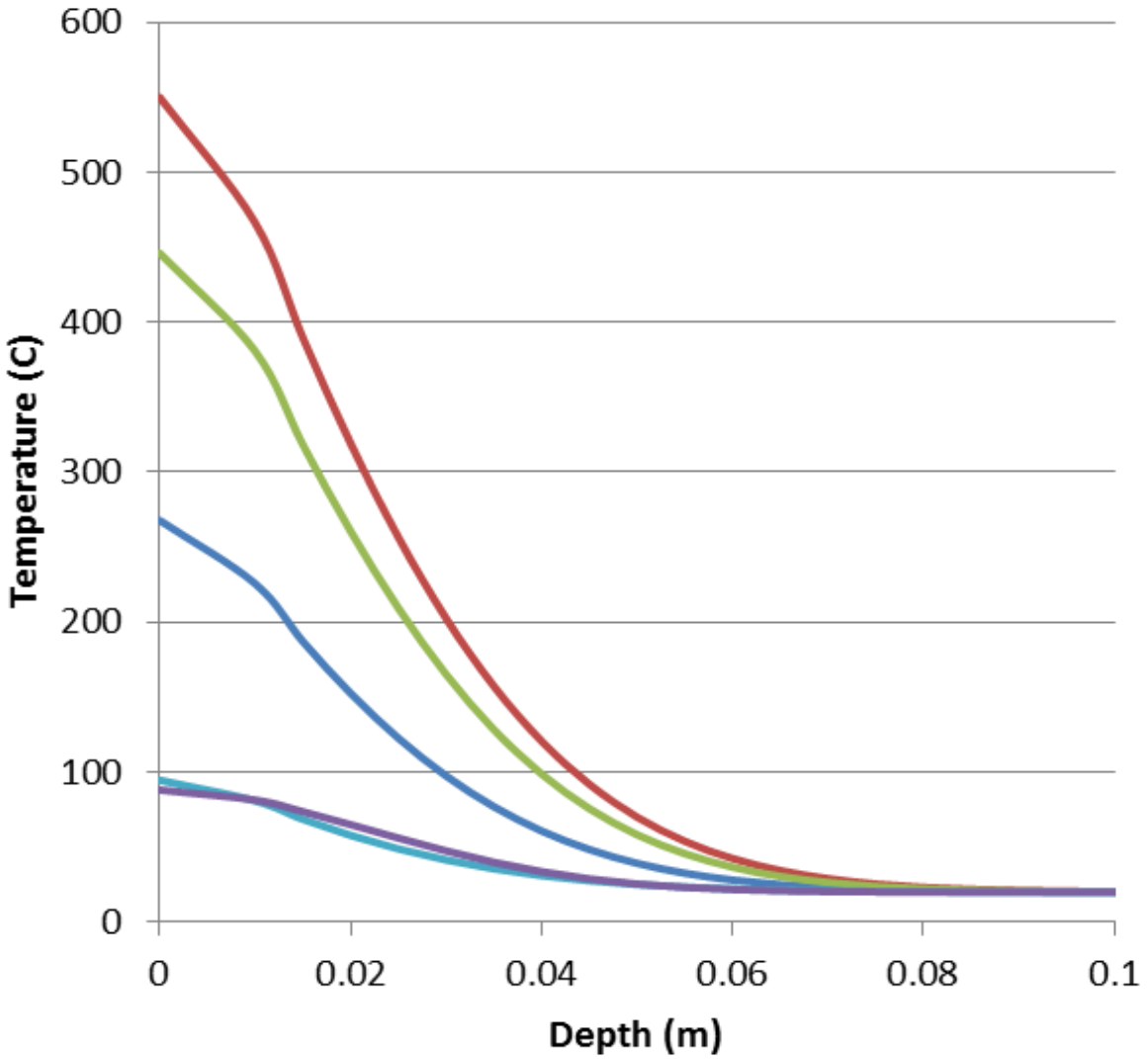
- Failure analysis:
  - Glazing separations
  - Unprotected steel structure

Evacuation Models

- Not a ‘fire’ model
- Estimate movement of occupants based on flow factors observed in experiments
  - Travel speed = function of population density and fitness
  - Queuing at exit doors = function of door / stair width

Examples





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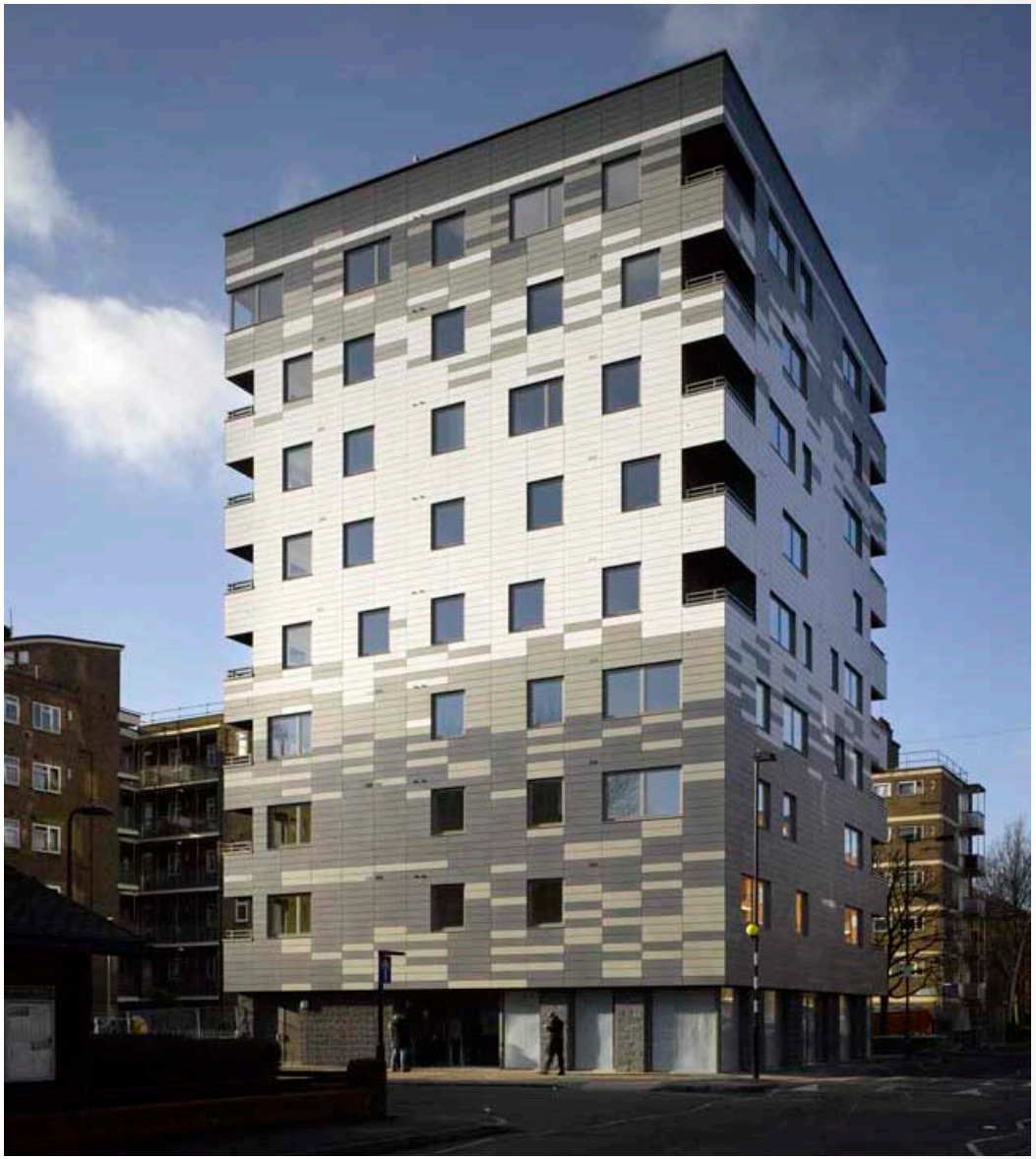
The Future

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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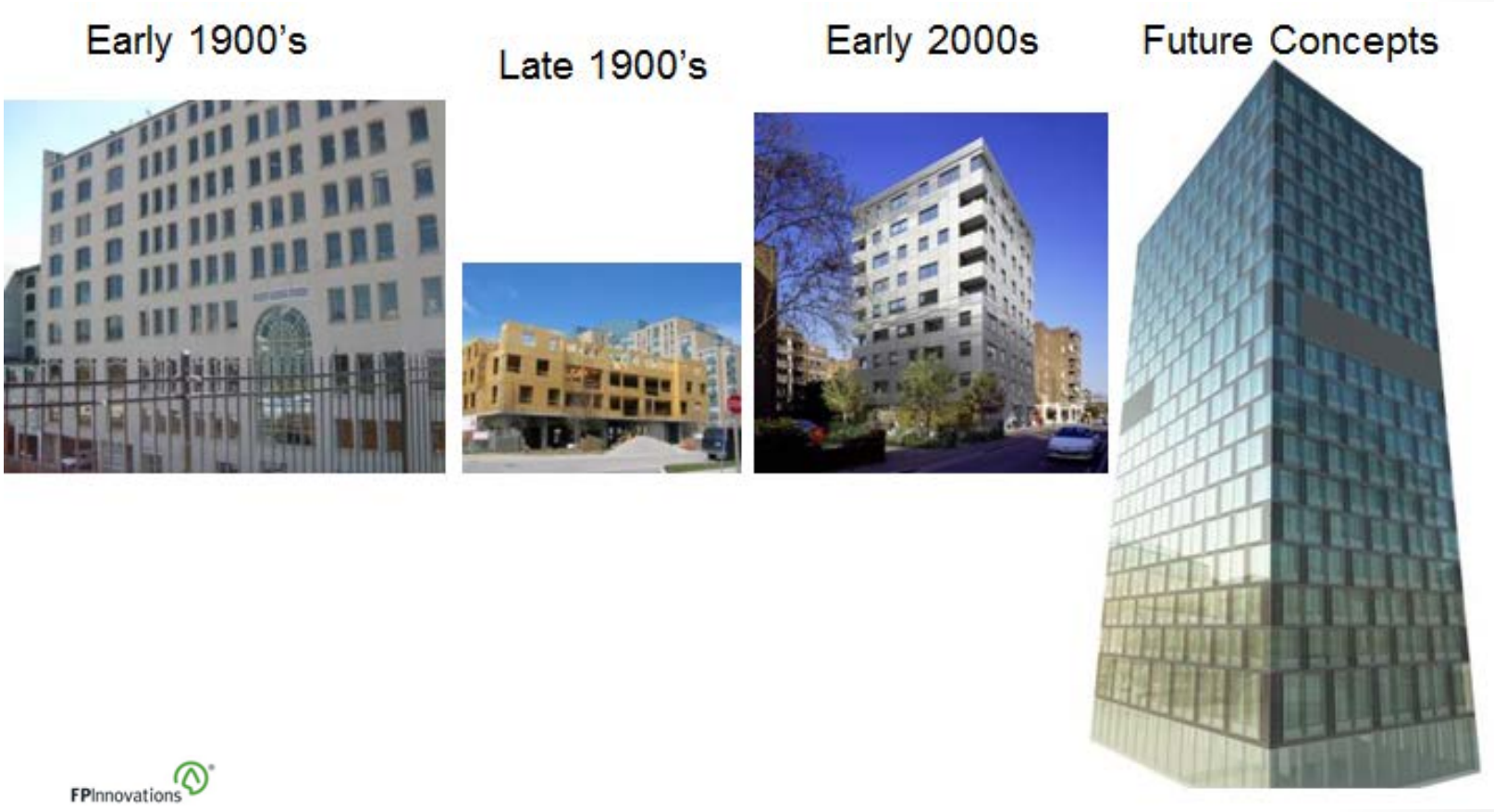
Wood Construction

Courtesy FPInnovations



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Conceptually, How High Can We Go With Wood?

Courtesy FPInnovations

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Green-Karsh 30-storey ~ 80m

36 storey ~ (95 m)
Switzerland

312 ft. (95 m) Sitka Spruce
Canada

FPInnovations

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Useful Links

- GHL CONSULTANTS LTD: www.ghl.ca
  Tall Wood Presentation: http://www.ghl.ca/shared/Tall_Wood_Presentation.pdf

- Woodworks! National:
  ww.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

- Woodworks! BC:
  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
- 44
- Canadian Wood Council: Innovating with Wood:
  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

Questions?

Thank you

A copy of this presentation is available at:

http://www.ghl.ca/shared/Tall_Wood_Presentation.pdf

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