Mass Timber

CP Course
October 2019

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This presentation is conceptual and intended to be presented by GHL. Application of concepts to a specific project must be confirmed by a specific GHL/client agreement.

Andrew Harmsworth, M Eng, PE, P Eng, CP, FEC
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
- PE – Washington State, 2001
- 30 years' experience in Equivalencies and Alternative Solutions

WOOD – My Journey

- Early work renovating old heavy timber buildings.
- British Columbia study 6 storey wood frame – Provincial Study and Code Chang
- NEWBuildS research network – academic study and mass timber fire tests.
  - Quebec – Retained to demonstrate safety of timber stair shaft
  - Currently on Codes Canada Standing Committee on Fire Safety

OUTLINE

- Codes (and why they matters)
- Fire Science
- Next Steps – What we can do NOW

BACKGROUND ON CODES

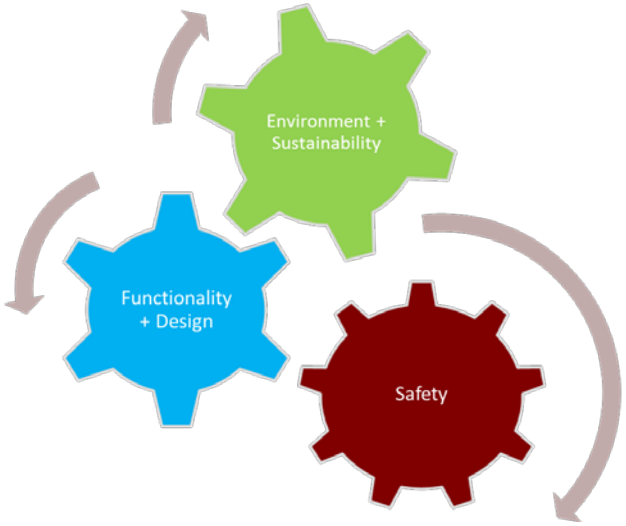
Why Discuss Codes / Fire

- Fire Concerns – Biggest Impediment to new materials and methods
- Fire concerns, in my opinion, outdated
- Alarms, Sprinklers, have reduced fire death rates to ‘de-minimus’ levels
- Statistics still bad due to old housing stock, SFD

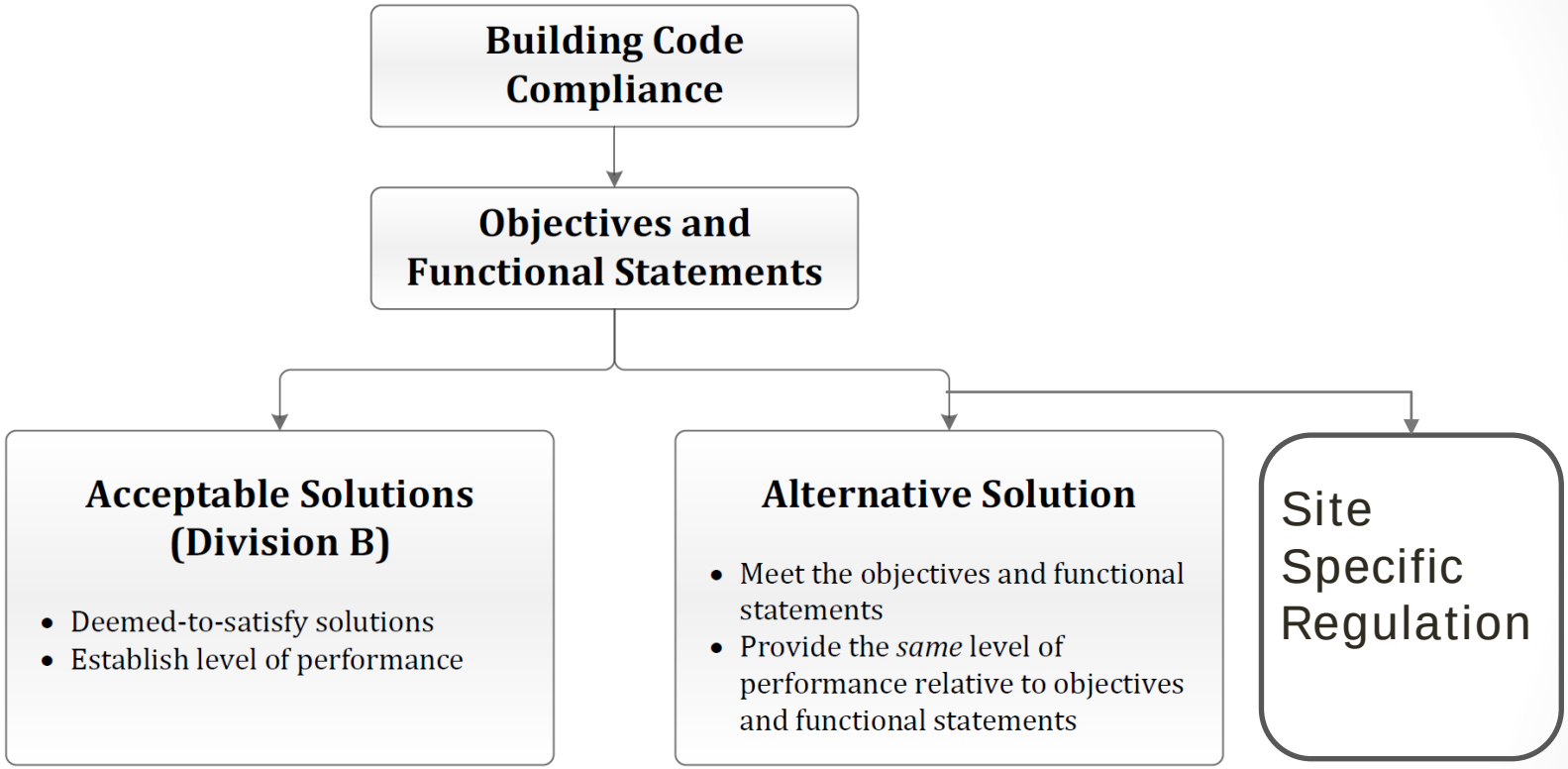
Why Codes?

- To provide the public with consistent levels of safety acceptable to the public

- So we don't have to do a safety check of every building we enter



Methods of Code Compliance



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Tools: Site Specific Regulation

- Similar to an Alternative Solution.
- Managed by Building Safety Standards Branch.
- Flexibility – can change the LEVEL of safety.
- Expert Panel Review Process.
- Unique to BC.

Jurisdiction Specific Resolution

- 2020 incorporates 12 storey encapsulated
  - Up to one wall or 25% of ceilings exposed
  - 2 layers 1/2in gwb
- Province committed to early implementation this fall
  - Requires council resolution of support
  - Called ‘Jurisdictional Specific Resolution

BACKGROUND ON FIRE

NRC/CWC Research Consortium

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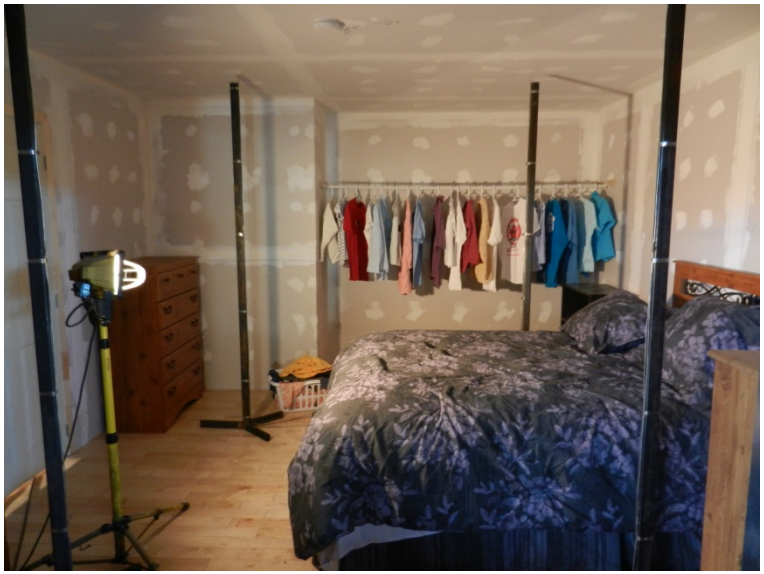
NRC/CWC Research Consortium



Fire Test Fuel

NRC/CWC Research Consortium

LWF Start of Test

CLT Start of Test

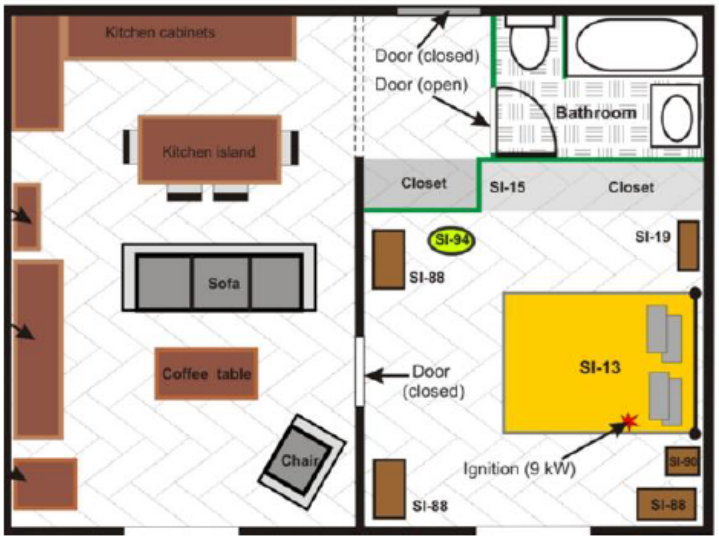
NRC/CWC Research Consortium

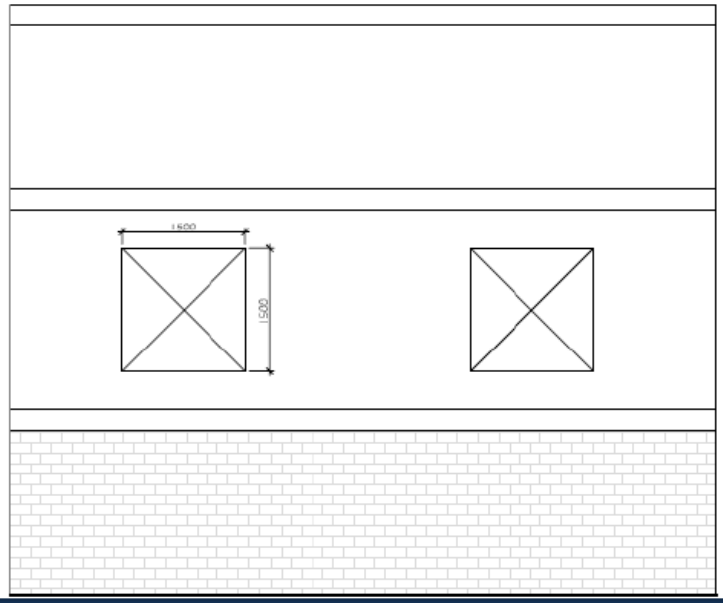
LWF Fire Test

CLT Fire Test

Encapsulation – Full-Scale Apartment Fire Tests

- Encapsulated cross-laminated timber (CLT) structure
- Encapsulated lightweight wood-frame (LWF) structure
- Lightweight steel-frame (LSF) structure using UL listed 60-min assemblies and meeting minimum code requirements





NRC·CNRC

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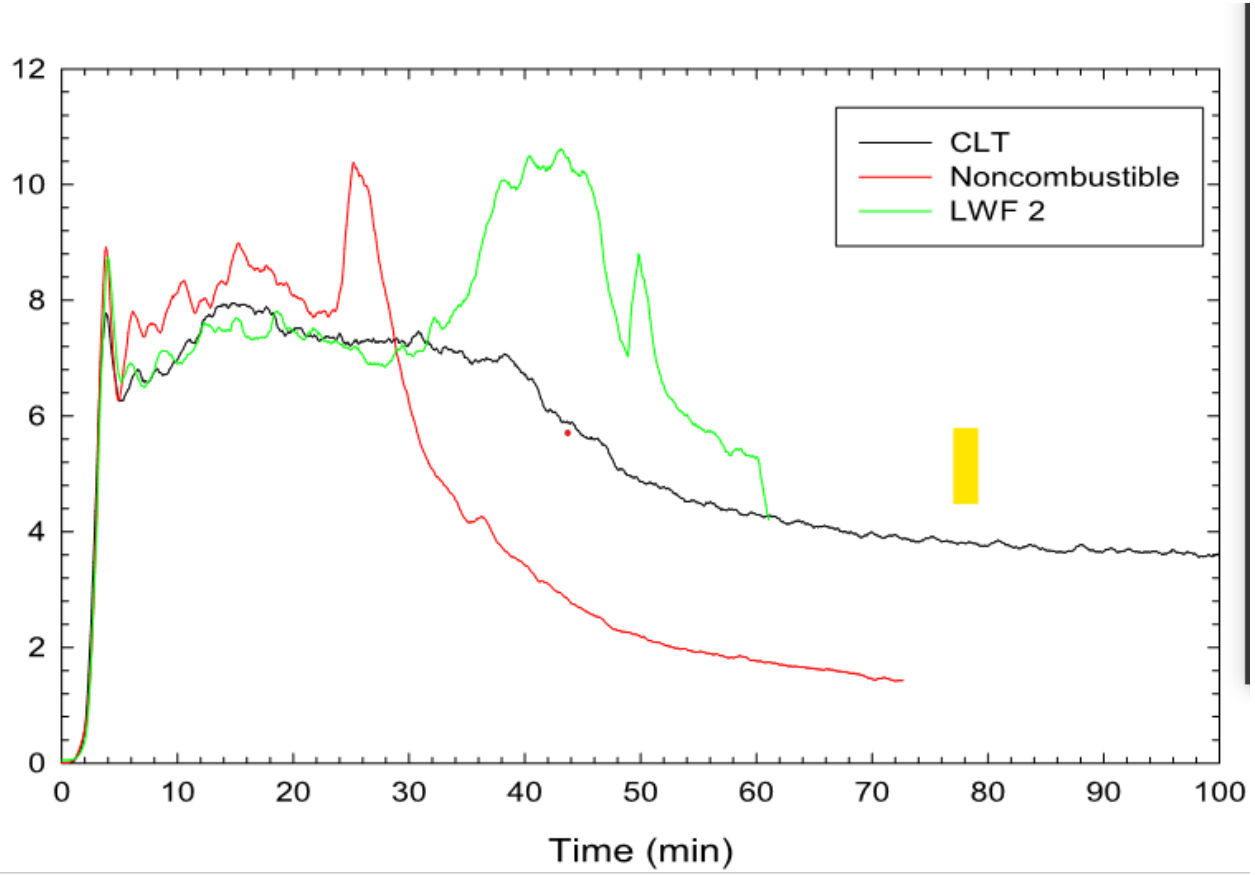
Fire Endurance Test

CLT vs LWF vs Steel Stud



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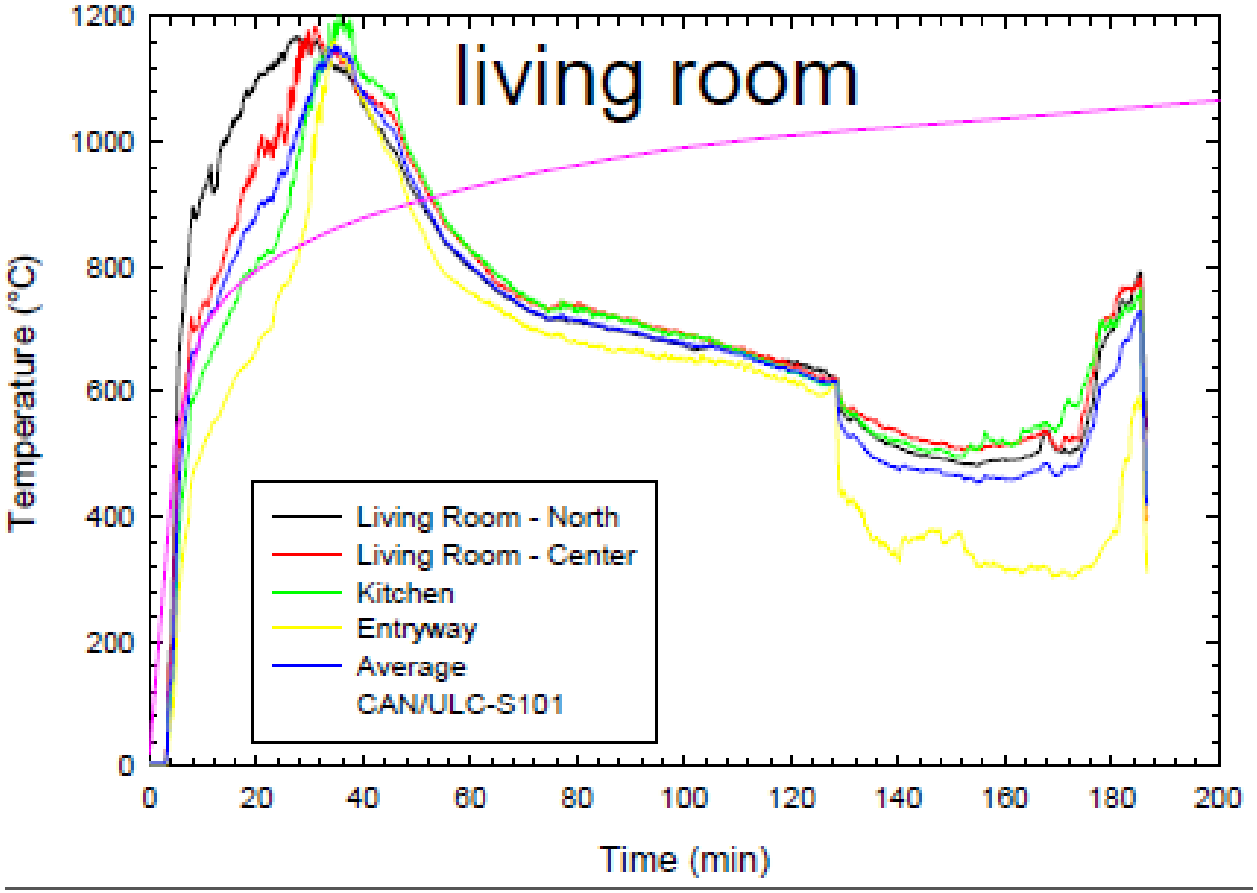
3h Encapsulation -CLT Test



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First 30 minutes

- Sprinklers activate.
- >95% of fires with sprinklers confined to the room of origin.
  - Even if sprinklers fail, majority of cases, sprinklers will trigger the flow switch, sounding the alarm and calling the Fire Department.
- All timber suites have minimum 2 exits.
- Fire Department called and responds to building in 10 minutes.

Mass Timber vs Noncombustible

- Fire in the first 30 minutes is not affected by the presence of mass timber.
- Evacuation time for a much larger building ~20 minutes.
- It follows that occupant safety is not affected by mass timber.
- Concern is firefighter safety and spread to adjacent buildings.

Response Times - 1920

- 1900 – Human detection could be delayed, not unreasonable to say 10 to 30 minutes if fire starts in an unoccupied room.
- Fire could be full developed by the time Fire Department called.
- Occupants notified by Fire Department.
- Minimal sprinklers.
- Slow response, occupants may still be in building.

1928 American LaFrance 85ft Front Wheel Drive Aerial in service at No 6 Firehall. While answering an alarm at No 4 Firehall in 1948, the engine blew up. Converted to tractor-drawn by Pacific Truck and Trailer in 1948.

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Response Times - Today

- Sprinklers - 120 to 180 seconds
- Occupants notified immediately
- Fire suppression begins at 120 ~ 180 seconds
- If sprinklers don't control fire,
  - Occupants notified by Fire Alarm activated by sprinklers
  - 2h protected stairs for evacuation
  - FF still have protected staging space

The Landing - Gastown

- Constructed 1905
- Upgraded ~ 1980
- 8 Storeys
- 2100m²

- Keith Drive:
- 10 Storeys
- 1675m²

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Full-scale Demonstration

- Support approval and construction of Alternative Solution:
  - Fire severity, spread of smoke, building integrity
- Designed to challenge wall between shaft and adjacent apartment
- Show that 2 h non-standard severe design fire doesn't affect shaft:
  - Extinguish at 2 h

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Courtesy of FPInnovations

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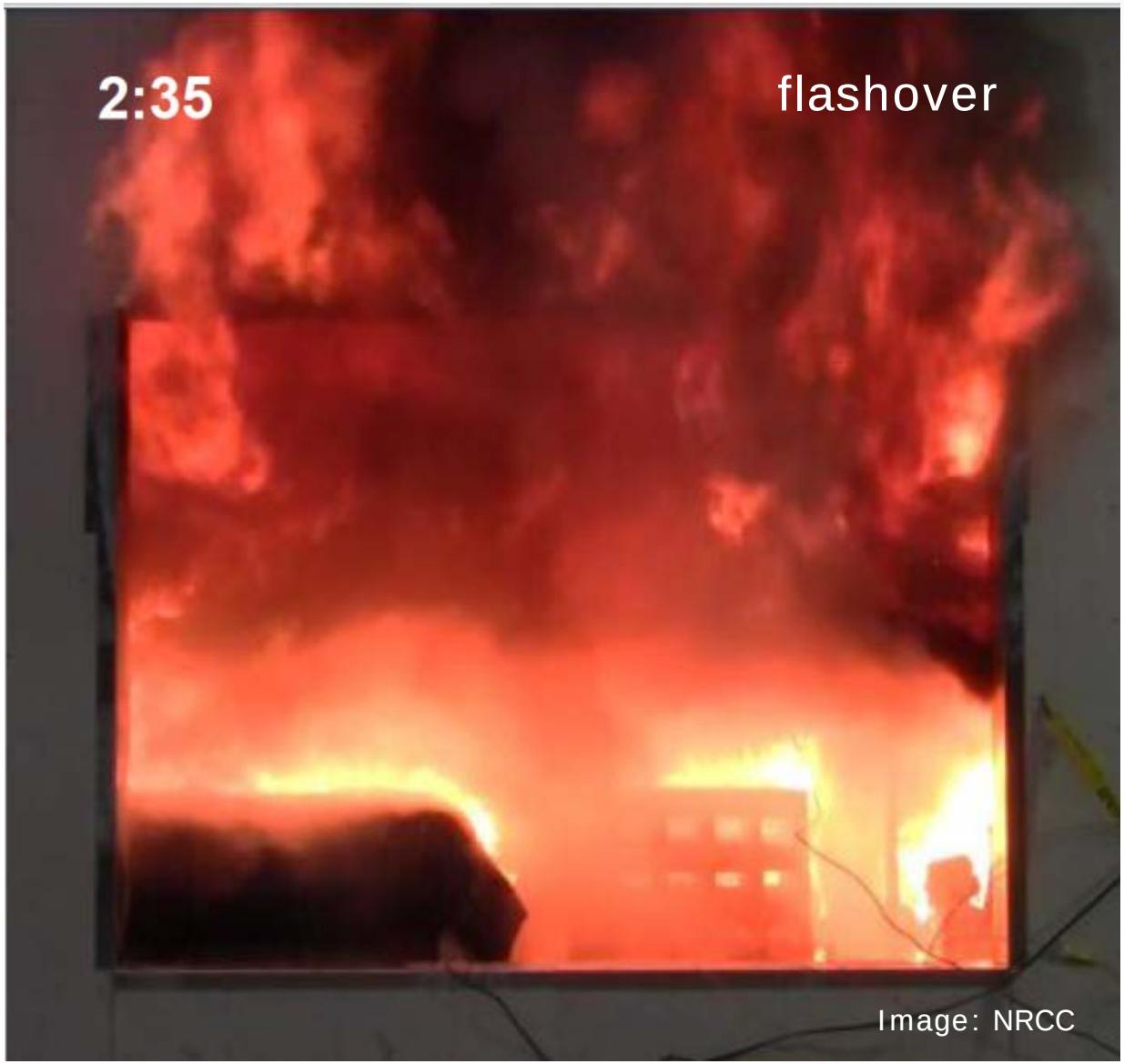

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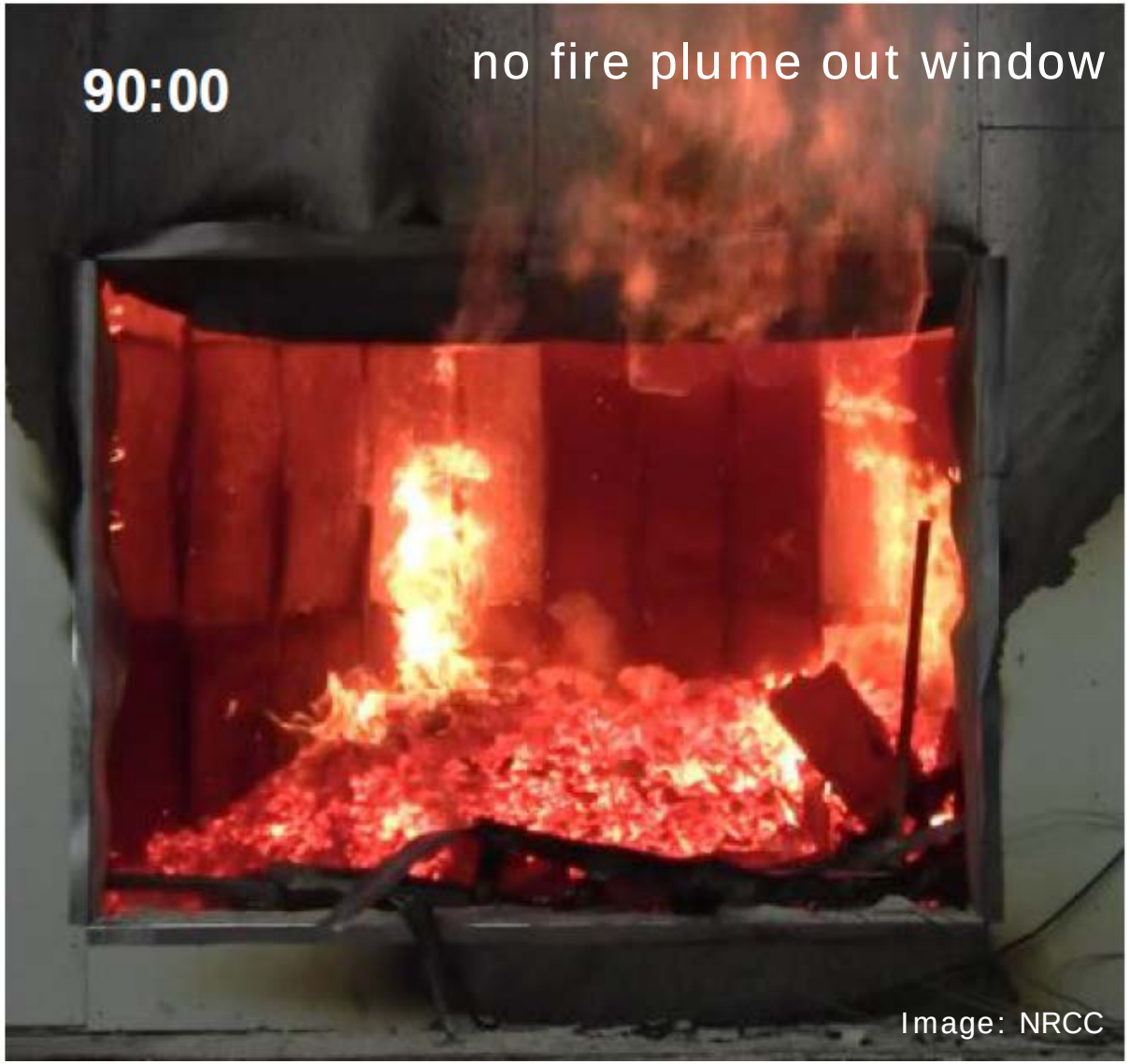

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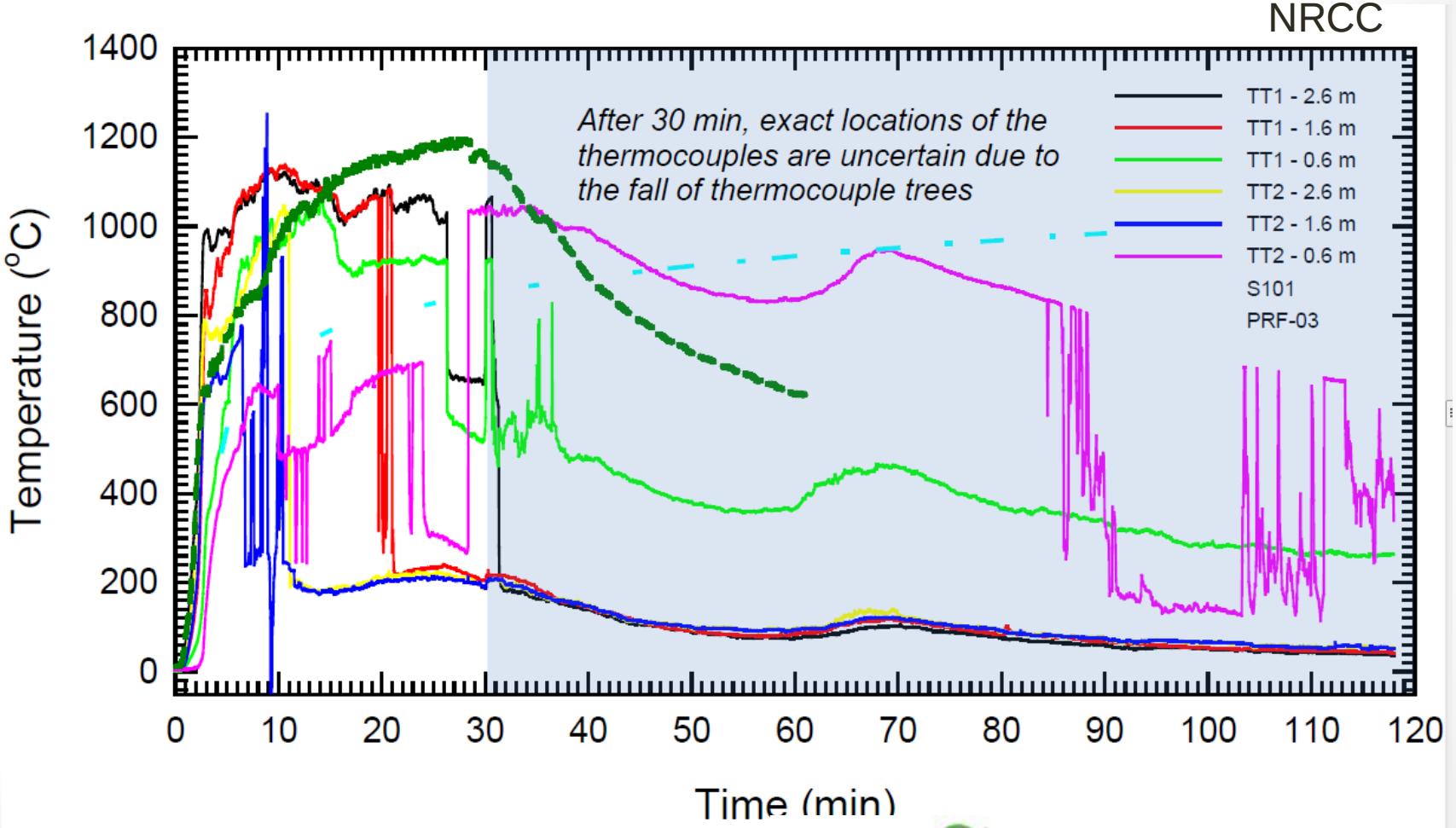
Temperatures

- More severe than CAN/ULC-S101.
  - Especially during first 30 min
- Peaked at 10 min in room.
- 30 min
  - Declining temperatures
  - TC trees fell
- 70+ min all temperatures decreasing.

Temperatures



Graph Courtesy FPInnovations

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Intact before suppression at 2h

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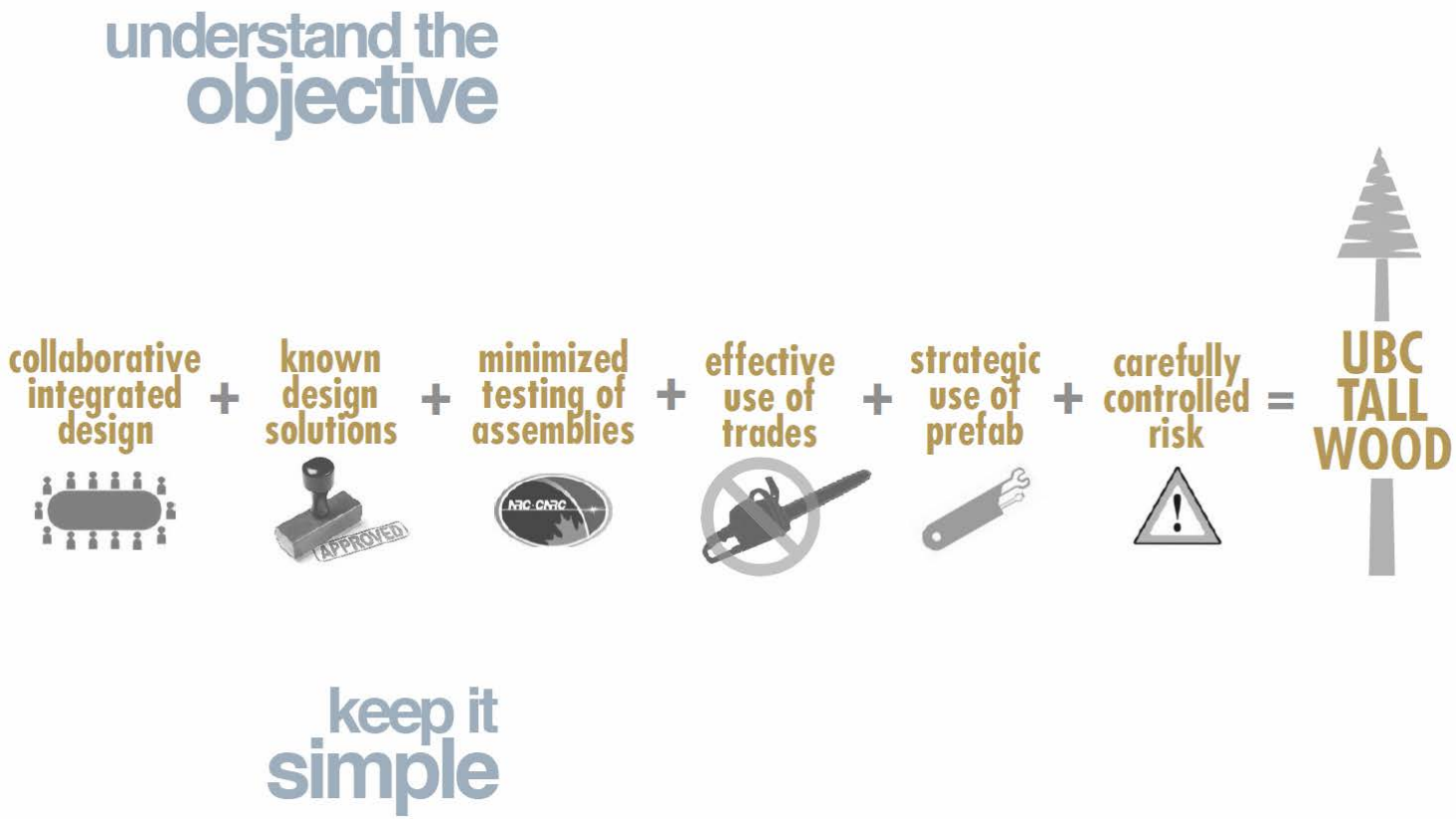
Tallwood House

Conservative

- 53m / 18 storey / 404 Student Rooms
- Concrete Cores
- Full encapsulation
- Enhanced (2h) Suite Separations
- On Site back up water supply
- Structure erected in 44 days

Russell Acton Acton Ostry Architects:



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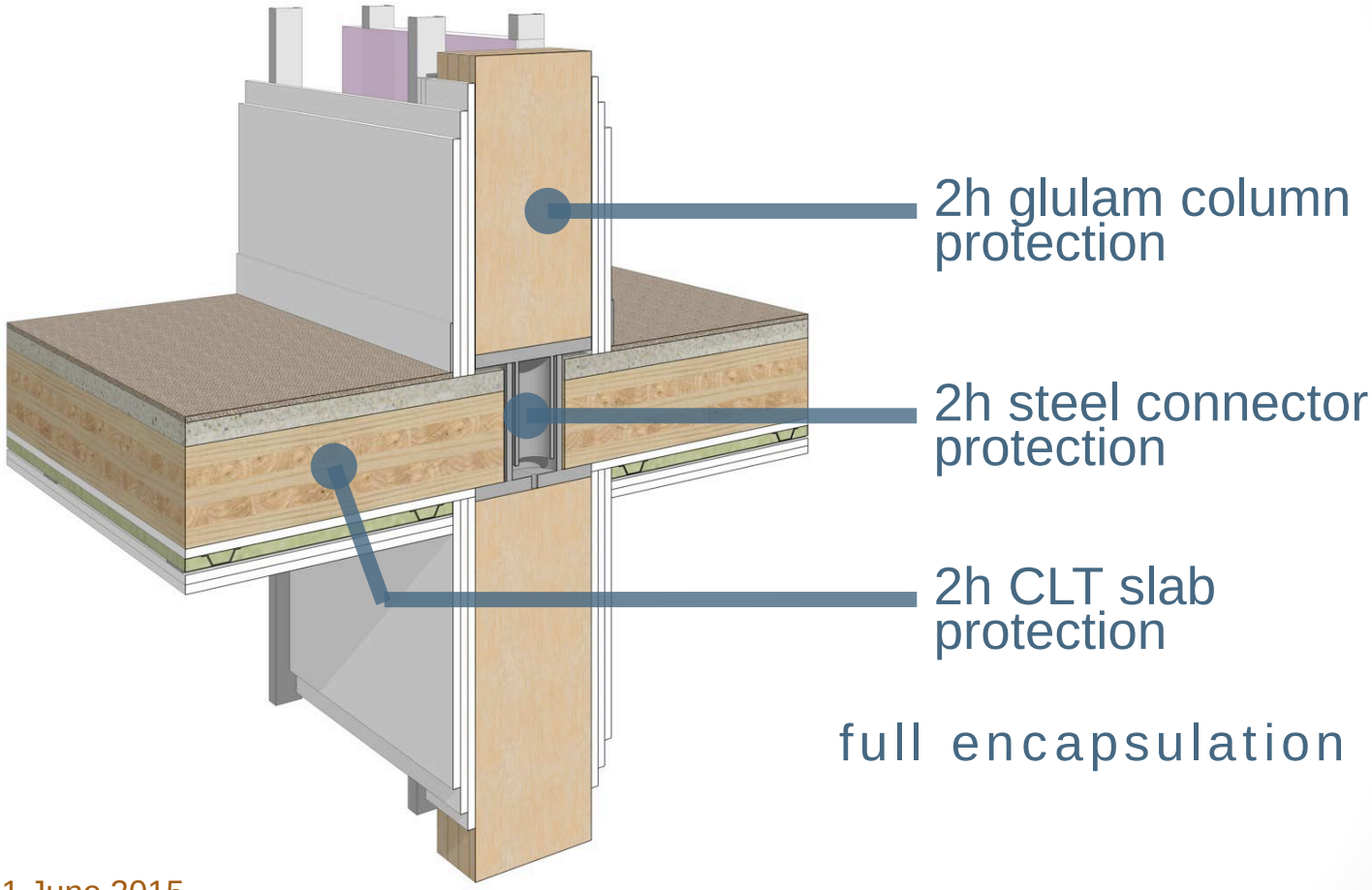
How it goes together



1 June 2015

Student Residence at Brock Commons
Image Courtesy Acton Ostry Architects|

Prefab

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Simple Assembly

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POINT SUPPORTED CLT

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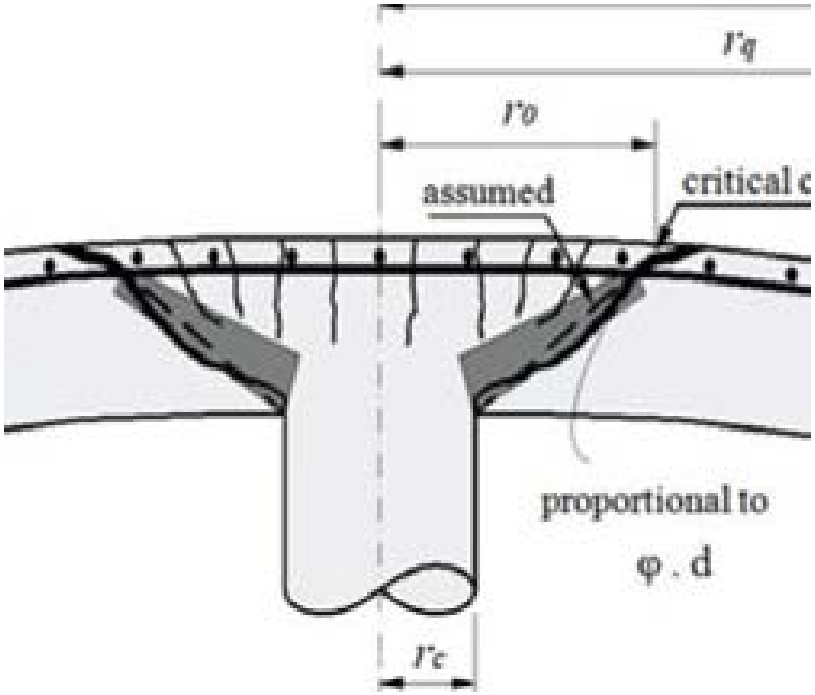
POINT SUPPORTED CLT



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COLUMN TO COLUMN CONNECTIONS

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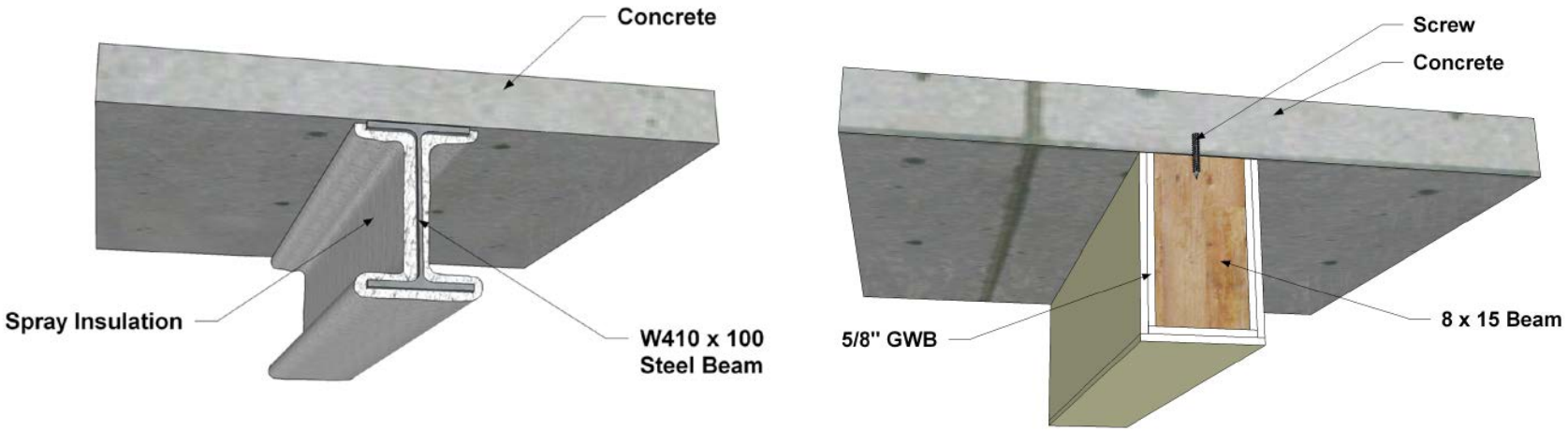
GRAVITY DESIGN

Compliant Approach - Fire Safety

- Building to substantially comply with Division B (Normal Code).
- Mass timber construction addressed by Site Specific Building Regulation (SSR).
- Full Encapsulation

Play 'what is the difference'?



- Steel cannot be exposed (critical temp approx. 500C)
- Wood begin charring at 270C
- For this building– minimal reliance on charring

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3h Steel Design

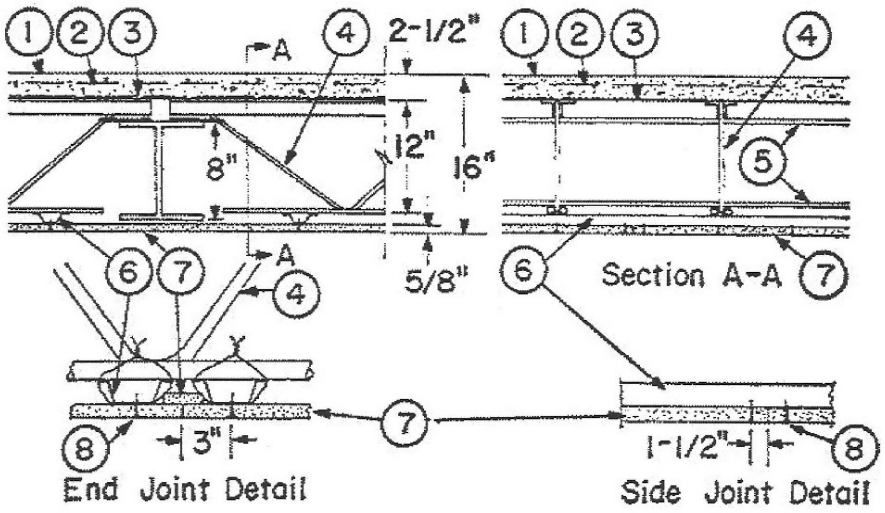
Fire Resistance Ratings - ANSI/UL 263

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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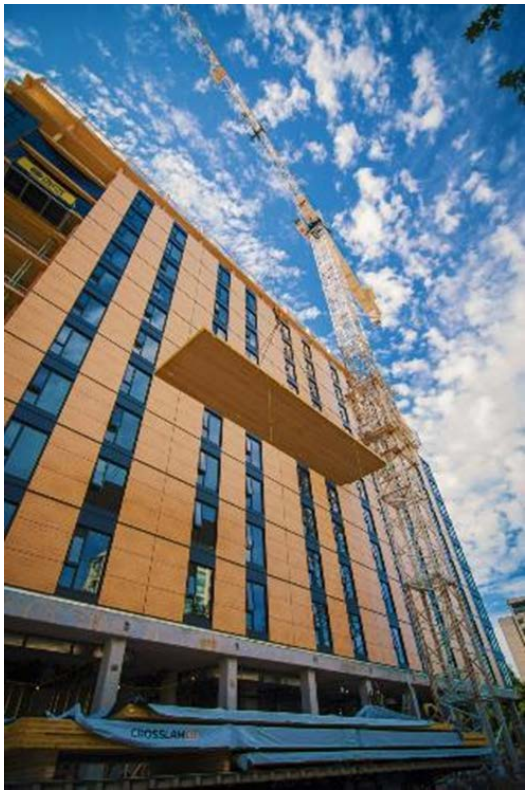
Errection: Seagate



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Errector's Perspective

What we thought / What Happened

- 1 floor done in 3 days
- 12 workers on site
- We'd have good weather
- 0 injuries
- It was going to be easy

- Complete in 2 ½ days
- 9 workers was sufficient
- It rained a lot
- We didn't even hurt anyone's feelings
- It was easier

SEAGATE Structures
QUALITY - INTEGRITY

The Team

- UBC – Dave English
- Acton Ostry Architects – Russell and Matt
- Fast+Epp
- GHL (often forgotten)
- RDH – Envelope
- Urban 1
- Cadworks
- Seagate Systems

Structural Fire Resistance

ANNEX B - 2016

- Chair: Dr. Steve Craft

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CSA O86 – ANNEX B

Annex B (informative)
Fire resistance of large cross-section wood elements

Notes:

(1) *This informative (non-mandatory) Annex has been written in normative (mandatory) language to facilitate adoption where users of the Standard or regulatory authorities wish to adopt it formally as additional requirements to this Standard.*

Δ **(2)** *When this informational (non-mandatory) Annex is not otherwise adopted formally by building regulatory authorities as additional requirements to this Standard, the methodology presented provides information that may be useful to users of the Standard in the development of a proposal for an alternative solution to meet the objectives of the* National Building Code of Canada *(NBC).*

B.1 Scope

B.1.1

The design tables, data and methods specified in Annex B provide a design methodology to develop fire-resistance ratings of large cross-section wood elements based on structural criteria.

Δ **B.1.2**

The design methodology is intended to be used as an alternative approach for determining fire-resistance ratings for establishing compliance to the *National Building Code of Canada* (NBC), as determined by testing in conformance with CAN/ULC-S101.

Note: *The fire performance criteria for evaluating the separating function of building elements related to the passage of flames or hot gases and transmission of heat through the assembly, as defined in CAN/ULC-S101, are outside the scope of Annex B, except as otherwise noted.*

National Research Council of Canada Research

- CLT manufactured with new non-delaminating PUR adhesive
- A total of 5 tests were completed with wood cribs
  - Test 1: 3 layers of 12.7 mm gypsum board
  - Test 2: Exposed back wall and 10% of ceiling
  - Test 3: Exposed beam and columns
  - Test 4: Exposed ceiling with beam and column
  - Test 5: Exposed ceiling and end walls
- Ventilation factor same as smaller opening used in FPRF tests

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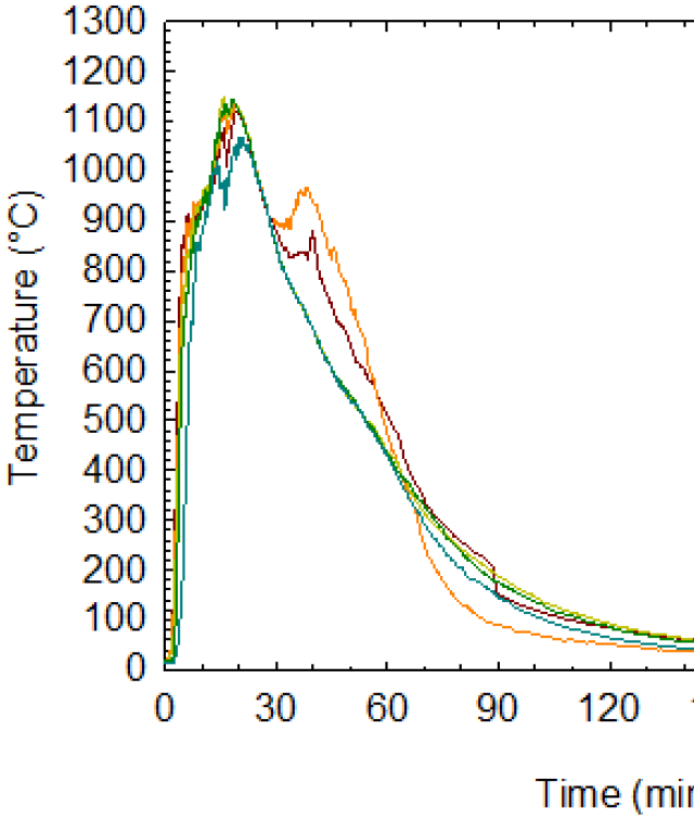
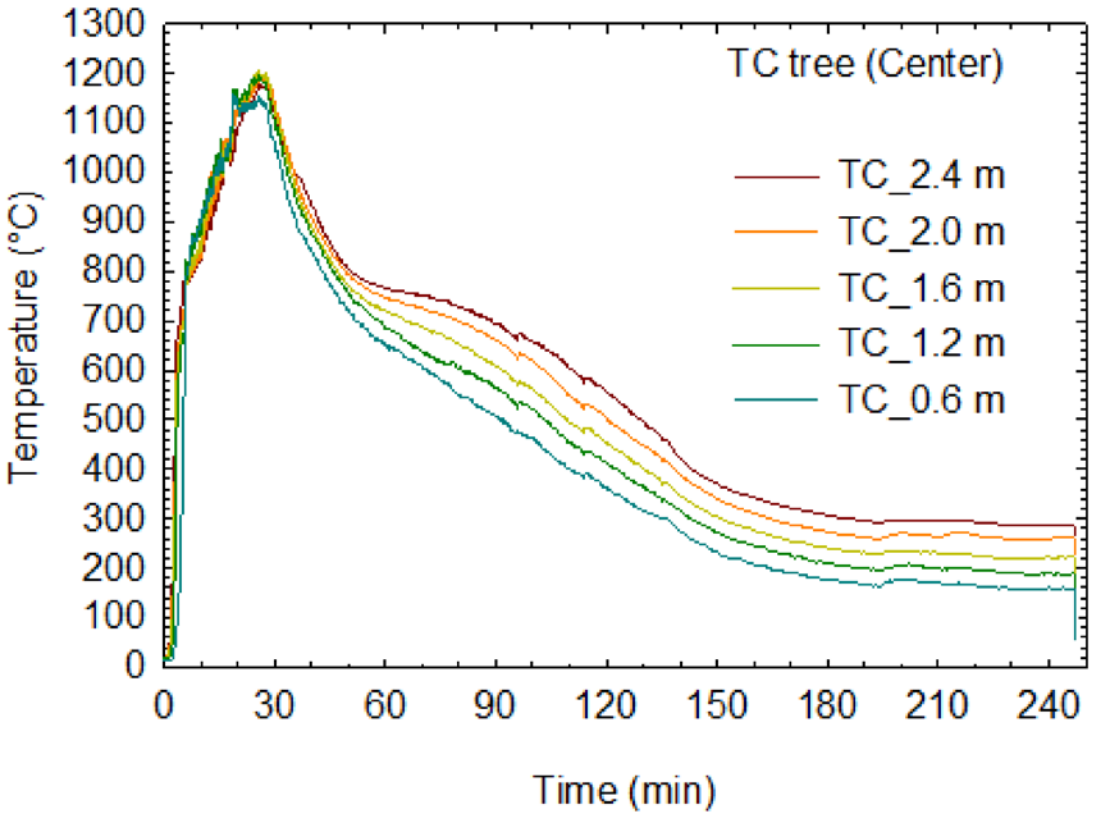
Fully encapsulated



Exposed wall and 10% ceiling



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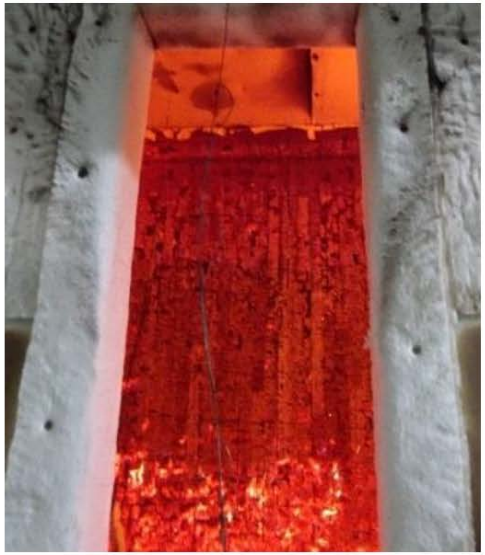
(a) flashover at 3.3 min

~ 1200 °C

(b) at 30 min

~ 750 °C

(c) Wall A and ceiling at 60 min



~ 650 °C

(d) Wall A and ceiling at 90

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~ 600 °C

(e) Wall A and ceiling at 110 min

~ 400 °C

(f) Wall A and ceiling at 140 min

~ 250 °C

(g) Wall A and Wall D at 210 min

~ 250 °C

(h) Wall A and ceiling at 240 min

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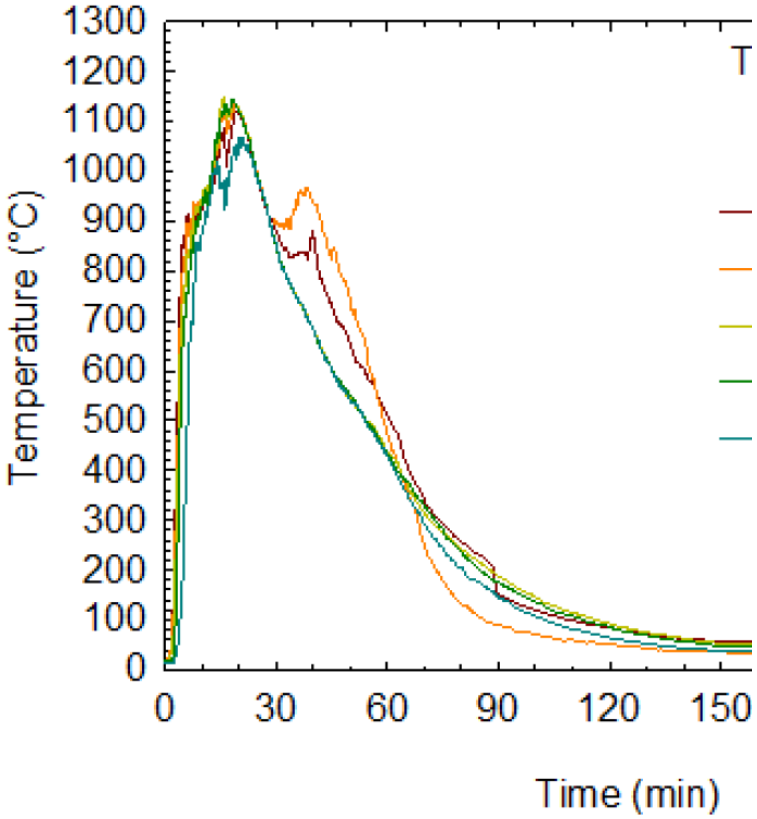
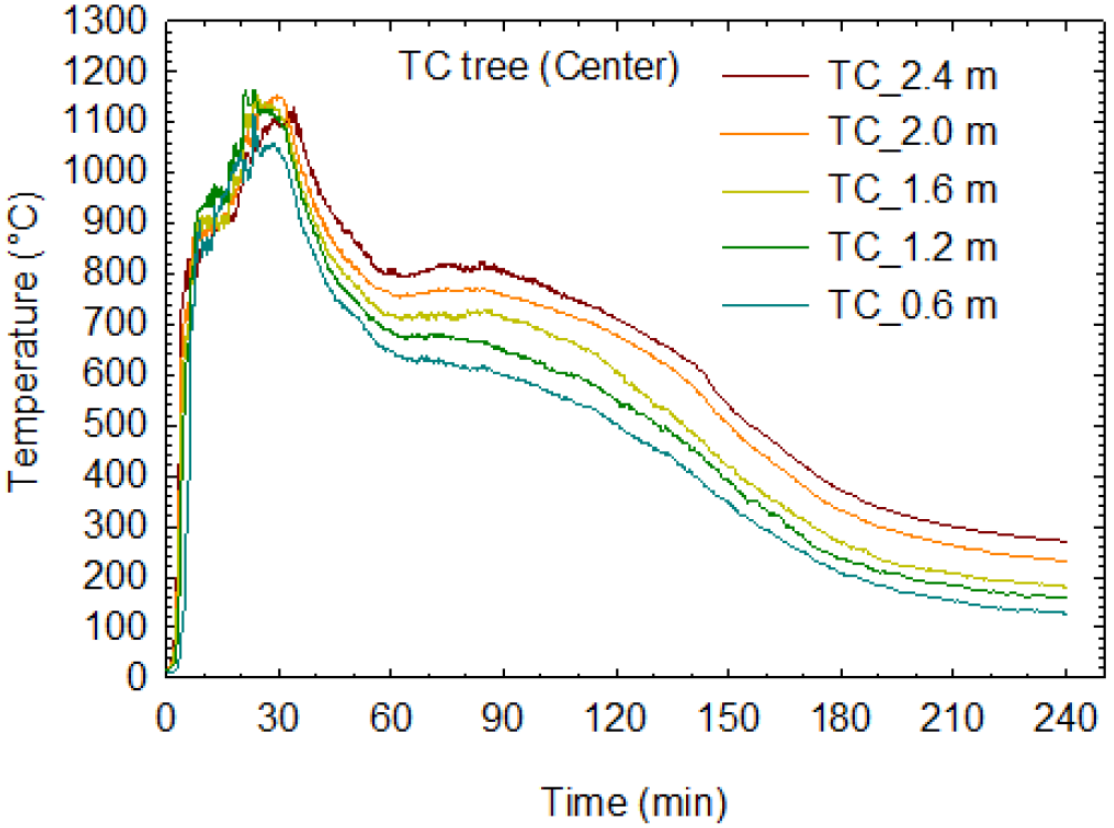
Fully encapsulated



Exposed column, beam and ceiling



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(a) at 40 min

(b) at 55 min

(c) at 90 min

(d) at 130 min

(e) at 150 min

(f) at 220 min

Char depth at end of 4 hrs. on average less than that calculated for 2 hrs. FRR

City of Vancouver

- Highly supportive of Mass Timber
- Knowledgeable top technical staff
- The big projects with complex alternative solutions go very well.
- Unlike the tiny projects;-(
- CP Process is essential, and for mass timber, CP needs expertise in mass timber.

2150 Keith Drive

- Approval in concept, subject to acceptable peer review!

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NEXT STEPS

NBC 2020 – BCBC 2024?

- 12 Storey Encapsulated
- 2 Layers GWB or Equivalent Encapsulation
- New Test of Encapsulation
- Allowing limited exposure in suites: One wall, 30%
- Public Comment
- **Residential and Office, Assembly & Retail level 1 - 3**

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Encapsulated Mass Timber Construction (EMTC), NBC 2020

- Type of construction to be incorporated into the NBC 2020
- Permits up to 12 storey Office & Residential EMTC buildings
- Minimum dimensions of timber
  - (~96mm if floor or wall; ~192mm for columns/beams)
- Encapsulation criteria

NBC 2020 Code Change – Encapsulated Mass Timber Construction

- Encapsulation of mass timber elements to limit contribution to fire spread and duration
  - 2 layers of 12.7-mm-thick Type X gypsum board,
  - 38-mm-thick gypsum-concrete topping, or
  - Other material or assembly of materials that provides an "*encapsulation rating*" of at least 50 minutes
- Mass timber elements to be protected from adjacent spaces, including concealed spaces

NBC 2020 Code Change – Mass Timber Minimum Dimensions

- Minimum size requirements for structural timber elements to be considered “mass timber”

Table 3.1.18.3.
Minimum Dimensions of Structural Timber Elements in Encapsulated Mass Timber Construction
Forming Part of Sentence 3.1.18.3.(2)-2020

Structural timber elements	Type of Dimension	Minimum Dimensions (mm)
Wall, floor and roof assemblies	thickness/depth	96
Beams, columns and arches with 2-sided or 3-sided fire exposure	cross-section	192 x 192
Beams, columns and arches with 4-sided fire exposure	cross-section	224 x 224

NBC 2020 Code Change – Exposed Timber Permitted

- Some mass timber surfaces permitted to remain exposed
  - Beams, Columns, and Arches within a suite or fire compartment
  - ➢ Beams, columns and arches in suites or fire compartments with aggregate surface area ≤ 10% of total wall area of perimeter of suite or fire compartment
  - Walls within a suite
  - ➢ Exposed walls within suite must face same direction, up to 35%
  - Ceilings within a suite
    - ➢ Exposed ceilings within suite, up to 25% (up to 10% if any exposed walls)

American Model

TABLE 2:

Required Noncombustible Protection on Mass Timber Elements by Construction Type

	IV-A	IV-B	IV-C	IV-HT
Interior Surface of Building Elements	Always required. 2/3 of FRR, 80 minutes minimum	Required with exceptions. 2/3 of FRR, 80 minutes minimum	Not required*	Not required*
Exterior Side of Exterior Walls	40 minutes	40 minutes	40 minutes	Not required*
Top of Floor (above Mass Timber)	1" minimum	1" minimum	Not required*	Not required*
Ceiling (below Mass Timber)	Per interior protection	Per interior protection	Not required*	Not required*
Shafts	2/3 of FRR, 80 minutes minimum, inside and outside	2/3 of FRR, 80 minutes minimum, inside and outside	40 minutes minimum, inside and outside	Not required*

**Not required by construction type. Other code requirements may apply. 5/8" Type X gypsum = 40 minutes.*

5

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18 Storeys

- Canada

- 18 – Brock Commons
- No exposed
- 3 layers 5/8in

- US

- 18 storey
- No Exposed
- 2 layers 5/8

12 Storeys

- Canada
- NBCC
- No exposed
- 2 layers ½ in X

- US
- No Exposed
- 2 layers 1/2X

9 Storeys

- Canada

- NBCC
- No exposed
- 2 layers ½ in X

- US

- 18 storey
- Fully Exposed
- Shafts 2 layers 1/2X

Firestopping

Firestops and Service Penetrations

- Prior Tests
  - → F-rating of 1½h

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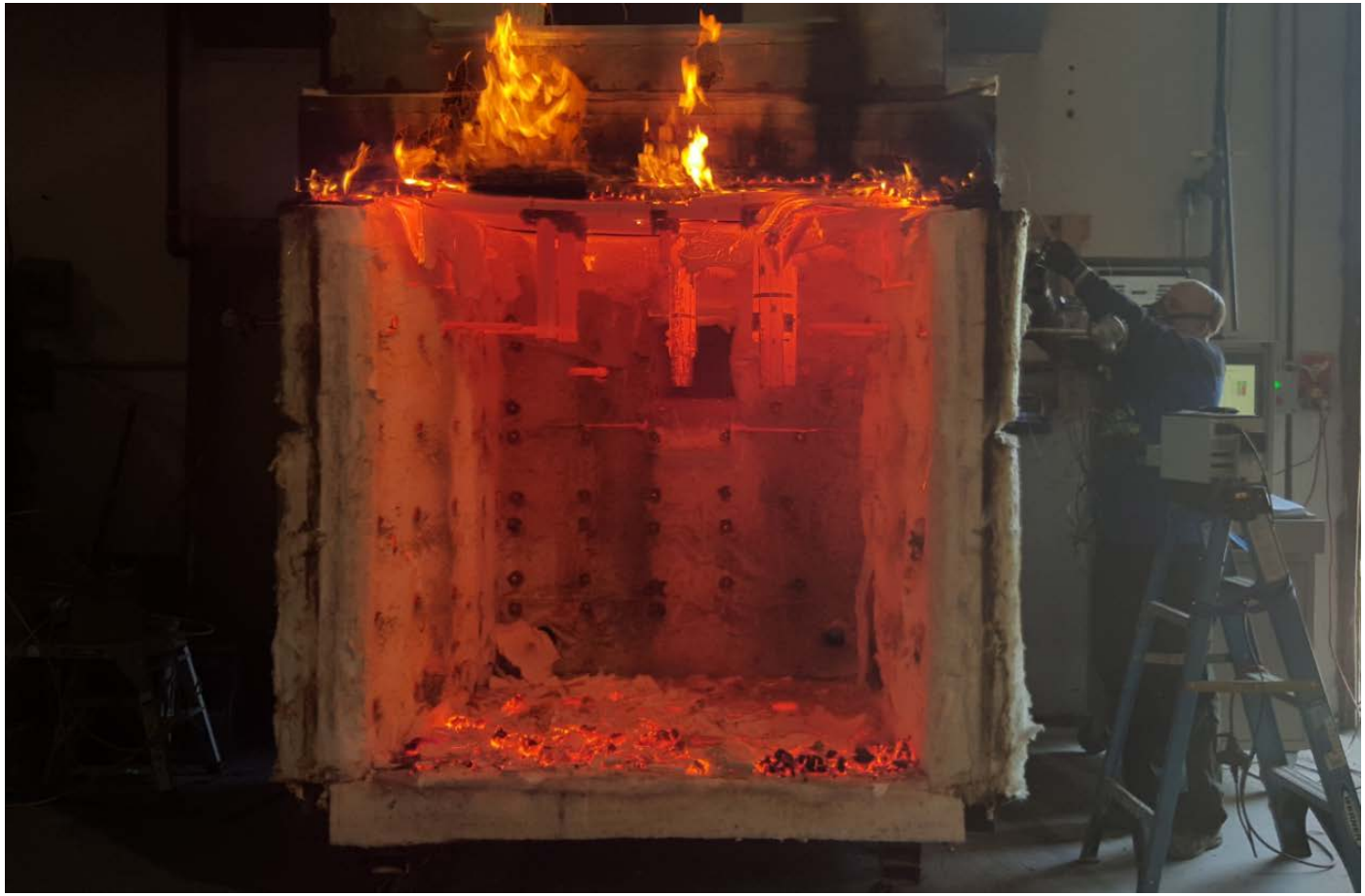
In OUR Opinion

- There was sufficient information available to address firestopping based on engineering judgments
- Notwithstanding, project specific testing was required and performed

Opening Furnace at 2h



Firestop Testing

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Firestop Testing

Confirmed only minor charring at 2h

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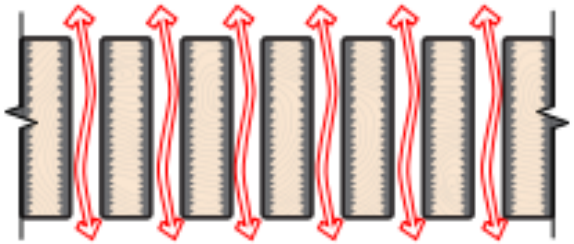
Firestop Frustrations

- Multiple EJ's from major manufacturers that are WRONG
- Unsealed
- Very simple principal – insulate wood from metal

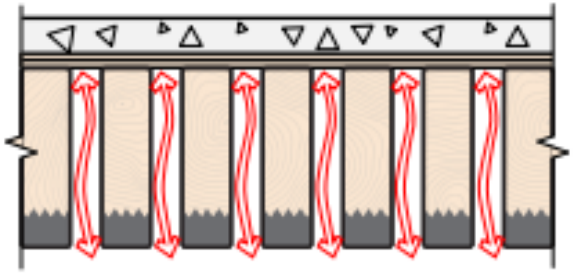
- Note EGBC bulletin on EJ's being sealed by an engineer

Construction Joints – NLT

Nail Laminated Timber



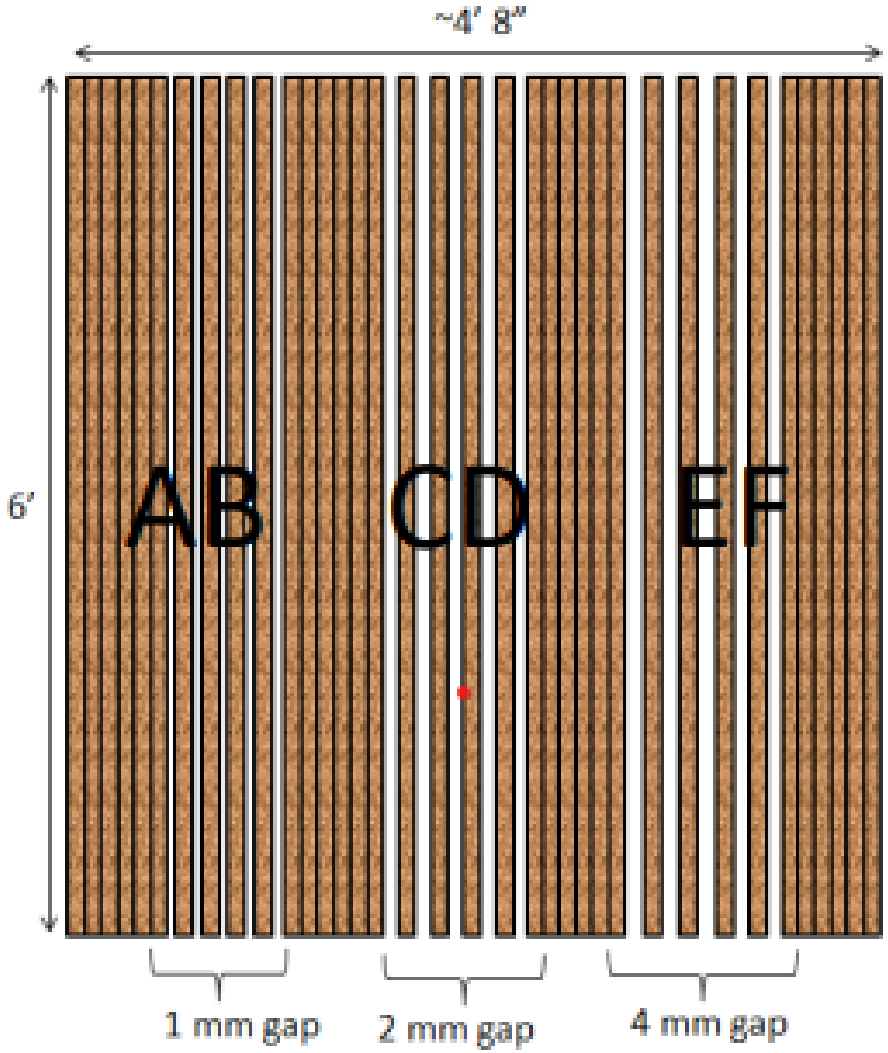
Air Movement Possible
Account for Side Charring



Air Movement Prevented
Treat as Solid Timber Element

Figure 3.5: *Air Movement Through NLT*

Tested NLT samples



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NLT Gaps

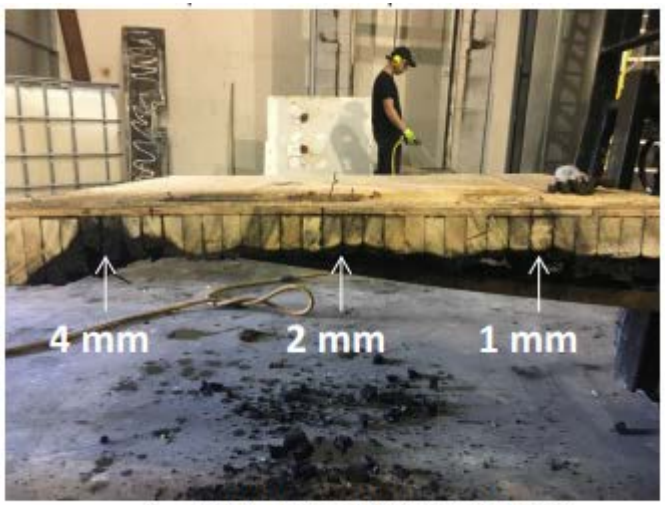
a) Test 1 exposed surface

b) 1 mm gaps (AB)

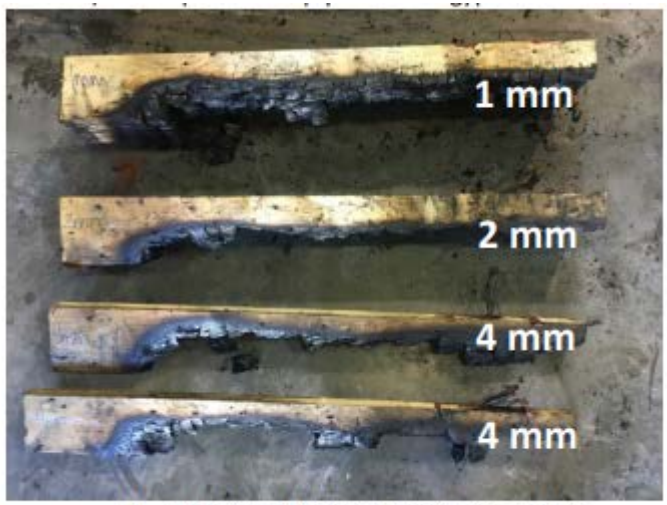
c) 2 mm gaps (CD)

d) 4 mm gaps (EF)

Figure 4. Gap spacing in Test 1

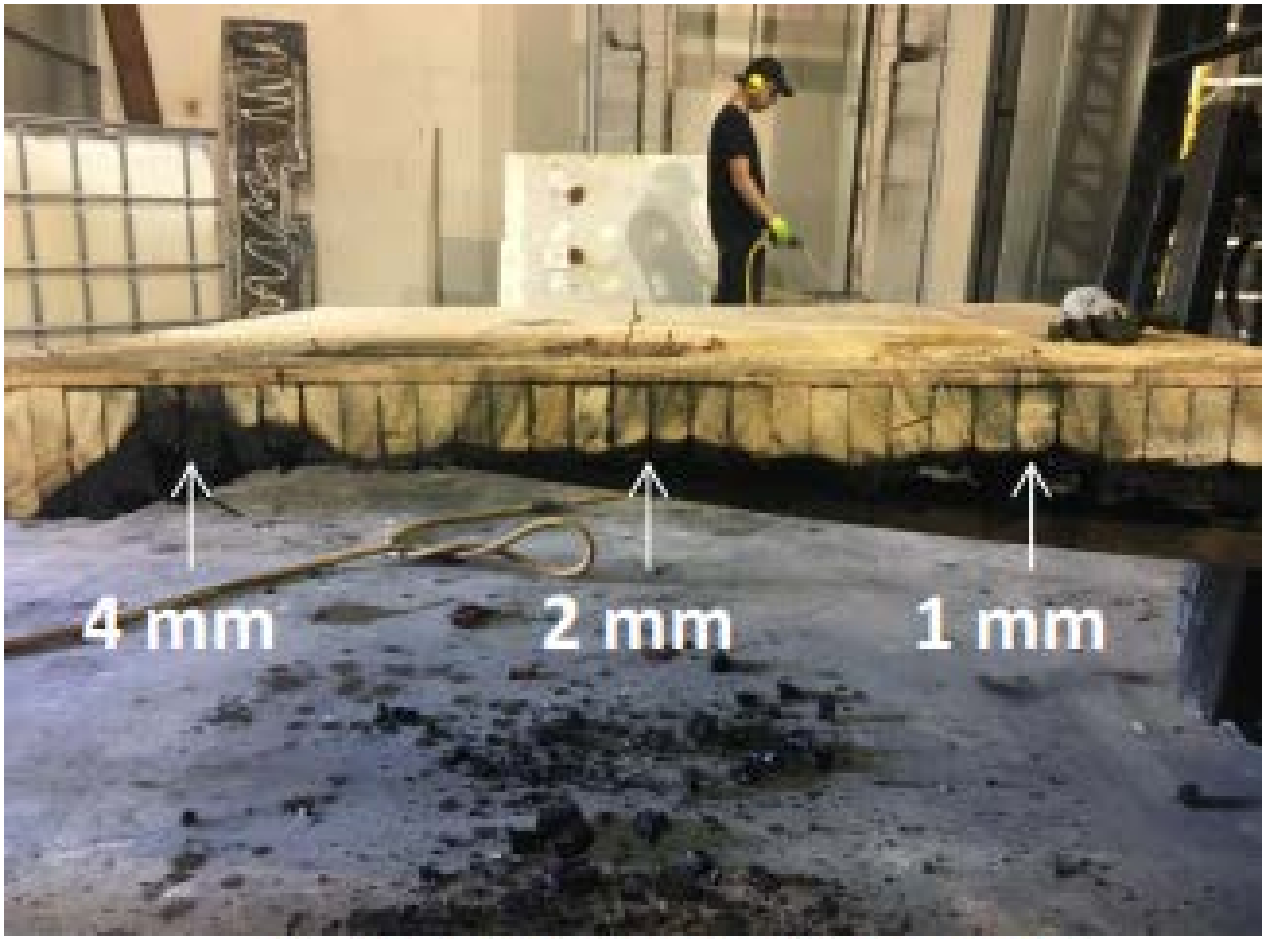


c) Profile of assembly cut at mid-span



d) Charring of boards at each gap spacing

Assembly at mid span



c) Profile of assembly cut at mid-span

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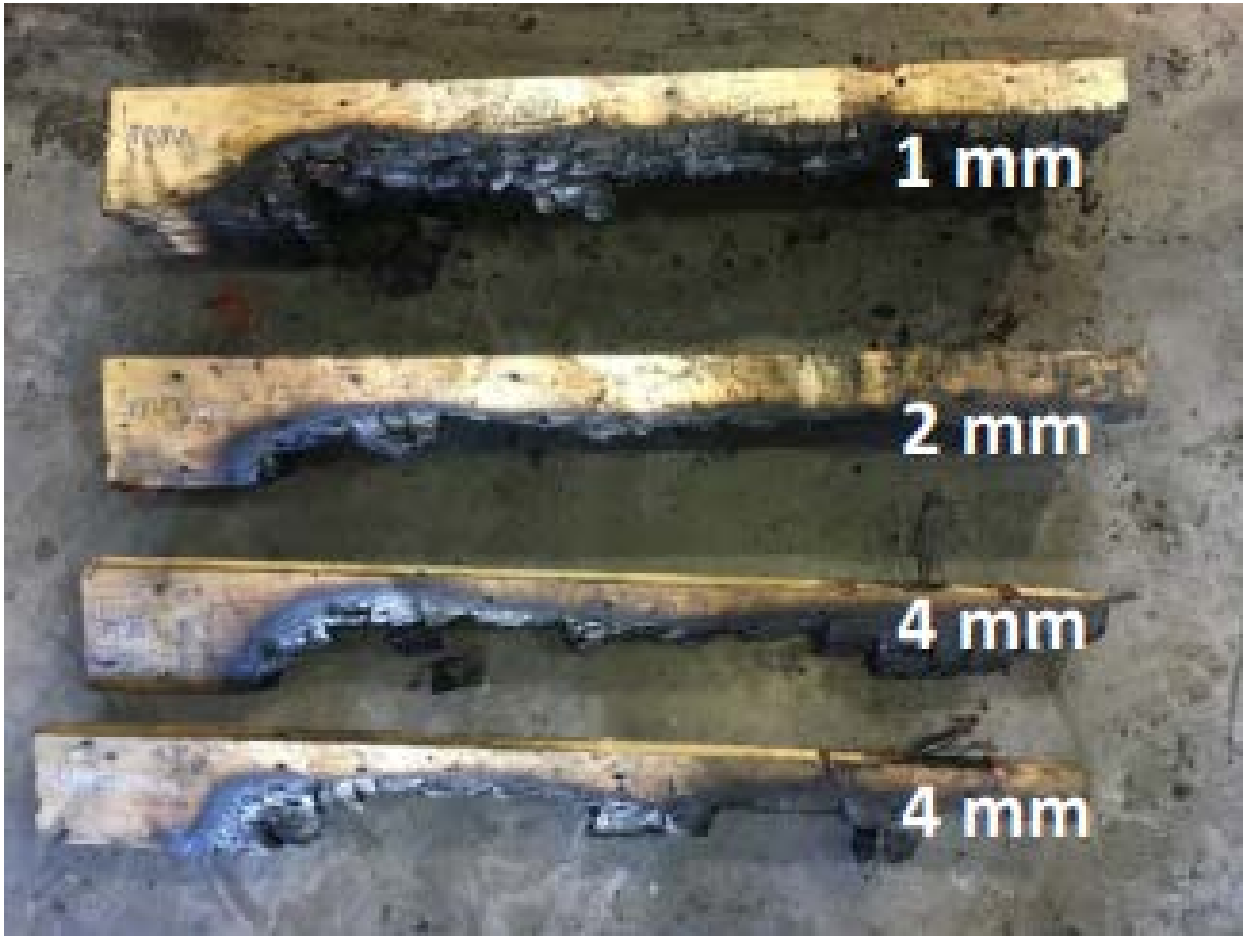

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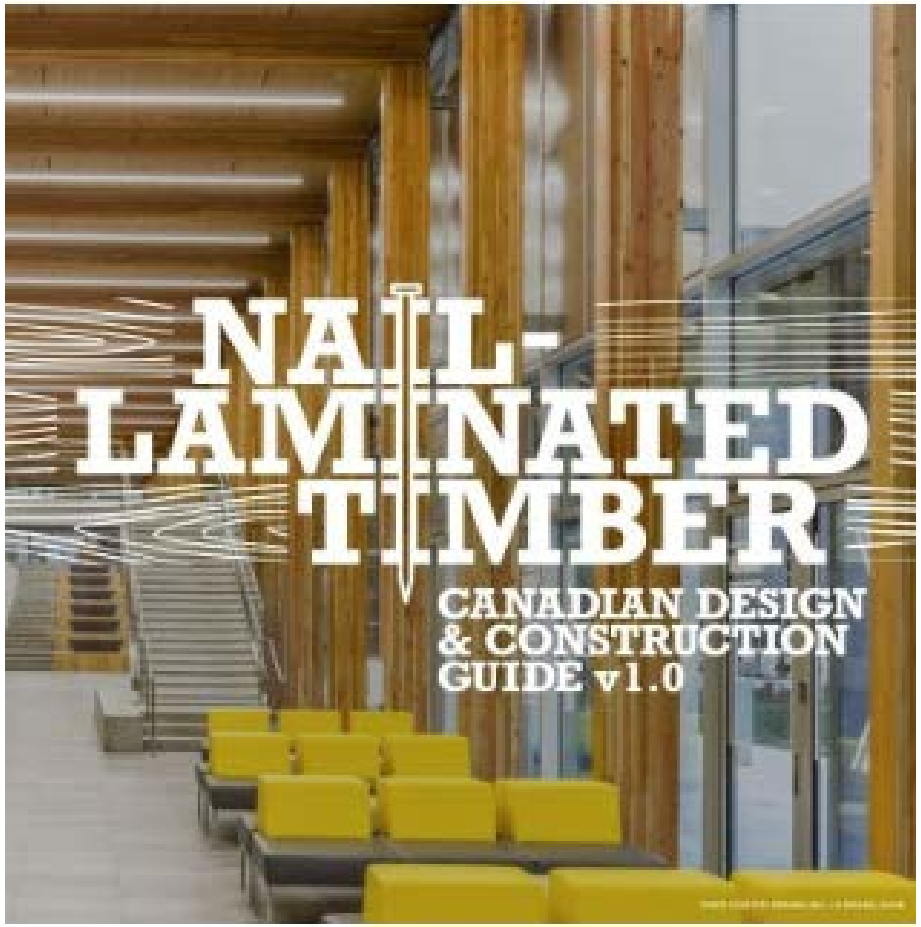
NLT Penetration, 2mm Gaps

Nail Laminated Timber



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Penetration, 2mm Gaps

c) unexposed side during the test

d) assembly removal after the test

Figure 15. Test 2 assembly during test

Guidance on Joints CLT / NLT

- NLT, DLT needs a continuous membrane/topping
  - See old HT designs – they knew their stuff
- CLT panels, tight (< 1mm) – acoustic sealant
  - Above the char line
  - Panels screwed or splined together
- CLT not tight (1mm<6mm) Intumescent caulk
  - Above the char line
- Wide gaps, mineral wool and intumescent caulk

Dowel Laminated Timber

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DLT – QC controlled NLT

- Fabricated in Factory Conditions
- Lumber is planed twice
  - Once in manufacture
  - Once at Structurecraft (will see what other manufacturers do)
- Fabricated on a press
- More dimensionally stable than NLT
- Better Fire Properties than NLT
- How Much – we don't know

CONSTRUCTION FIRE SAFETY

Construction Fire Safety Plan

- Inherent part of the design discussions.
- Hot Work Permit System.
- Encapsulate as fast as practical.

Assess Exposures

Limit / Protect Exposed Combustibles

- No more than 4 levels of unprotected wood during construction.

- Protection during construction either:
  - 1 layer of Type X gypsum board or
  - equivalent measures may be also be explored at contractor's discretion

- Control Exposures to adjacent structures.

Lessons Learned: Construction Fires

- 4 levels unprotected was impractical.
- It WILL RAIN – even in June.
- Refined to a schedule of up to 6 levels protected.
- Perceived Risk was less than initially imagined.

Lessons Learned: Construction Fires

- There was NO significant combustible refuse.
- There was NO hot work adjacent to wood (as I understand).
- Perceived Risk was less than initially imagined.

Construction

Construction

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Construction

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Mass Timber ≠ Light Frame

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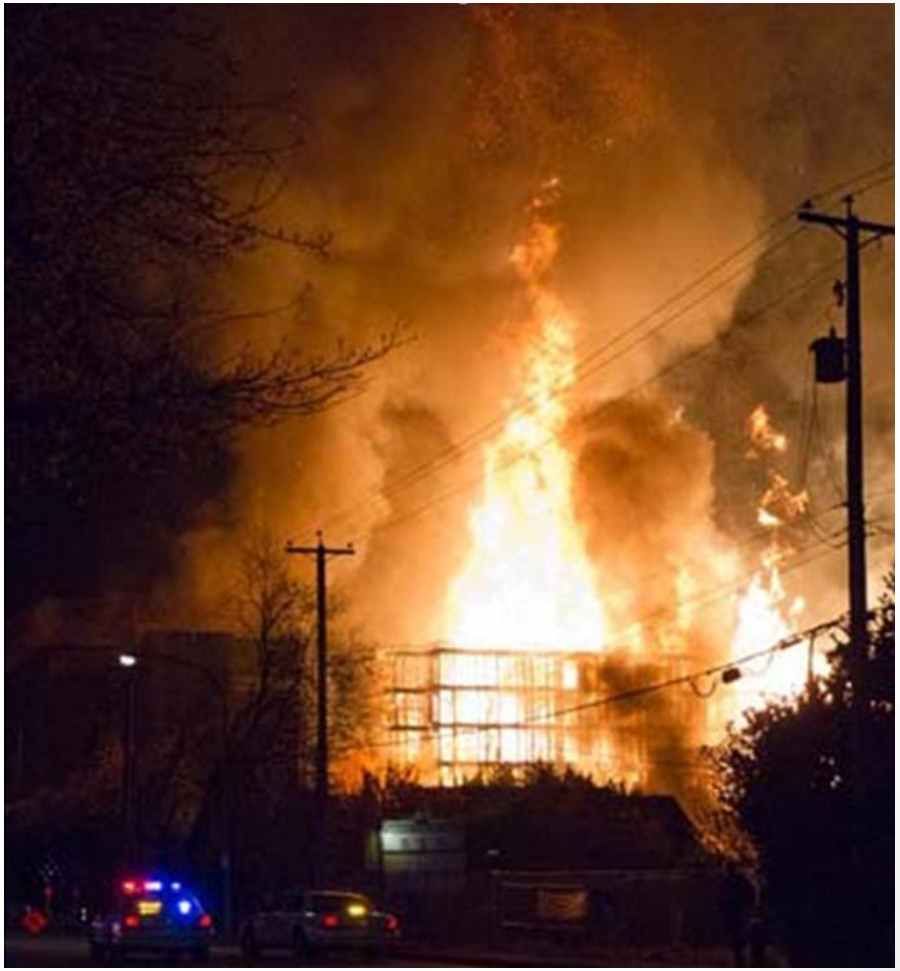
Temporary Stair Fire Door

- Fire doors in place
- ½ GWB on Plywood
- Bungee cord closer
- Fish line hold open

Light Frame – 100% involvement



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Surrey Fire Demonstration

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Fire During Construction

- Mass Timber compartment under construction
- High Fuel Load
- (much higher than Tallwood House at UBC)

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After Fire

- Still Intact
- Still Carrying Load

Fire Code Provisions

- Standpipes – Charged or air pressure
- Protected Stairs
- Minimize Refuse
- Waste storage 3m away from building
- No more than 4 levels not protected by GWB

4 levels protected

- US is 6 levels
- Not Practical
- Is it needed?

What I Propose

- Stairs – c/w 20min FRR doors (1/2gwb on plywood)
- Hold Opens and Closers (Bungee Cords and Fishing Line)
- Cover all openings minimum 1/2gwb and plywood

Future of Midrise

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Health Care - Thoughts

Health Care Options

- Medical OFFICE – 12 Storey Mass Timber permitted (JSR/2020)

- Argument can be made that Encapsulated Mass Timber is equivalent in reliability to Spray protected steel
  - Adds fuel - but
  - More reliable
  - Additional measures like on site water can improve safety

Care Type Occupancies

- I think the old ‘enhanced ‘C’ approach in BC was better than the new ‘Group B3’
- We allowed 4 storeys
- Should allow 12 storeys 2h B3 MT – like ‘enhanced C’.

Full Treatment Hospital

Infection Control

- No Data on Infection Control Health Care
- However, I can't believe that spray on fluffy stuff is worse than mass timber.
- Surface materials are the same.

Hospital, circa 1900

- St Ann's Academy
- 6 Storey Wood Frame
- Convent
- TB Treatment Facility and other health care uses

Resiliency

- Whether concrete, steel or wood Treatment hospital should be:
  - designed for 100 year life
  - designed for flexibility
  - reliable redundant fire protection - No FLUFFY STUFF
  - Properly protected connections – No intumescent
  - On Site water supply
  - Redundant fire pumps

FUTURE

Division B – 3.2.2

- Essentially a collection of ‘Acceptable Solutions
- Over time, more solutions will be added
- Schools, Assembly Occupancies

Vancouver

- Highly Supportive
- Respects Expertise
- Requires Peer Review
- Requires Time – Parallel the Development Permit Process
- Willing to issue letters of support

Predictions: Approval Process

- Further divergence between Code and Alternative Solutions
  - Code Can't Keep Up
  - Brock Commons approach in 2020NBC – 2024BCBC??
  - US moving ahead, but very conservative
- Greater acceptance of Alternative Solution process.
  - Peer Review will become more accepted
- SSR may enable a Political Champion to make BIG advances.

Predictions

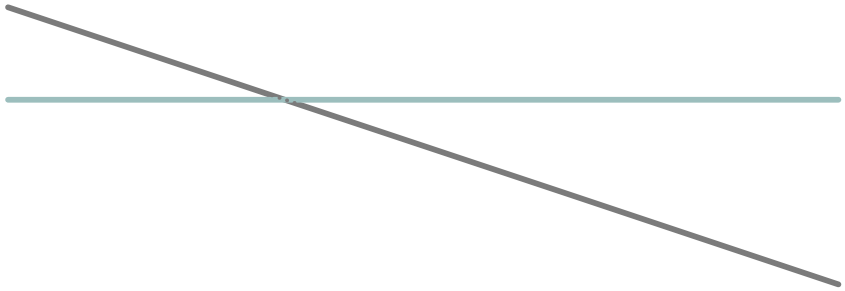
- We are early in the game,
- Prefab is the future, mass wood facilitates prefab
- Hybrid – best material for the job
- New products will reduce costs
  - New CLT layups to reduce ‘wasted wood’
  - Nail Laminated Timber – Factory Produced
  - Dowel Laminated Timber
  - Prefab, enclosed, nonstructural components such as walls, floors

Speed of Construction

- Speed of Erection not factored into costs properly
  - 3+ floors per week, multiple small teams
- Speed of construction hampered by other team members expectations
- We will see many refinements reducing costs
  - Integrated electrical systems (pre-installed conduit)
  - Integrated plumbing systems
  - Prefab wall and floor modules
  - Simple ‘Lego-like systems’ expanded to more complex layouts

Cost Curves

- Great potential for reducing construction duration
- Great potential for reducing construction costs
- Prefab - realized



Final Thoughts

- Design costs will increase – all consultants need to develop new details
- Understand the value of good consultants
- Don’t let frustration with planning hinder Code innovation
- Should be countered by reduced construction costs
- Alternative Solutions will become the norm

Thank you

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Questions?