Mass Timber Demonstration Fire Test Program (MTDFT 2021 – 2022)

Observations, Lessons Learned and Implications for Alternative Solutions and Code Changes

December 7, 2022

S. Claire Yuan, P Eng

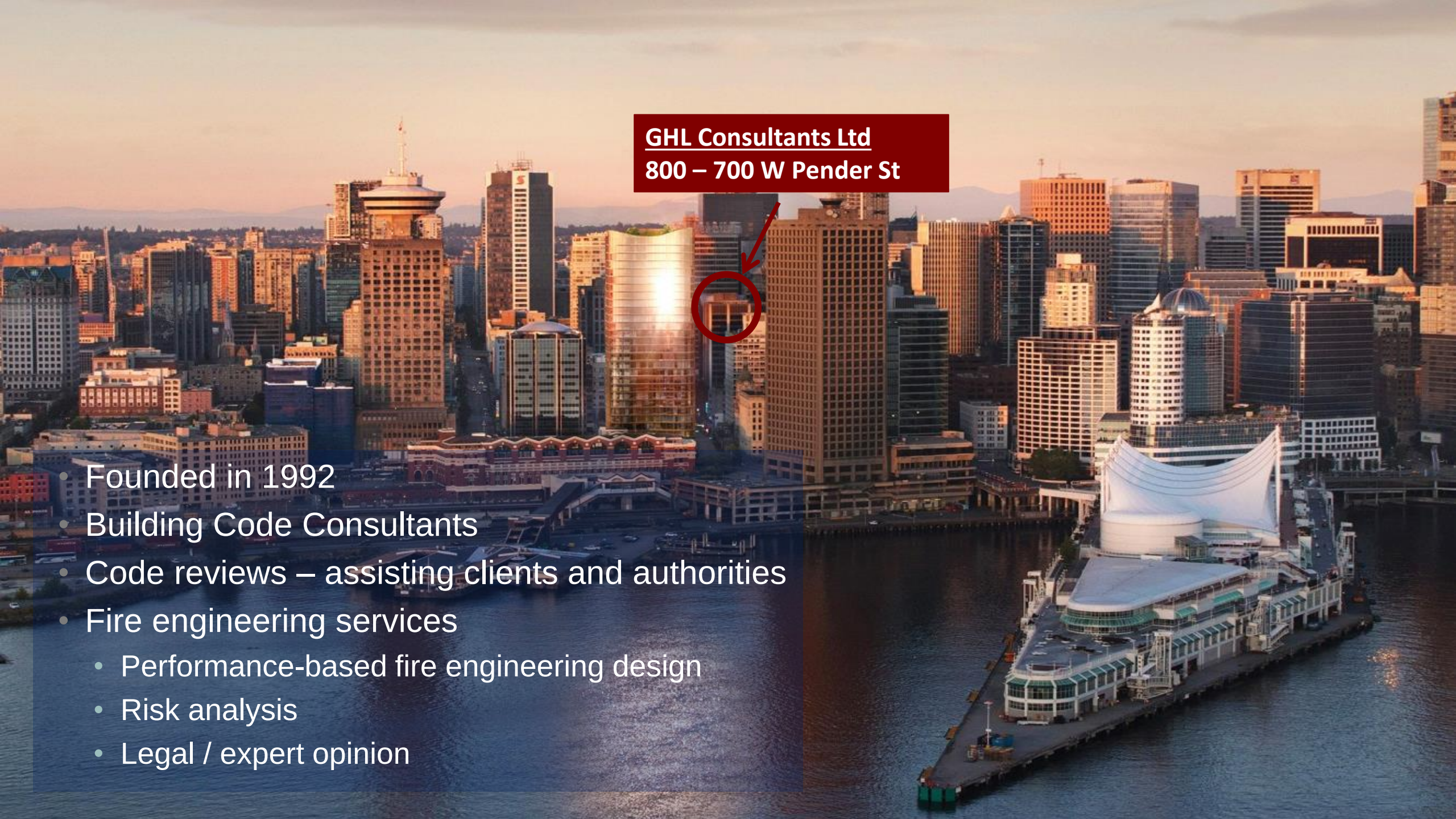
Email: cy@ghl.ca

Web: www.ghl.ca

Copyrights and Limitations

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.

GHL

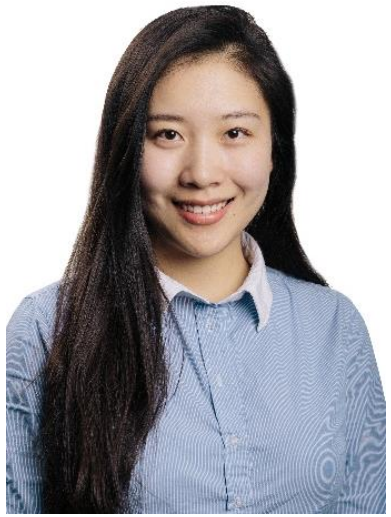


- Founded in 1992
- Building Code Consultants
- Code reviews – assisting clients and authorities
- Fire engineering services
  - Performance-based fire engineering design
  - Risk analysis
  - Legal / expert opinion

S. Claire Yuan, P Eng

Associate, GHL Consultants Ltd

Email: cy@ghl.ca



- BASc, University of Alberta, Chemical Engineering
- MASc (progressing), University of Waterloo, Fire Protection Program
  - Performance Based Design Challenges in Canadian Building Code Environment
- Performance Based Design and Mass Timber Research
  - Improved Char Rate of EMTC Study
  - Mass Timber Demonstration Fire Test Program
  - Exposed Steel Connections in Mass Timber Construction
  - Construction Fire Safety

GHL

Andrew Harmsworth, M Eng, P Eng, PE 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
- Principal, GHL – 30 years now!
- Andrew's Timber Journey
  - Early work renovating old heavy timber buildings.
  - BC study 6 storey wood frame – Provincial Study and Code Change
  - NEWBuildS research network – academic study and mass timber fire tests.
  - Currently on Codes Canada Standing Committee on Fire Safety

GHL

Experience with Mass Timber – Completed

- Fire Engineers – Tallwood House at Brock Commons

UBC Brock Commons
18 Storey - 2017

UBC Earth Science Building
2012
5 Storeys – Office/Assembly

Wilson School of Design – KPU
2018
5 Storey A-2

GHL

Approved and Under Construction

The Arbour, George Brown College, Toronto
Moriyama & Teshima Architects + Acton Ostry Architects

1250 Keith Drive, Vancouver
Dialog, Bentall Green, Under Construction

GHL

Learning Objectives

- Understand: What is mass timber?
- Understand: Why mass timber?
- Prototypes
- Understand basic NBC Requirements for Mass Timber
- Mass timber Demonstration Fire Test Program
- Potential Alternative Solutions

GHL

What is Mass Timber?

Mass Timber Options

CLT

GLT

NLT

DLT

Minimum Dimensions

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

Table 3.1.6.3.
Minimum Dimensions of Structural Mass Timber Elements in Encapsulated Mass Timber Construction
Forming Part of Sentences 3.1.6.3.(2), 3.1.6.8.(1) and 3.1.6.17.(1)

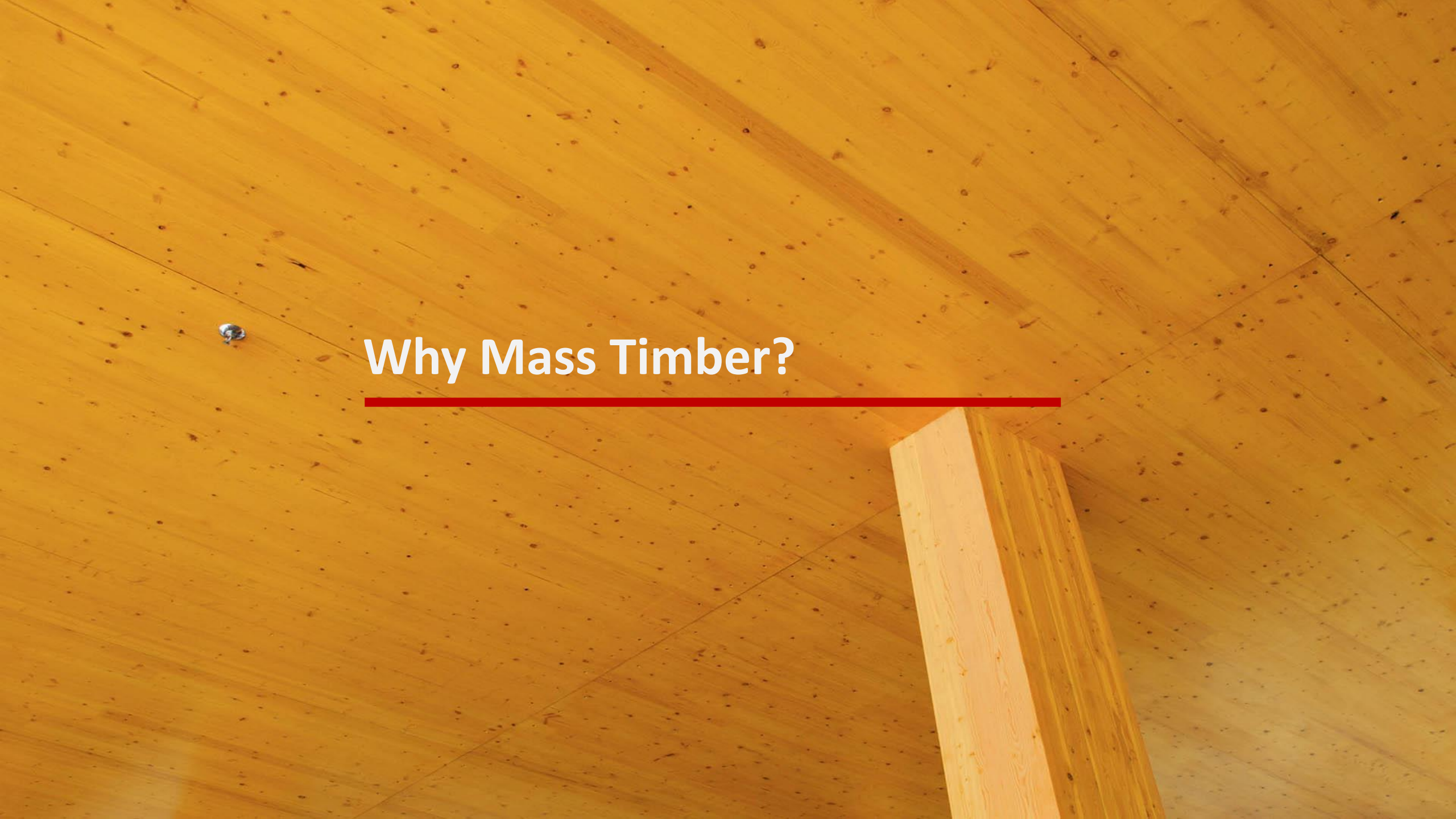
Structural Wood Elements	Minimum Thickness, mm	Minimum Width × Depth, mm × mm
Walls that are *fire separations* or exterior walls (1-sided fire exposure)	96	—
Walls that require a *fire-resistance rating*, but are not *fire separations* (2-sided fire exposure)	192	—
Floors(1) and roofs (1-sided fire exposure)	96	—
Beams, columns and arches (2- or 3-sided fire exposure)	—	192 × 192
Beams, columns and arches (4-sided fire exposure)	—	224 × 224

Notes to Table 3.1.6.3.:

(1) The minimum dimensions for floor assemblies are also applicable to mezzanines and exterior balconies.

[1] Excerpt from NBC 2020

GHL



Why Mass Timber?

Change in Fire Safety Tools

- Circa 1900
  - Building construction material was the main tool for fire control
  - Fire detection was manual – visual detection
  - Fire may be fully developed by the time fire department called
  - Minimal sprinklers

- Today
  - Many more tools
  - Fire detection in the incipient stages
  - Automatic detection
  - Automatic fire control – sprinklers
  - Automatic monitoring – system reliably calls fire department

GHL

Mass Timber vs Noncombustible

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

GHL

The Landing - Gastown

8 Storey Heavy Timber

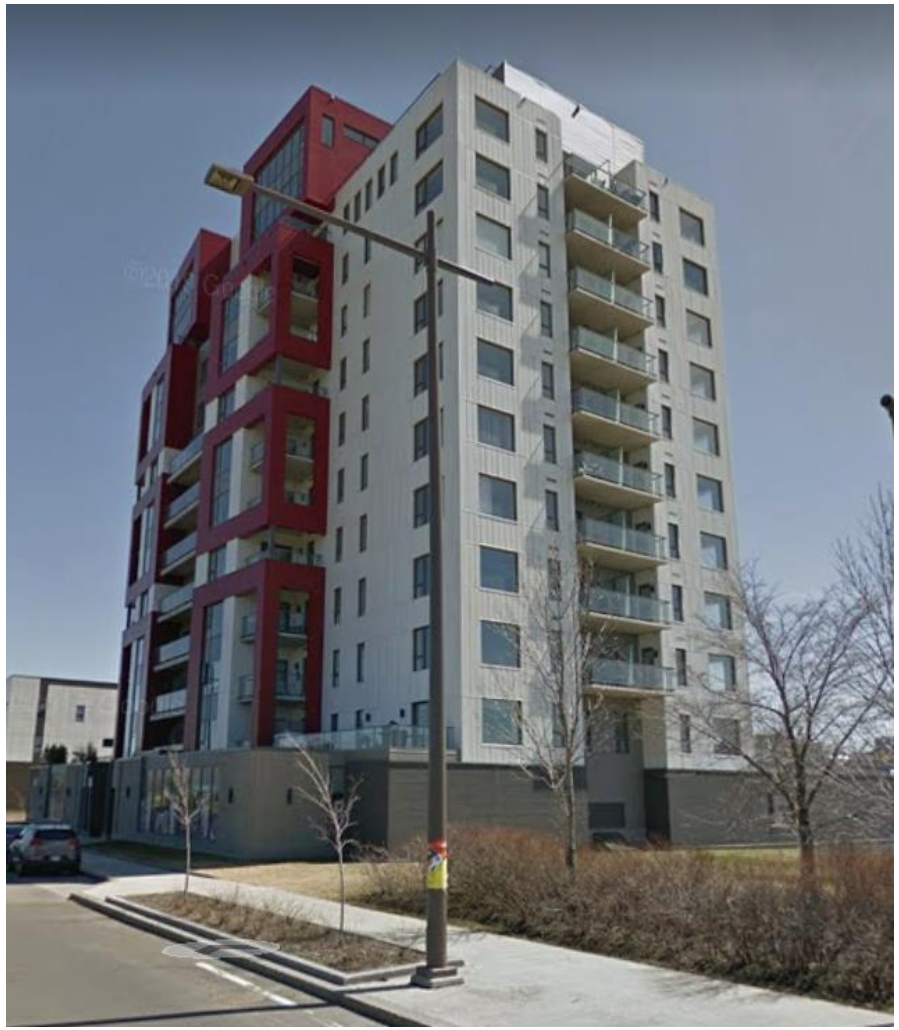
- Constructed 1905
- Upgraded ~ 1980
- 8 Storeys
- 2100m²

GHL

Prototypes

Origine – Quebec City

- 13 storeys, Group C
- Encapsulated Glulam and CLT
  - Nordic Structures
- challenge to demonstrate a CLT stair shaft was ‘as safe as concrete’



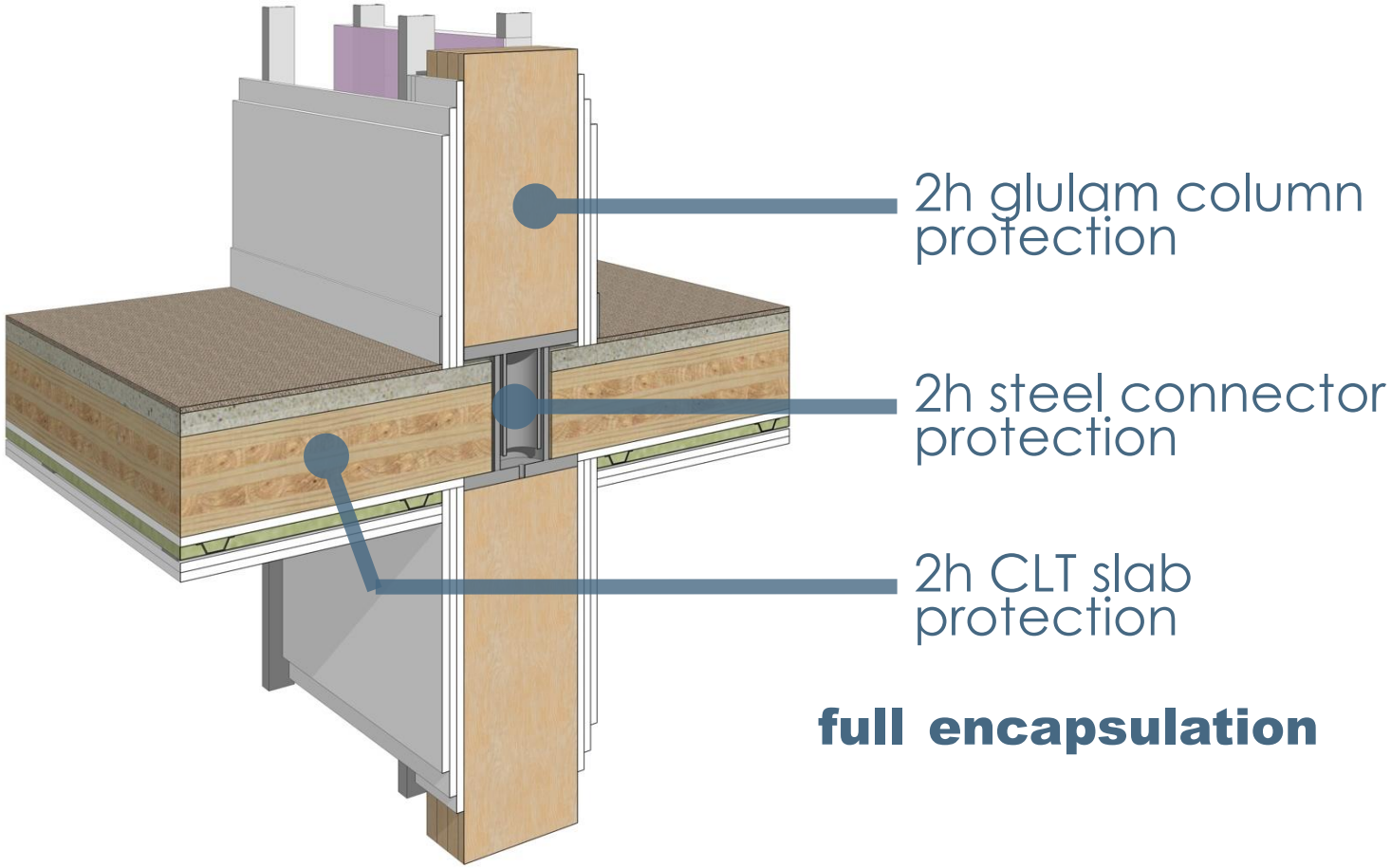
GHL

Tallwood House – UBC

- 18 storeys, Group C
- Fully Encapsulated Glulam and CLT
  - Structurlam
- Concrete stair cores
- Timber Erected in 44 days

GHL

How to protect these buildings?



GHL

Simple Assembly

GHL

Column to Column Connections

GHL

Erector'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

GHL

NBC 2020 / BCBC 2018

Encapsulated Mass Timber Construction (EMTC), NBC 2020

- Incorporated into the NBC 2020
- Permits up to 12 storey Office & Residential EMTC buildings
  - Assembly, Retail, and Medium / Low hazard Industrial permitted on lower storeys
- Minimum dimensions of timber
  - (~96mm if floor or wall; ~192mm for columns/beams)
- Allowing limited exposure in suites:
  - Beams and columns; 10% of aggregate wall area
  - One wall facing one direction, 35%, and
  - 10% of total ceiling area, or 25% of ceiling, with no exposed mass timber surfaces
- Encapsulation criteria

GHL

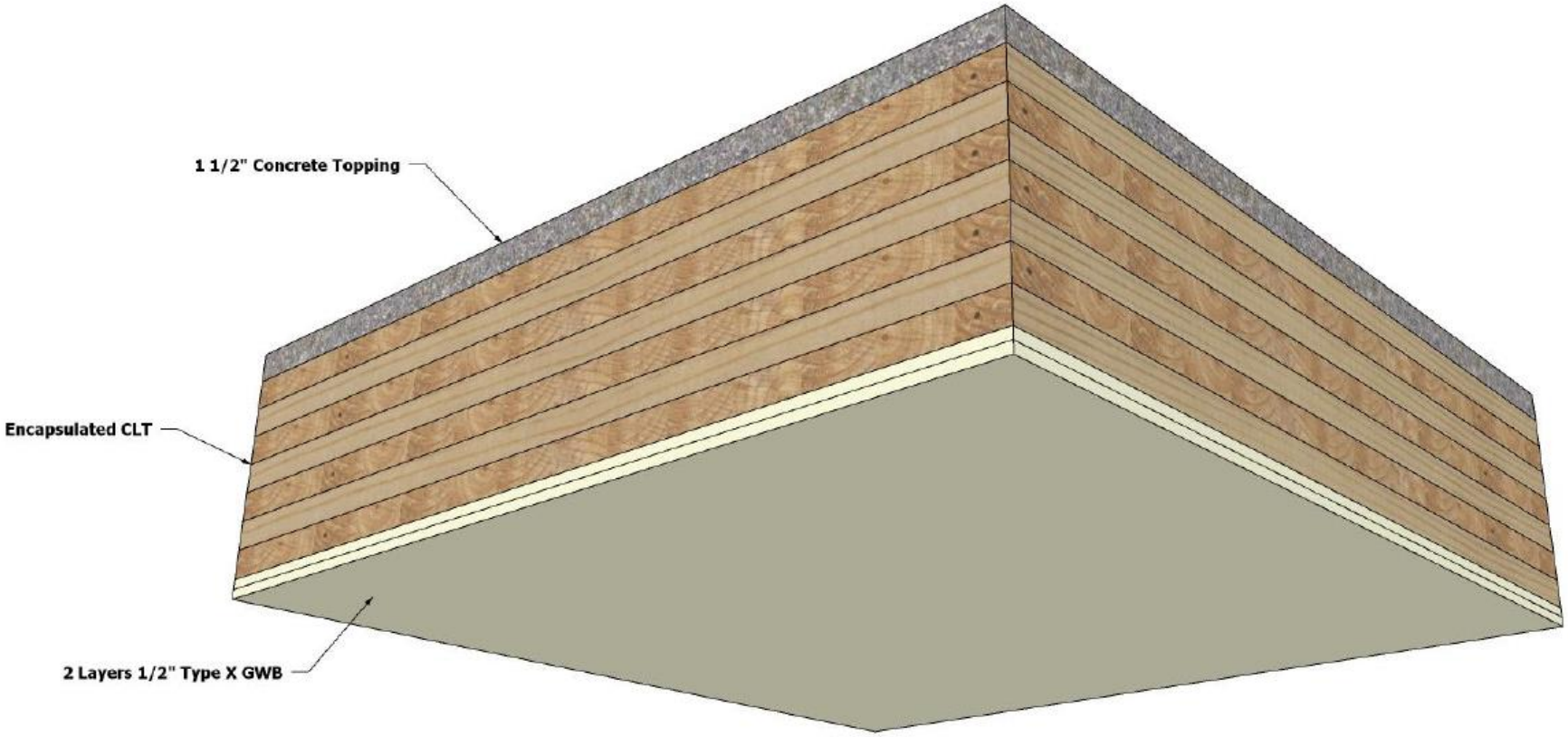
Encapsulated Mass Timber Construction

- Encapsulation of mass timber elements to limit contribution to fire spread and duration
  - 2 layers of 12.7-mm (1/2in) 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

GHL

NBC 2020 Encapsulation



Encapsulated CLT - 2 Layers 1/2in Type X GWB provides 60min FRR

GHL

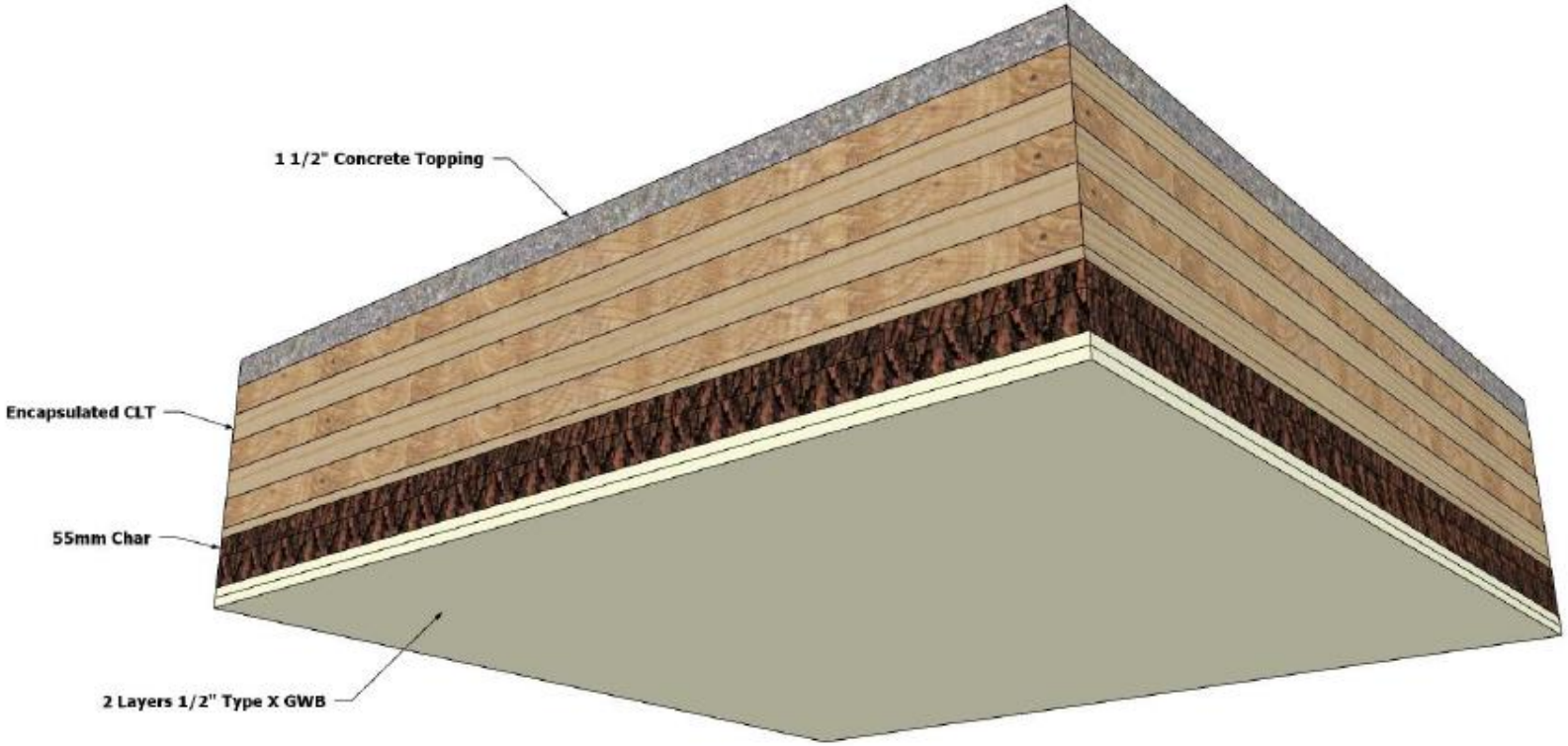
Encapsulation ≠ Fire Rating

- Encapsulation
  - Time for wood behind encapsulation layer to char (~270C)
  - Does not equal fire rating

- Fire Resistance Rating
  - Time for wood to withstand the passage of flame or transmission of heat
  - Includes the mass timber and encapsulation material (if provided)

GHL

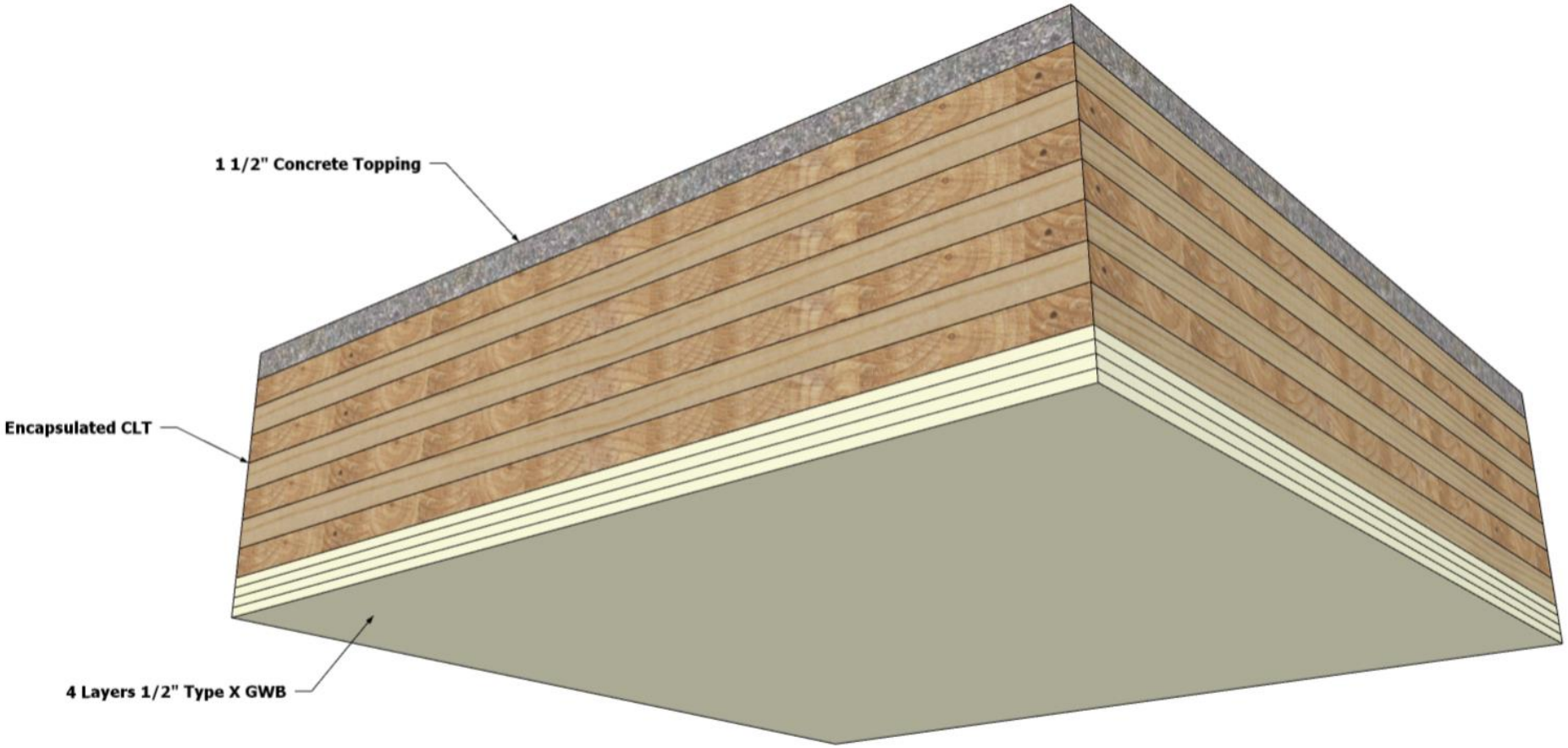
NBC 2020 Encapsulation



Encapsulated CLT - 2 Layers 1/2in Type X GWB provides encapsulation rating at 50 minutes and FRR at 120min with 55mm char (2@30min + 60min x 0.8mm/min + 7mm)

GHL

Encapsulation plus Fire Resistance



Encapsulated CLT - 4 Layers 1/2in Type X GWB provides 120min FRR

GHL

3h Steel Design

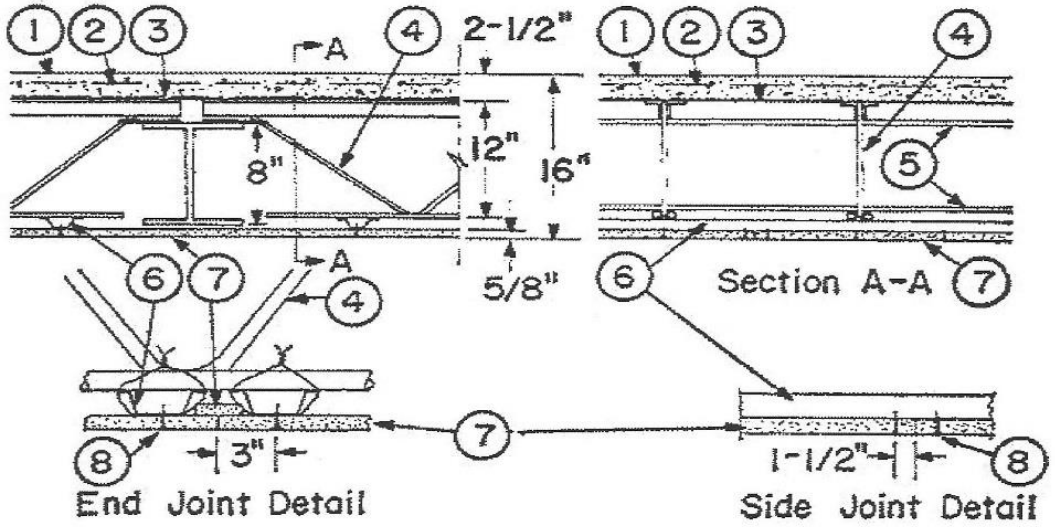
Fire Resistance Ratings - ANSI/UL 263

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.

GHL

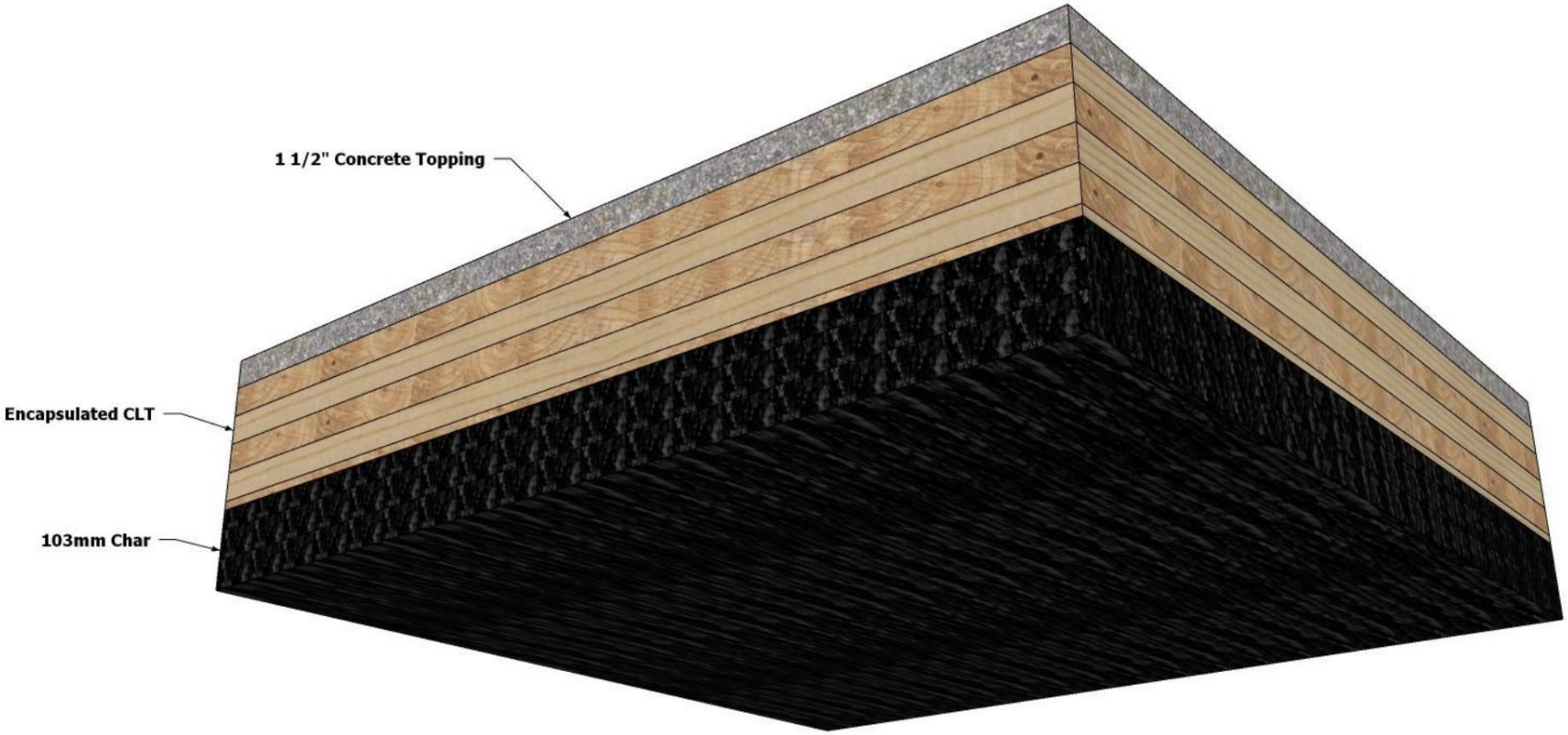
NBC 2020 Exposed Timber Permitted

Some mass timber surfaces permitted to remain exposed:

- Beams or Columns within fire compartments or suite
  - Aggregate surface area up to 10% of total wall area
- Walls within a suite
  - Exposed walls within a suite must face same direction
- Aggregate surface area of above noted mass timber element within a suite not exceed 35% of total wall area of the perimeter of the suite.
- Ceilings within a suite
  - Up to 25% of total ceiling area with no other exposed mass timber
  - Up to 10% if any other mass timber is exposed

GHL

Exposed Timber



Exposed CLT - with 103mm char provides 120min FRR
(0.8mm/min x 120min + 7mm)

GHL

Mass Timber Char Values - Conservative

Photo Credit CHM Fire Consultants Ltd.

Char depth at end of 4h tests is on average less than that calculated for 2h FRR
Typical residential fire peaks at 1h

GHL

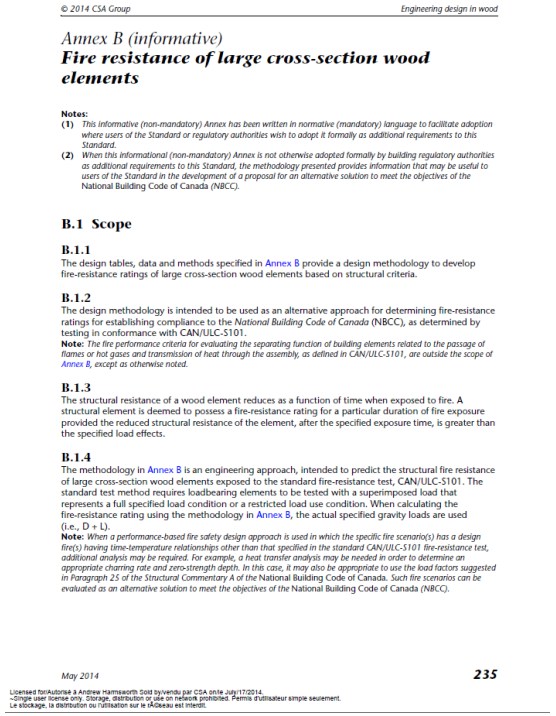
Calculating Fire Resistance

CSA GROUP™

CSA O86:19
National Standard of Canada

Engineering design in wood

Standards Council of Canada
Conseil canadien des normes



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.*
(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 *(NBCC).*

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.

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* (NBCC), 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.*

B.1.3
The structural resistance of a wood element reduces as a function of time when exposed to fire. A structural element is deemed to possess a fire-resistance rating for a particular duration of fire exposure provided the reduced structural resistance of the element, after the specified exposure time, is greater than the specified load effects.

B.1.4
The methodology in Annex B is an engineering approach, intended to predict the structural fire resistance of large cross-section wood elements exposed to the standard fire-resistance test, CAN/ULC-S101. The standard test method requires loadbearing elements to be tested with a superimposed load that represents a full specified load condition or a restricted load use condition. When calculating the fire-resistance rating using the methodology in Annex B, the actual specified gravity loads are used (i.e., D + L).
Note: *When a performance-based fire safety design approach is used in which the specific fire scenario(s) has a design fire(s) having time-temperature relationships other than that specified in the standard CAN/ULC-S101 fire-resistance test, additional analysis may be required. For example, a heat transfer analysis may be needed in order to determine an appropriate charring rate and zero-strength depth. In this case, it may also be appropriate to use the load factors suggested in Paragraph 25 of the Structural Commentary A of the* National Building Code of Canada. *Such fire scenarios can be evaluated as an alternative solution to meet the objectives of the* National Building Code of Canada *(NBCC).*

Annex B of CSA 086, 2019 provides guidance on calculating fire resistance rating

GHL

Principles of Materials - Wood

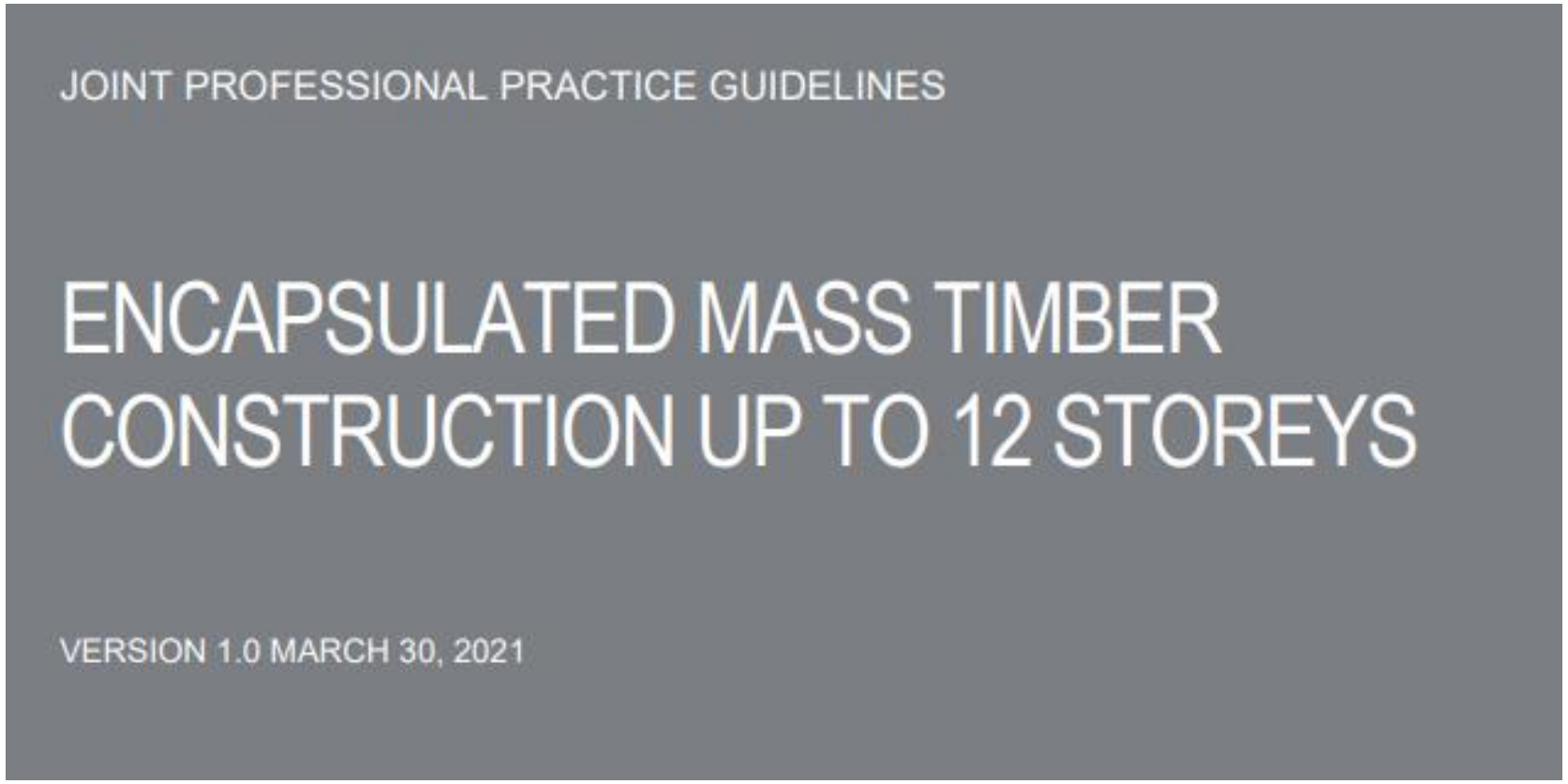
- Various types of mass timber available.
  - NLT, CLT, glulam, etc

- 0.65mm per minute (1½ inch / hour) of char
  - Flat surfaces and glues
  - Use 0.8mm/min for the effect of cracking, formation of fissures and corner rounding

- Time to failure depends on:
  - Size of members
  - Loading

GHL

EGBC Guide to EMTC



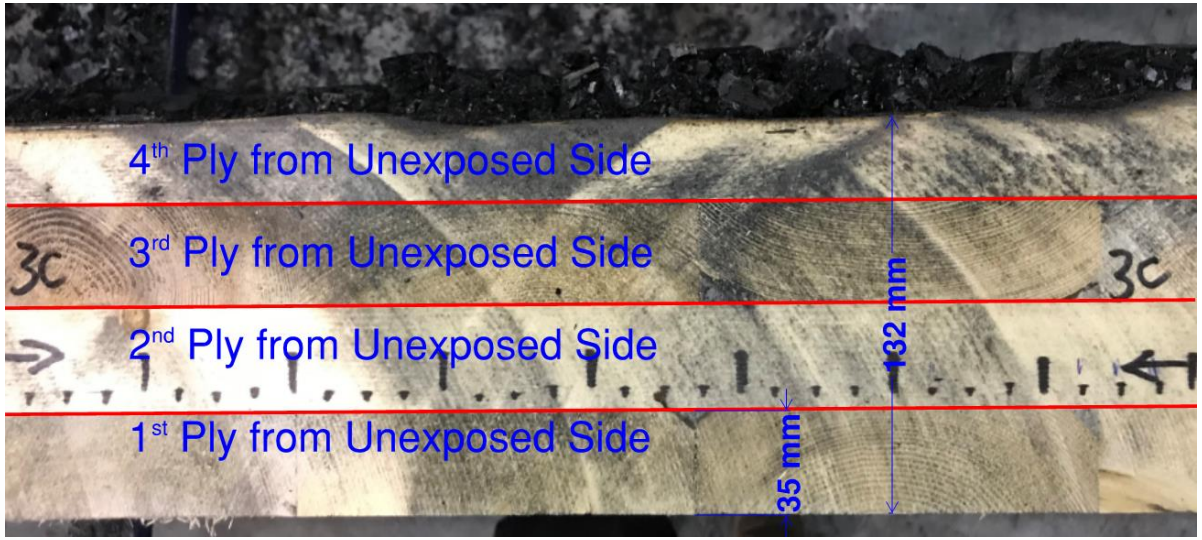
EGBC – Encapsulated Mass Timber Construction

GHL

Fire Research and Testing

Forefront Research in Mass Timber

- Improved char rate analysis
- Increasing mass timber exposure
- Firestopping & Connection
- Mass Timber Demonstration Fire Test



GHL

Mass Timber Demonstration Fire Test Program

MTDFT 2021-2022

Project Funders / Bailleurs de fonds

Canada

Ontario

British Columbia

Québec

Alberta

Forestry Innovation Investment

Research & Testing / Partenaire de recherche et essais

Symposium Funders / Bailleurs de fonds

Government of Canada / Gouvernement du Canada

National Research Council Canada / Conseil national de recherches Canada

Federal Economic Development Agency for Northern Ontario / Agence fédérale de développement économique pour le Nord de l'Ontario

Government of Canada / Gouvernement du Canada

Natural Resources Canada / Ressources naturelles Canada

Canadian Wood Council / Conseil canadien du bois

GHL

Program Partners & Contributors / Partenaires et Contributeurs

wood WORKS! A Canadian Wood Council Program

Canadian Wood Council
Conseil canadien du bois

cecobois
Centre d'expertise sur la construction commerciale en bois

FPInnovations

TIMMERMAN TIMBERWORKS

GHL CONSULTANTS LTD
Building Codes & Fire Science

CHM

ISL 35 YEARS

Sponsors / Commanditaires

MTC SOLUTIONS

ROCKWOOL

HILTI

Manufacturers / Fabricants

Western Archrib
Structural Wood Systems

STRUCTURLAM
MASS TIMBER CORPORATION
Intelligence In Wood

ELEMENT5

NORDIC STRUCTURES

StructureCraft

GHL

Objectives

- Demonstrate the mass timber fire performance under, during and post-construction fire scenarios in a way that is comparable to (or superior to) conventional materials
- Demonstrate mass timber fire performance to key stakeholders including building officials, fire service and insurance industry
- Encourage Building Code advancements that will allow for taller and larger wood buildings
- Support future Code change proposals and the development of alternative solutions towards performance-based design

GHL

Program Setup

Phase 1 – Pilot Scale Demonstration

- Led by GHL Consultants Ltd
- Performed on June 16, 2021
- Richmond Fire Rescue Training Facility

Phase 2 – Large Scale Fire Tests

- Led by CHM Fire Consultants Ltd
- Performed from June 2022 to Sep 2022
- Canadian Explosives Research Laboratory (NRCan – Ottawa)

GHL

Phase 1 – Pilot Scale Demonstration

Richmond, BC – June 16, 2021

- 4 assemblies:
  - Light Wood Frame (LWF)
  - Protected Light Wood Frame (PLWF)
  - Mass Timber 1 (MT 1) – small box
  - Mass Timber 2 (MT 2) – L-shape design

- 4 fire scenarios representing potential construction fire emergencies

GHL

Phase 1 – Pilot Scale Demonstration

Richmond, BC – June 16, 2021

Objectives:

- To better understand the performance of mass timber in a construction fire
- Provide a baseline information for appropriate Construction Fire Safety Plan
- Alleviate the need to 'encapsulate as you go'
  - Impractical with respect to moisture control
    - -- Nearly impossible to avoid moisture/mold issues
  - Cost impact very expensive
- To provide support future Code Changes proposals to National Fire Code

GHL

Phase 1 – Pilot Scale Demonstration

Background

Fire Code Safety Measures for EMTC Subsection 5.6.3

- 30min protected exits c/w 20min rated temporary doors, closers and latches
- Refuse control
- Charged standpipes and Signage

- Encapsulate as you go:
  - Protect (Cover) timber during construction

GHL

Encapsulate As You Go

- Initially envisioned for Tallwood House at Brock Commons
- Proved difficult to implement:
  - Sequencing issues
  - Moisture control issues
  - Managed to encapsulate to 6 – 7 levels exposed - <u>Not possible to meet 4 levels</u>

GHL

Encapsulate as you go: Limit of 4 levels exposed

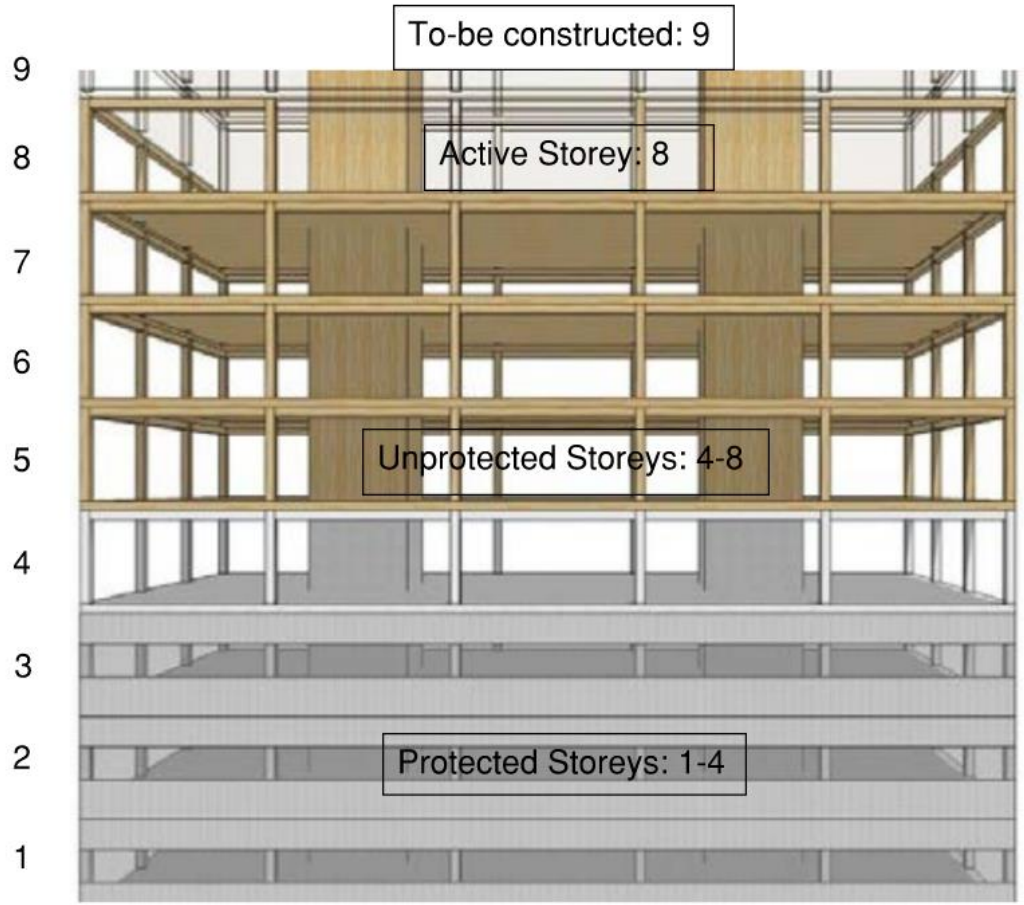


Image courtesy AWC

GHL

Burn 1 – Garbage Can Fire

GHL

Three Structures – 3m x 3m x 2.4m

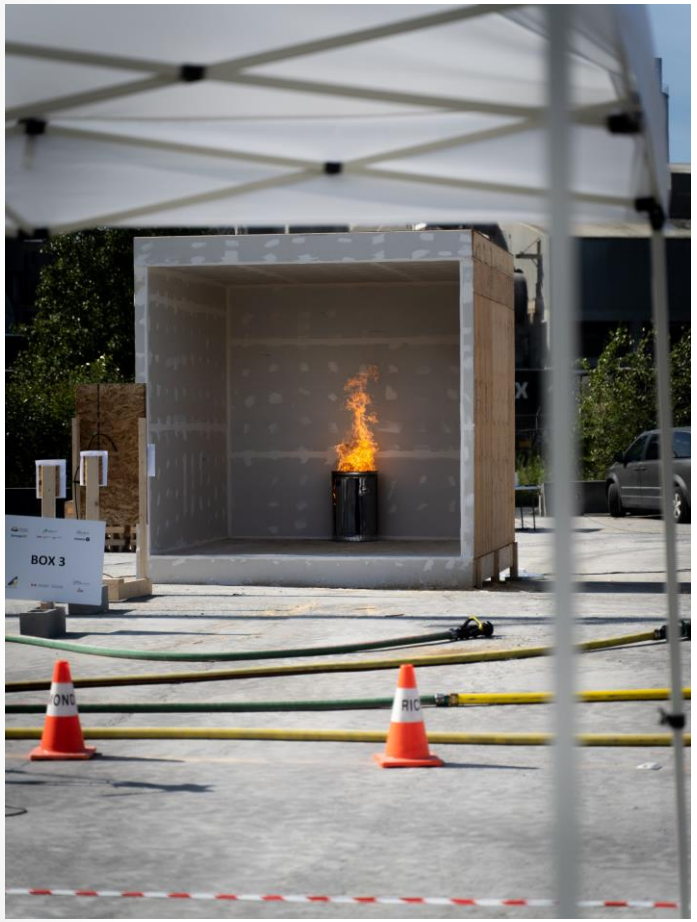
Protected Light Wood Frame

Light Wood Frame

Mass Timber 1

GHL

Burn 1 – Garbage Can Fire



GHL

Burn 1 – What Did We Learn?

- Protected frame performs well, no significant damage
- During construction, LWF is vulnerable
- Mass timber charred, but did not fully ignite
- Mass timber structure remained standing and structurally sound

Burn 2 – Wood Cribs

- Second burn, two wood cribs in each assembly (PLWF and MT)
- 80cm x 80cm x 70cm each crib
- Fuel load is 219 MJ/m^2

GHL

Burn 2 – Wood Cribs

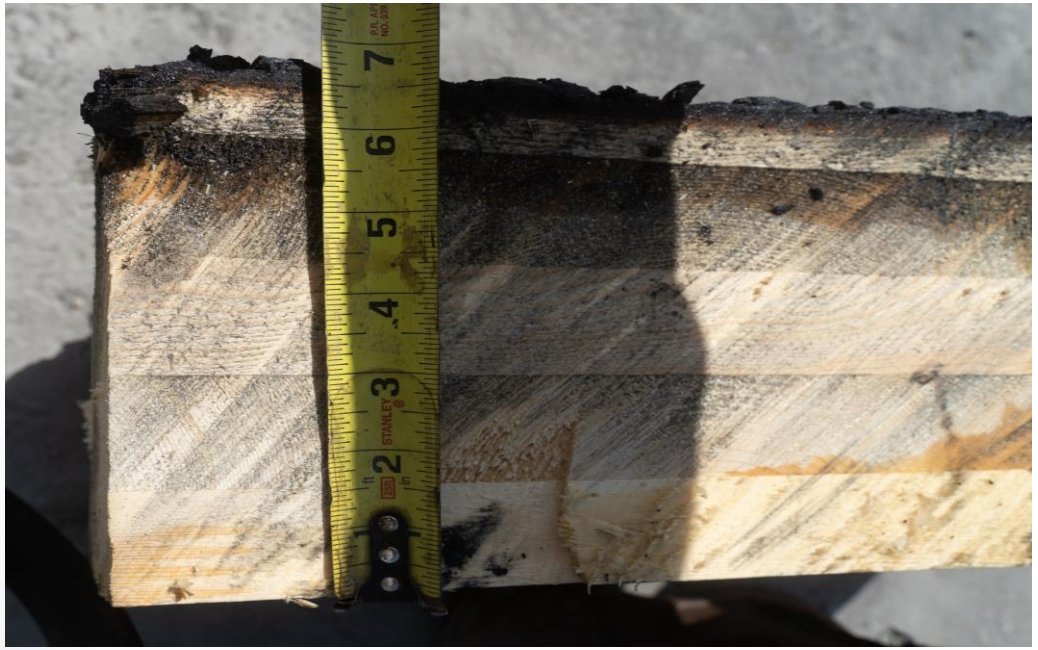
GHL

Burn 2 – Sampling

GHL

Burn 2 – Sampling

- Less than ½ ply out of 5 ply slab charred



GHL

Burn 2 – What Did We Learn?

- Mass timber structure remained standing and structurally sound
- Minimal Char, even with 2 wood cribs
- Fire burned out

GHL

Burn 3 - Propane Burner

- Propane Heaters are a necessity for drying operations
- Potential ignition source, damaged propane heater or cut propane hose
- Similar burner size as Propane Torch
- Firefighter placed Torch on CLT for 10min

GHL

Burn 3 – What Did We Learn?

- Flames from damaged heaters, roofing heat guns, not likely to ignite Mass Timber
- Timber charred slowly and flaming died down upon removal of heat

GHL

Burn 4 – Wood Cribs in Larger Structure

Burn 4 – Wood Cribs in MT 2

GHL

Burn 4 – Wind Effects

- It is significant that the fire was oriented so that wind fanned the fire
- Would have substantially increased the rate of burning
- Would have increased the length of flames
- An example of probable large construction fire

GHL

Burn 4 – Sampling

GHL

Burn 4 – Sampling

GHL

Burn 4 – What Did We Learn?

- Mass timber structures can withstand expected construction fires
- Once debris/contents/permitted light framing are consumed, fire will reduce in intensity
- Structure can be expected to remain in place and capable of sustaining loads of emergency responders post construction fire.
- It is possible to contain fire to one floor with proper fire safety protocol

GHL

Phase 2 – Full Scale Fire Tests

Ottawa, ON – June to September 2022

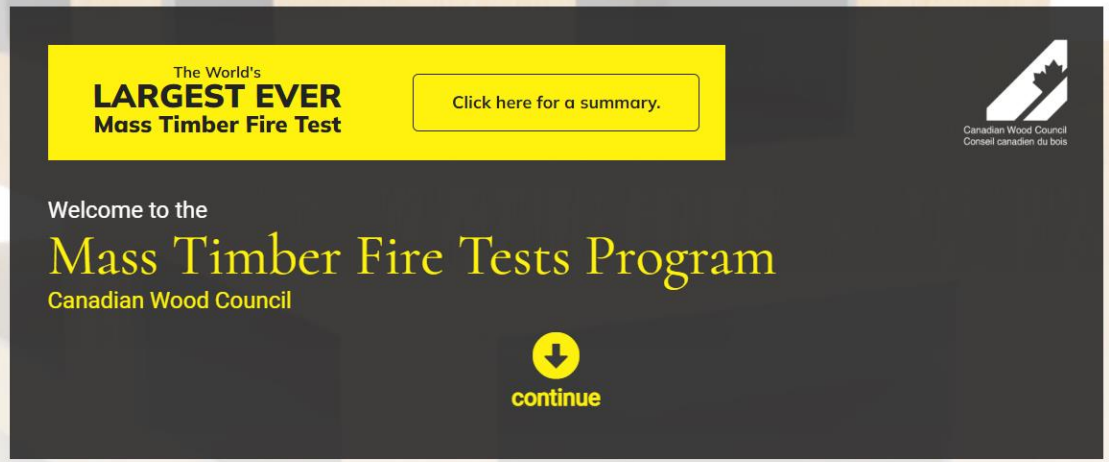
- World's largest mass timber fire test
- 5 real life fire scenarios in residential and office buildings
- First burn on June 22, 2022

GHL

Phase 2 – Full Scale Fire Tests

Ottawa, ON – June to September 2022

https://firetests.cwc.ca/



GHL

Phase 2 – Test Summary

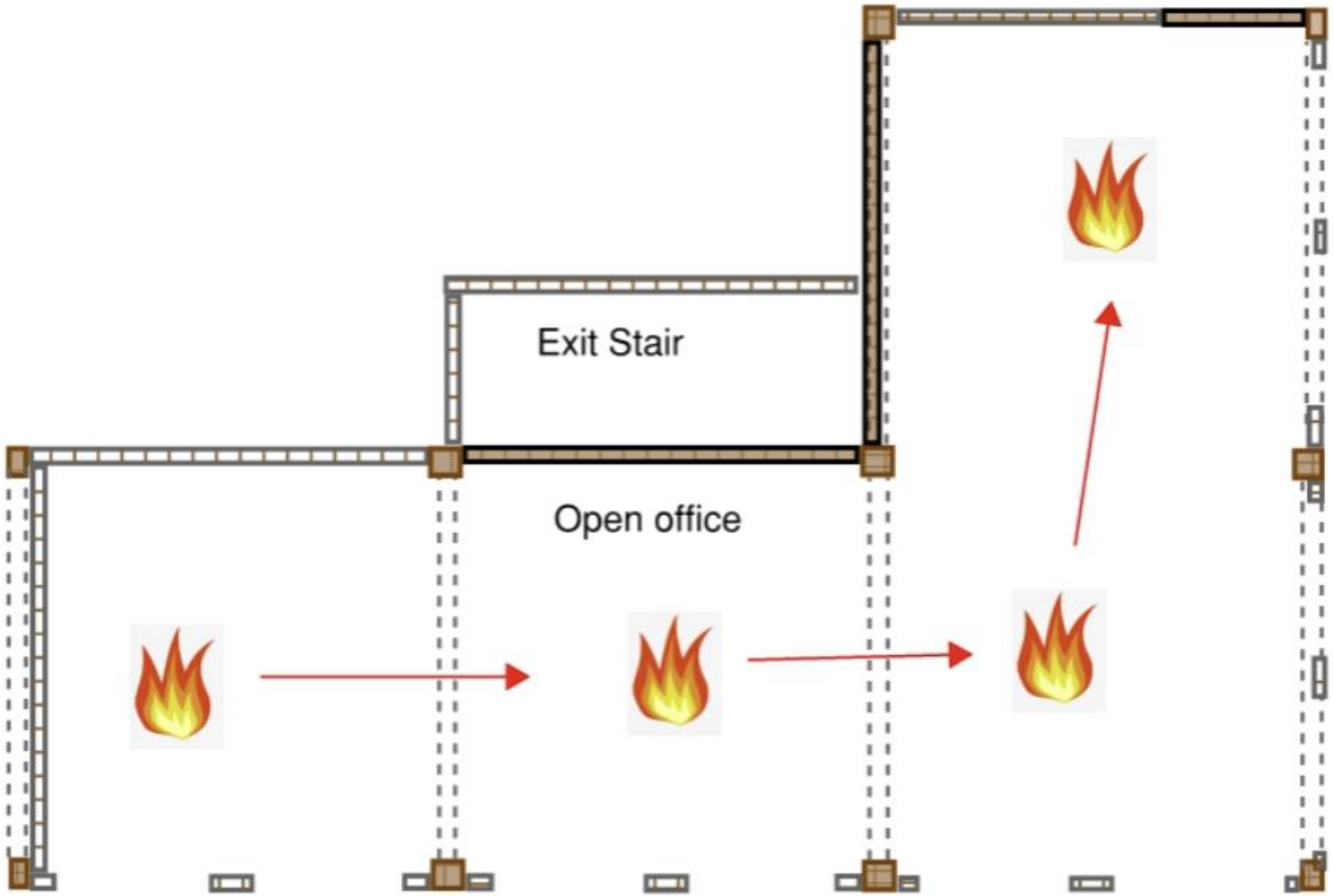
Ottawa, ON – June to September 2022

Test	Scenario	Location	Floor Finish	Walls		Ceiling	Beams/ Columns
				Exterior	Interior		
1	Residential	2nd storey Suite 1	2 x 5/8" GB	steel studs, gypsum board and sheathing, mineral wool insulation and outboard	2 x 5/8" GB 1" plywood lining	2 x 5/8" GB 2 x 1/2" FRT plywood lining	N/A
2	Residential	2nd storey Suite 2	2 x 5/8" GB		2 x 5/8" GB	Exposed	Exposed
3	Construction site Garbage bin fire	2nd storey Suite 1	Exposed		Exposed shaft wall	Exposed	N/A
4	Construction site LWF partition/WC	2nd storey corner suite	Exposed		2 x 5/8" GB	Exposed	Exposed
5	Open plan office	1st storey	2 x1/2" GB		Exposed shaft wall	Exposed	Exposed

GB: Type X gypsum board

GHL

First Test, Test 5 – June 22, 2022



GHL

First Test, Test 5 – June 22, 2022

- Typical open office layout

First Test, Test 5 – June 22, 2022

- Contents Consumed, Fire Died Down

First Test, Test 5 – June 22, 2022

After Fire Results

- Withstood full burnout
- Structural fire performance similar to noncombustible construction
- Structure remained for next four tests

GHL

Tests 1 and 2

- Code prescribed baseline scenario of residential suite for comparison with MT design

GHL

Tests 1 and 2

- MT Withstand full burnout and remain standing
- Structural fire performance similar to noncombustible construction

GHL

Tests 3 and 4

- Represent construction fire scenario similar to Phase 1 but more complete site condition
- Provide guidance for construction fire safety design

GHL

Tests 3 and 4

- Similar to Phase 1, structure withstand the full burnout
- Remain standing and Structural fire performance similar to noncombustible construction

GHL

Next Steps

- NRC report to be published in the next 6 months
- Support future code change proposals
- Facilitates alternative solutions development
- Guideline to Construction Fire Safety Plan

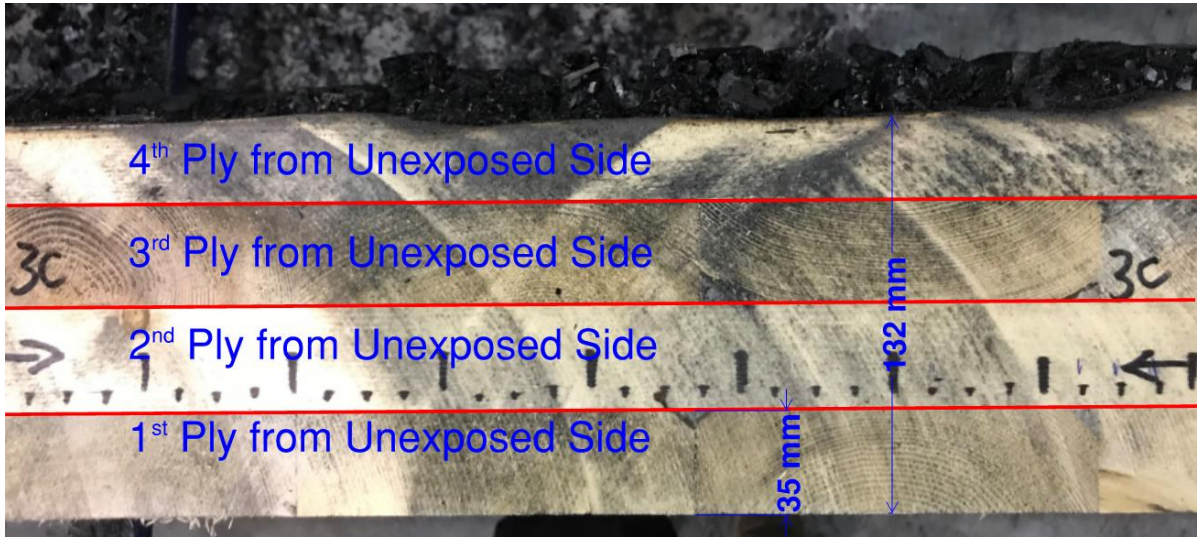
GHL

Alternative Solutions

GHL

Forefront Research in Mass Timber

- Improved char rate analysis
- Increasing mass timber exposure
- Firestopping & Connection
- Mass Timber Demonstration Fire Test



GHL

Potential Alternative Solutions

- Use of mass timer for Assembly occupancy
- Use of exposed mass timber for building height up to 10 storey
- Increased mass timber exposure – ceiling and walls
- Construction Fire Safety Plan for Mass Timber

GHL

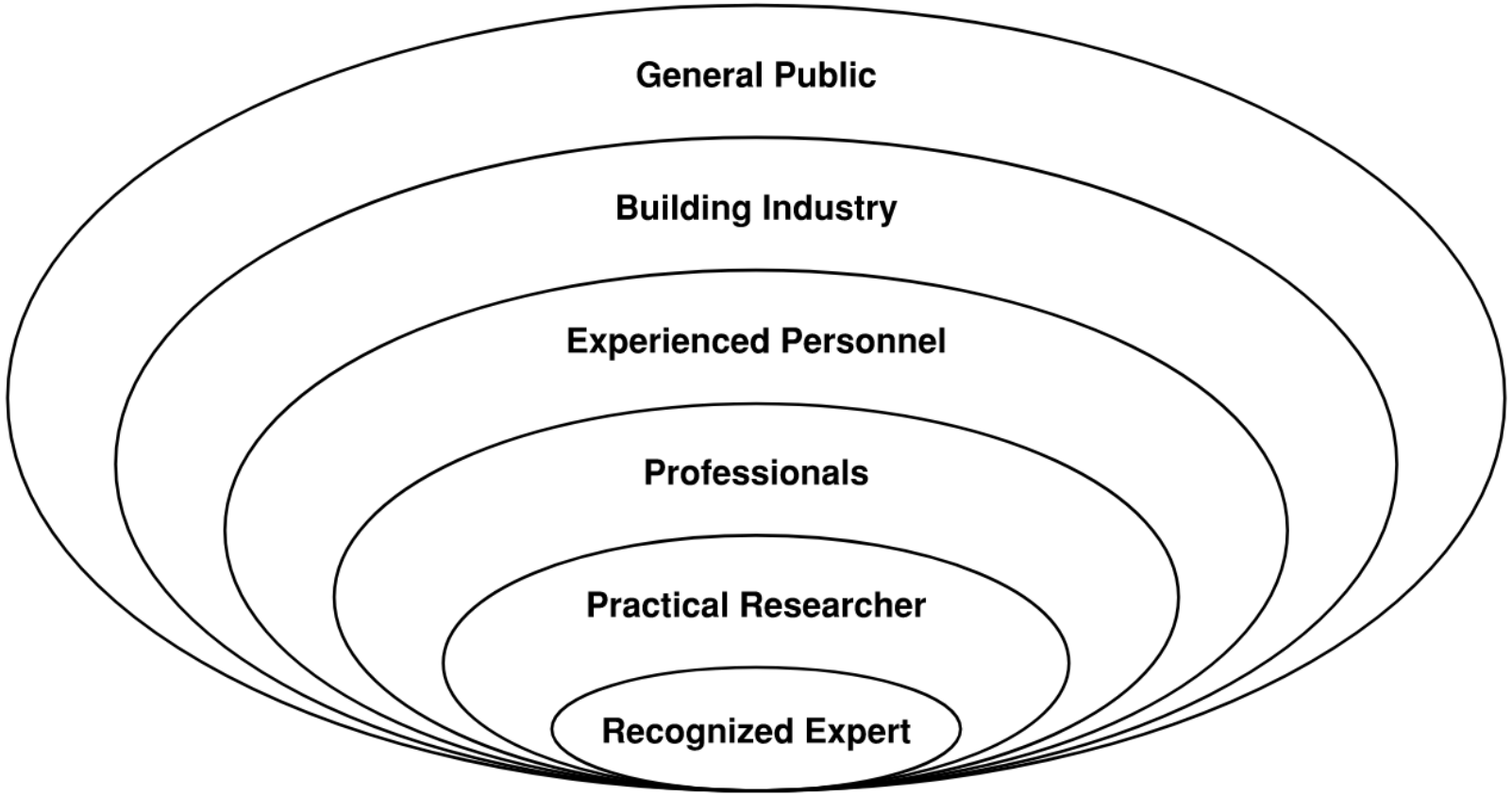
Approval Mechanisms – Good Engineering

- Direct Compliance (Division B) – does not recognize the realities of a dense city
- Alternative Solution
  - Limited to outdated level of performance
  - Does not address cumulative improvements in building overall performance
  - Sprinkler reliability based on 1970's levels (can trace back to 1920 UBC decision)

GHL

Different Levels of Experience

- Need appropriate designer and reviewer for peer review



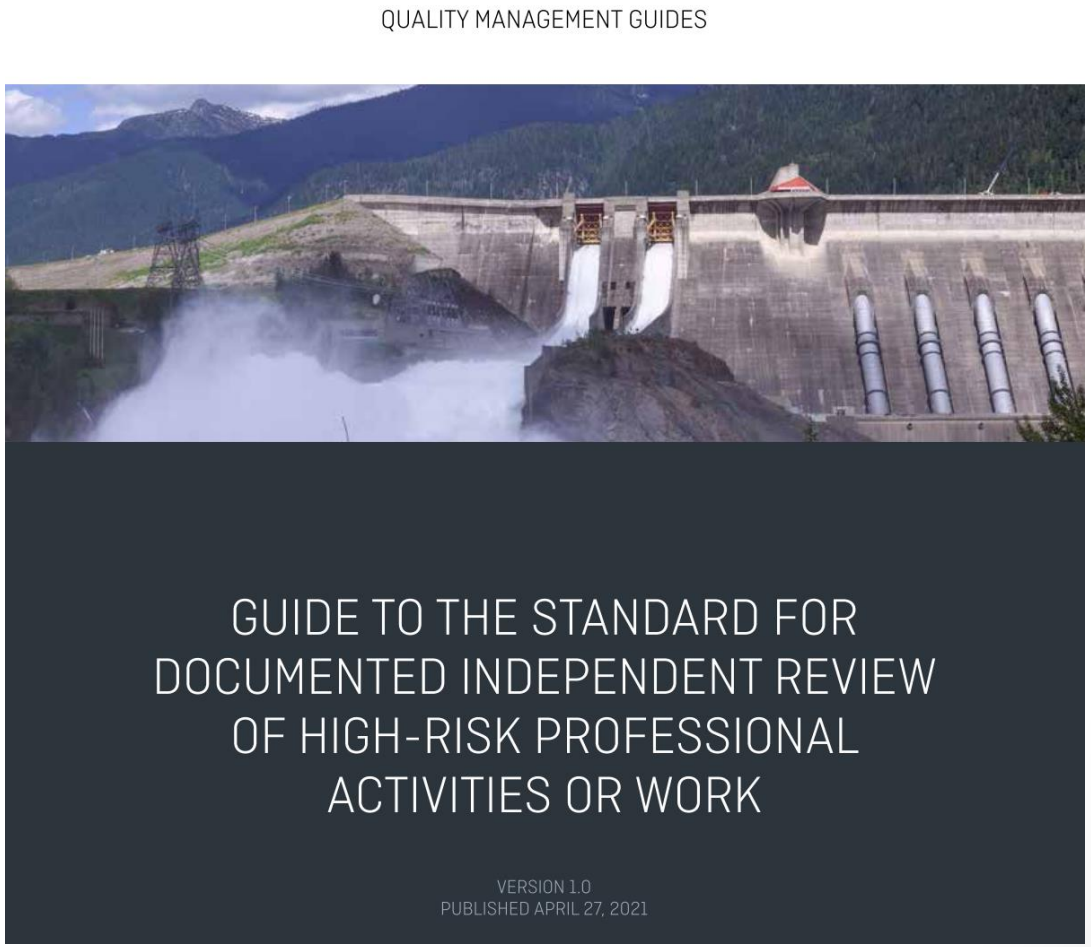
Approval Mechanisms – Good Engineering

- Site Specific Regulations (SSRs) allow the Building and Safety Standards Branch (BSSB) to change level of performance
- Performance Based Codes – a very slow progress

GHL

Approval Mechanisms – Good Engineering

- Suggestion – tag a system on to *"EGBC's Guide to the Standard for Documented Independent Review of High-Risk Professional Activities or Work"*



GHL

Questions and Comments?

GHL

Thank you

GHL Consultants Ltd

700 W Pender Street, Suite 800

Vancouver, BC V6C 1G8

Phone: (604) 689-4449

Email: ah@ghl.ca and cy@ghl.ca Web: www.ghl.ca

Project Funders / Bailleurs de fonds

Canada

Ontario

British Columbia

Québec

Alberta

Forestry Innovation Investment

Research & Testing / Partenaire de recherche et essais

Symposium Funders / Bailleurs de fonds

Government of Canada / Gouvernement du Canada

National Research Council Canada / Conseil national de recherches Canada

Federal Economic Development Agency for Northern Ontario / Agence fédérale de développement économique pour le Nord de l'Ontario

Government of Canada / Gouvernement du Canada

Natural Resources Canada / Ressources naturelles Canada

Canadian Wood Council / Conseil canadien du bois

GHL

Program Partners & Contributors / Partenaires et Contributeurs

wood WORKS! A Canadian Wood Council Program

Canadian Wood Council
Conseil canadien du bois

cecobois
Centre d'expertise sur la construction commerciale en bois

FPInnovations

TIMMERMAN TIMBERWORKS

GHL CONSULTANTS LTD
Building Codes & Fire Science

CHM

ISL 35 YEARS

Sponsors / Commanditaires

MTC SOLUTIONS

ROCKWOOL

HILTI

Manufacturers / Fabricants

Western Archrib
Structural Wood Systems

STRUCTURLAM
MASS TIMBER CORPORATION
Intelligence In Wood

ELEMENT5

NORDIC STRUCTURES

StructureCraft

GHL