Mass Timber Fire Design

Beyond the Code

Presented by Bevan Jones

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

The fire resistance ratings of Mass Timber and wood structures is commonly poorly understood, preventing jurisdictions from permitting them and clients buying in to the concept. A deeper understanding on fire resistance for these buildings is essential to ensure testing continues to evolve, to achieve innovation and to allow building designs to be permitted.

Learning Objectives

1. Understanding how to **achieve fire-resistance** requirements whilst reaching **design goals**

2. Identifying the latest testing that's **evolving fire resistant design** and how an **engineered approach** can support design innovation and achieve a **safe building**.

Agenda

1. Applying Mass Timber
2. Project Goals vs Fire Ratings
3. Fire Resistant Design
4. Value-Added Design

Bevan Jones, PE

Oversees Fire Engineering and Strategic Initiative for US projects.

Over 70 mass timber projects designed.

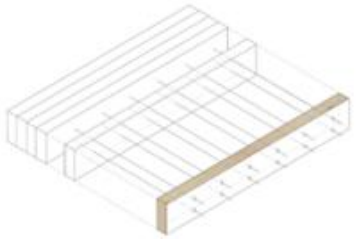
Holmes is part of the international team of 500+ engineers based in the US, Australia, New Zealand and The Netherlands.

Applying Mass Timber

What is Mass Timber?

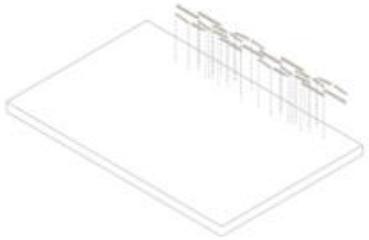
CLT

NLT



GLT

LSL

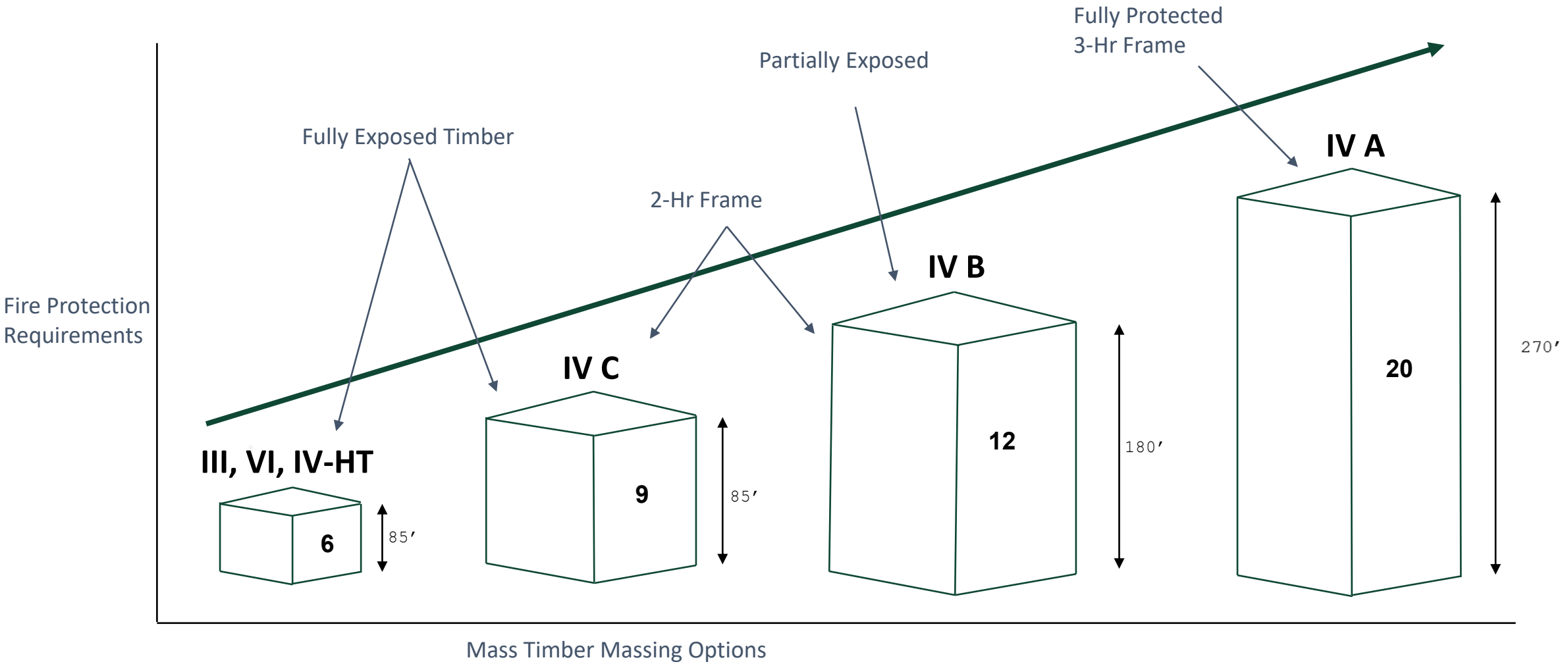


LVL

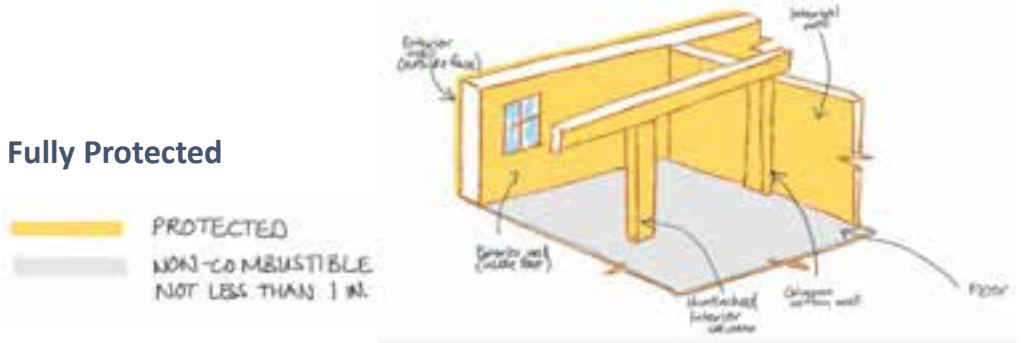
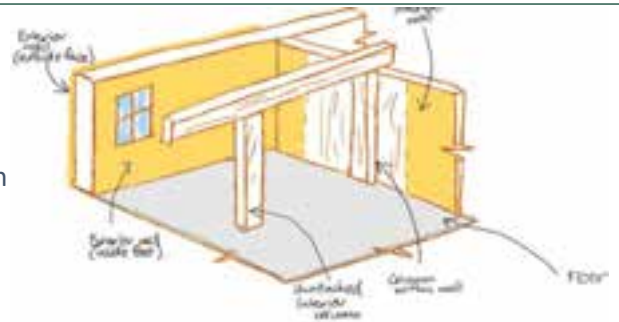
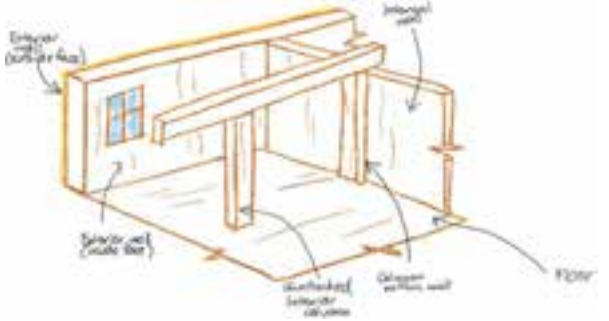
GLULAM

PSL

CBC 2019 Construction Types



Mass Timber Construction Types, Fire Rating

Construction Type	# Stories	Max Height	Mass Timber	Primary Frame Fire Rating
IV-A	18	250 - 270’	**Fully Protected** 	3 hour (2 hour floors)
IV-B	12	180’	**Partially Exposed** (20% of ceilings allowed to remain exposed) 	2 hour
IV-C	9	85’	**Fully Exposed** (Except outside of external walls, shafts and concealed spaces) 	2 hour

Project Goals

Fire Ratings

Goals for Mass Timber

(1) Sustainability

- Carbon footprint
- Renewable resourcing of materials

(2) Cost

- Material procurement
- Labor and construction costs

(3) Aesthetics

- Exposed structural system

(4) Construction Schedule

- Modular/prefab construction (kit of parts)
- Reduced onsite labor
- Safer construction methods and less waste

Exposed Mass Timber: Type IV-B

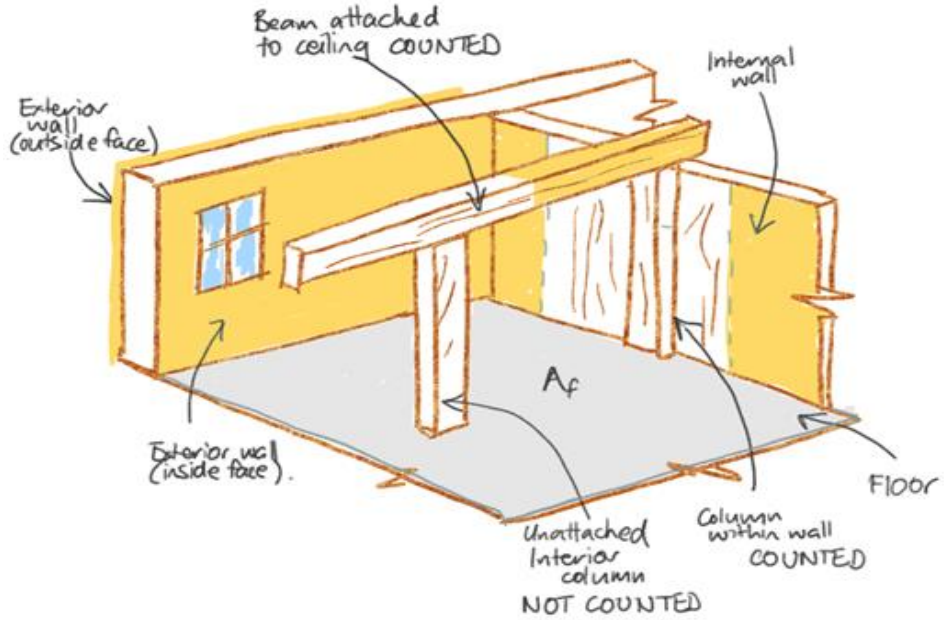
- Ceiling: 20% of floor area of dwelling unit, or fire area (integral beams included)

- Wall: 40% of floor area of dwelling unit, or fire area (integral columns included)
  - Wall + Ceiling: ratio < 1.0
  - Unprotected areas separated > 15’

- Rib-decks and similar system have increased surface area, therefore reduced exposed ceiling area in plan.

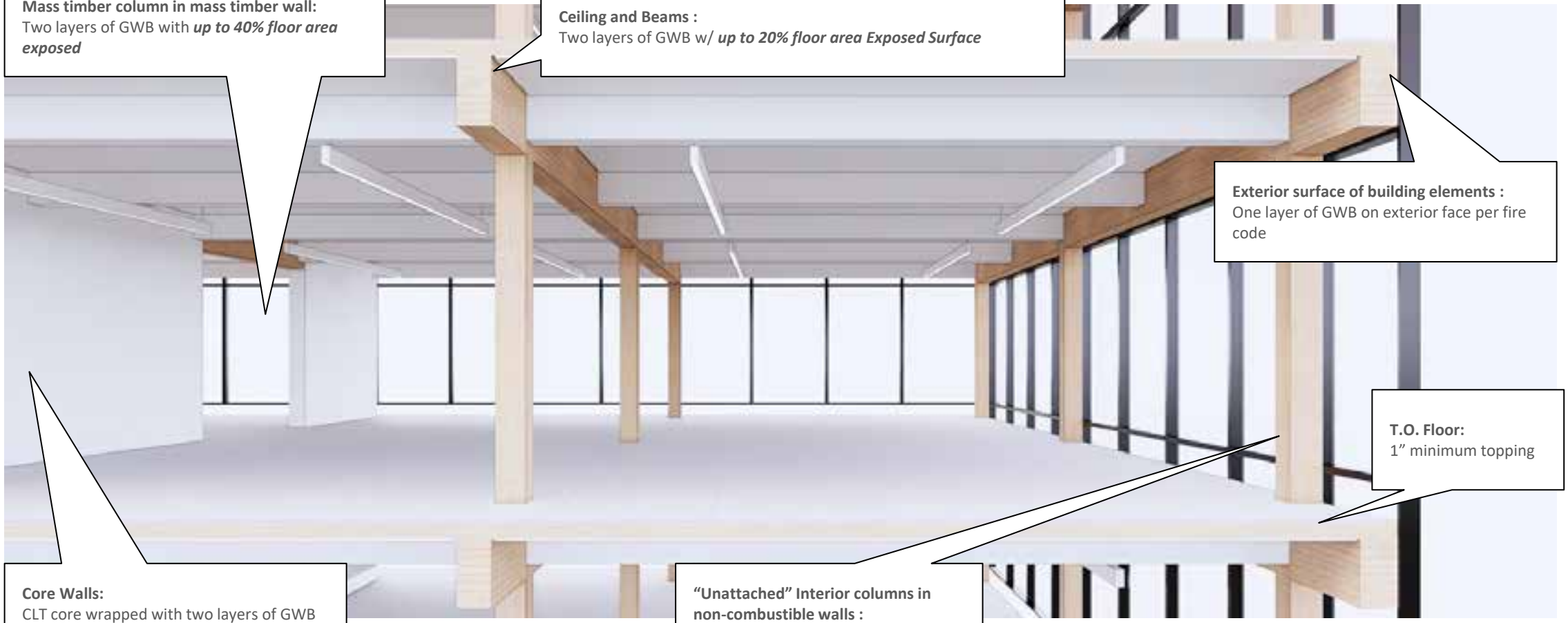
- Directly attached to mass timber (furred construction needs approval)

- AMM for increased exposed mass timber:

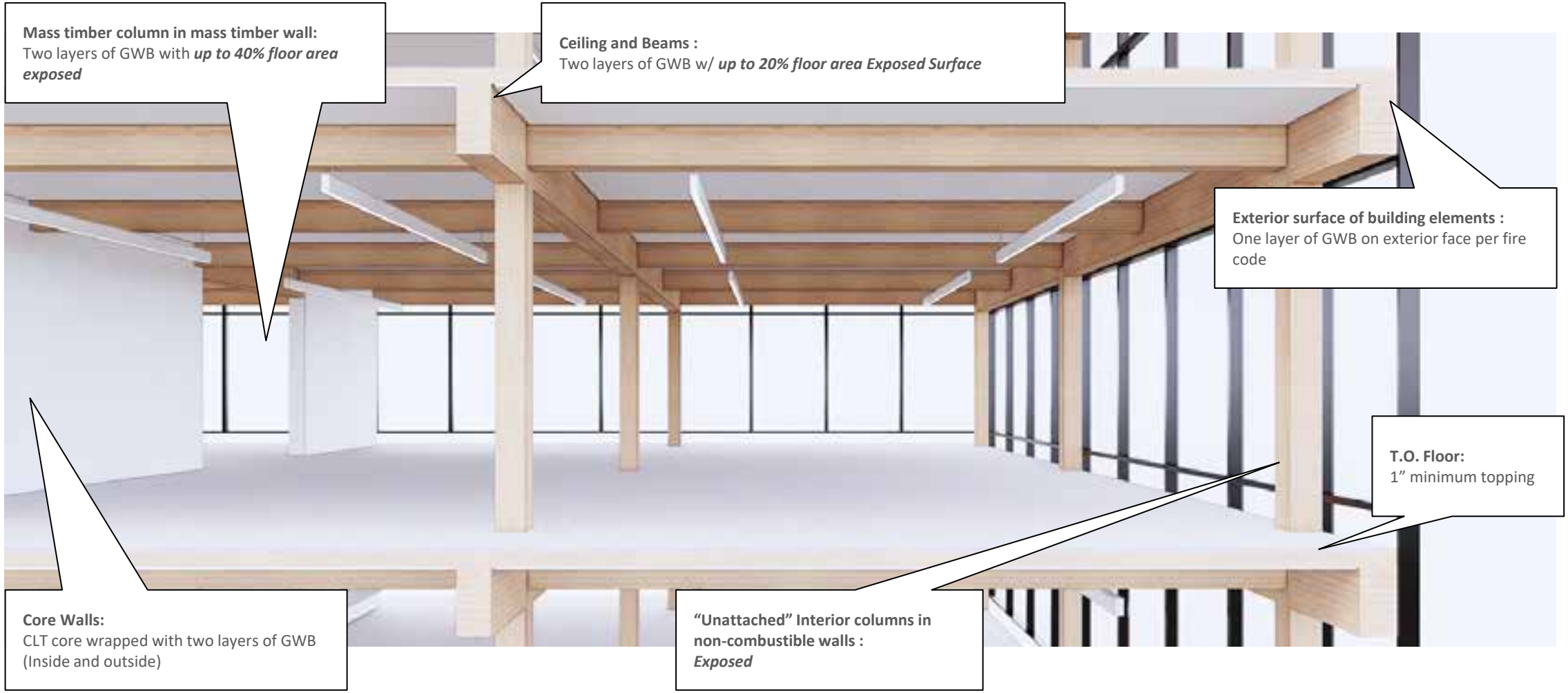


- Testing of Gen. 2.0 panels (PRG320-2018) + RISE
- Fire modelling
- Improved fire protection (passive + active)

Max Exposed Ceilings per Code Allowance: IV-B (20%)



50% Exposed Ceilings – Requires AHJ Approval (IV-B)



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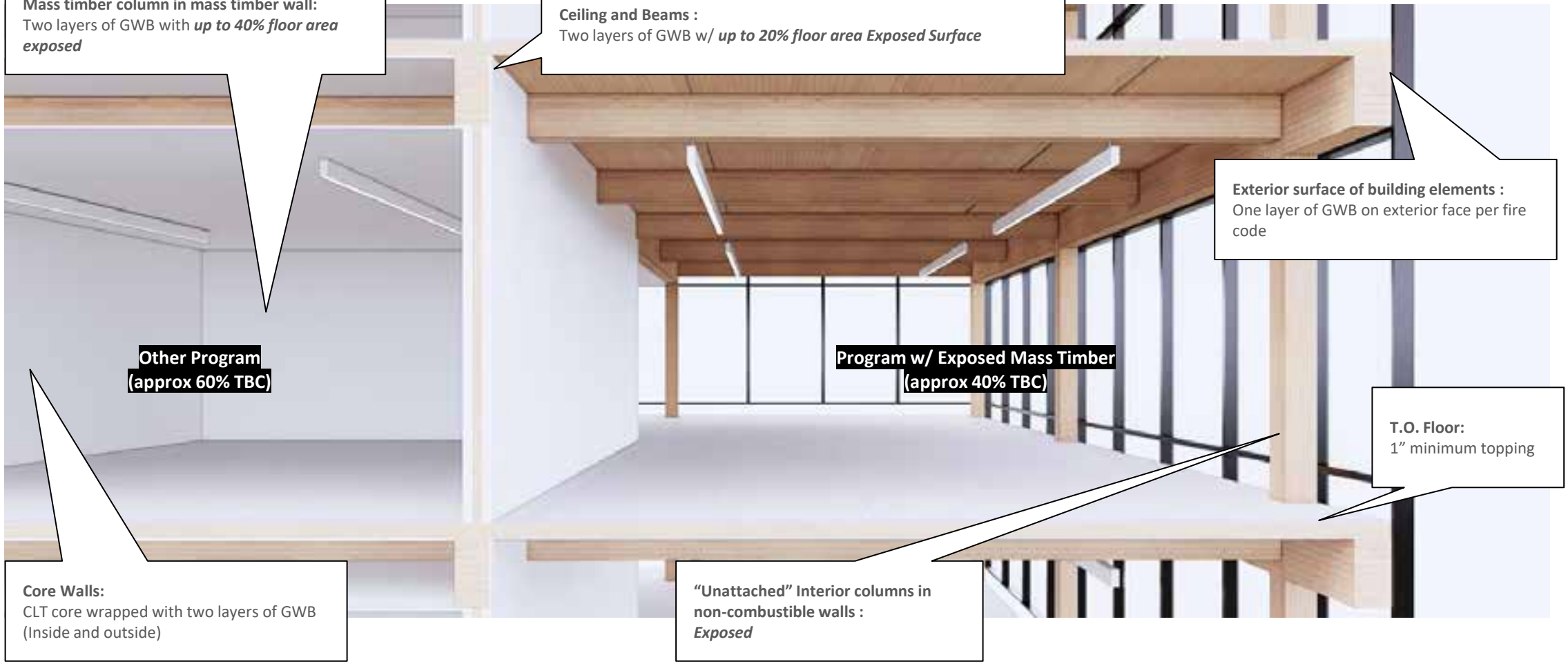
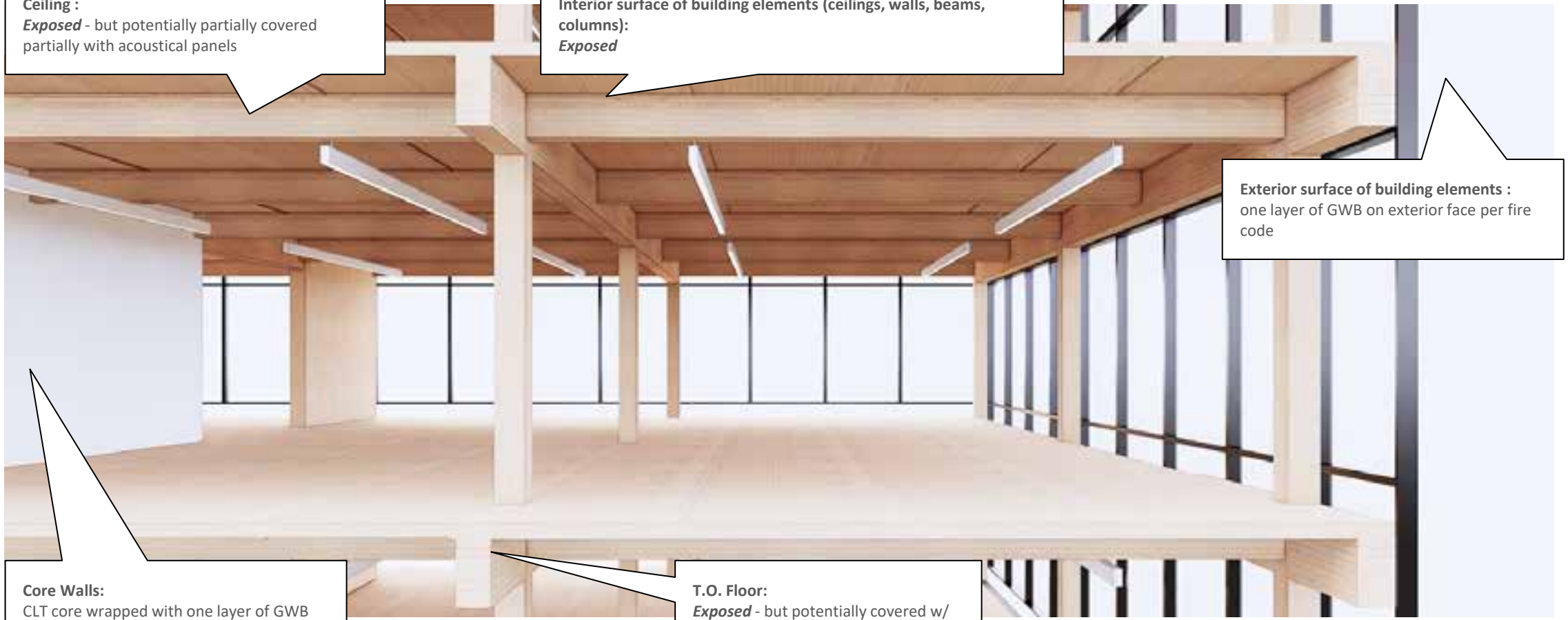


Fully Exposed – Requires AHJ Approval (IV-B)



Ceiling :
Exposed - but potentially partially covered partially with acoustical panels

Interior surface of building elements (ceilings, walls, beams, columns):
Exposed

Exterior surface of building elements :
one layer of GWB on exterior face per fire code

Core Walls:
CLT core wrapped with one layer of GWB (Inside and outside)

T.O. Floor:
Exposed - but potentially covered w/ acoustical layer and/or raised floor

Fire Resistant Design

Determination of Fire-Resistance Rating

IBC Table 601

Fire-resistance Rating Requirements For Building Elements

- The building elements shall have a fire-resistance rating not less than that specified in Table 601 and exterior walls shall have a fire-resistance rating not less than that specified in Table 602.
- The building elements shall comply with the applicable provisions of Section 703.2.

IBC 703.2

Fire-resistance ratings

- Test procedures set forth in ASTM E119 or UL 263 or in accordance with Section 703.3.

IBC 703.3

Methods for determining fire resistance

- ITEM 3, Calculations in accordance with Section 722.

IBC 722

Calculated Fire Resistance

- The calculated fire resistance of exposed wood members and wood decking is permitted in accordance with Chapter 16 of ANSI/AWC National Design Specification for Wood Construction (NDS)

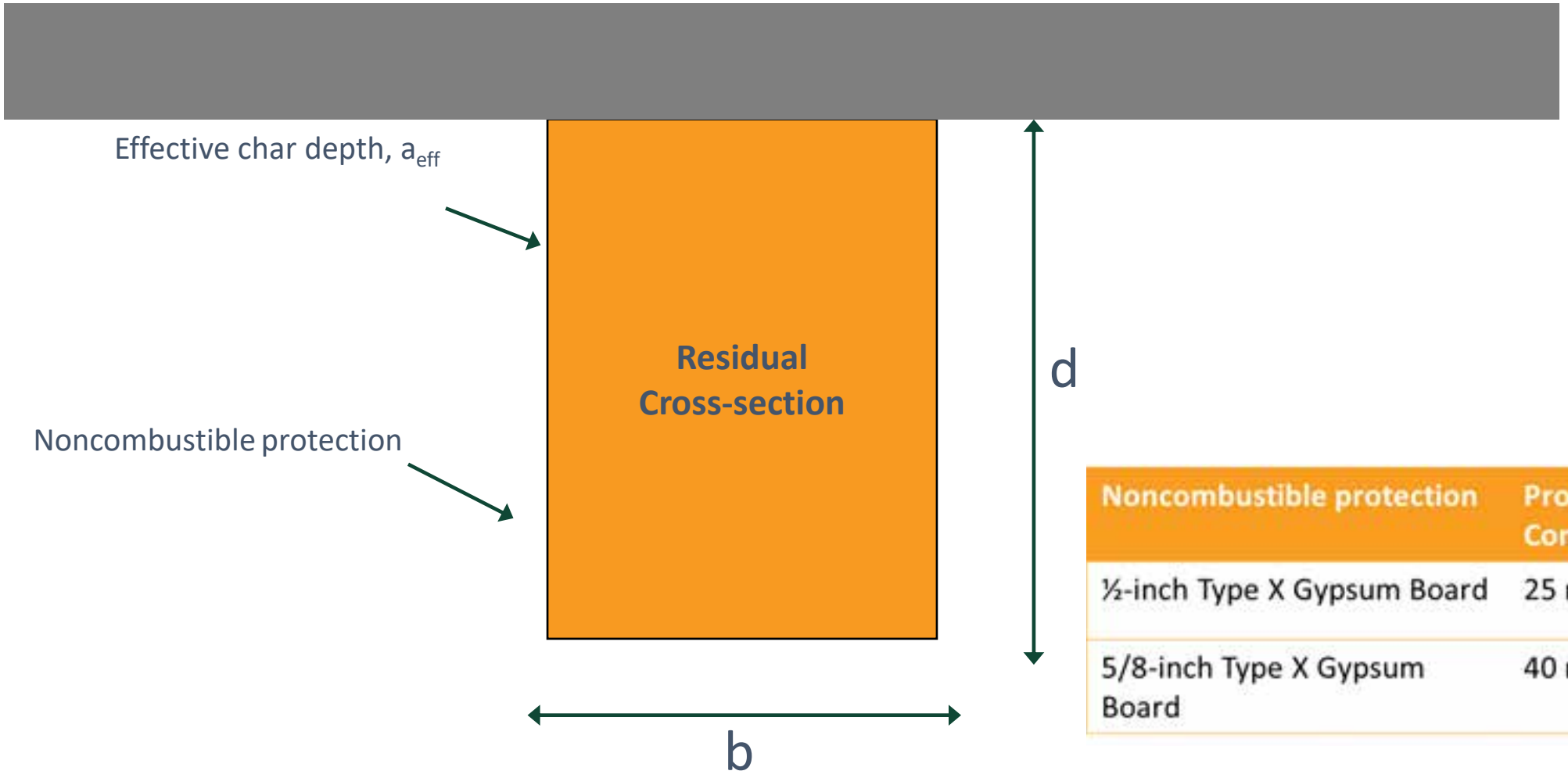
NDS Commentary Chapter 16

Fire Design of Wood Members

The design provisions in the NDS are intended for use in Allowable Stress Design (ASD).

- The mechanics-based design procedures in specification for exposed wood members are based on research described in AWC's Technical Report 10: Calculating the Fire Resistance of Wood Members.

Effect of Non-combustible Protection

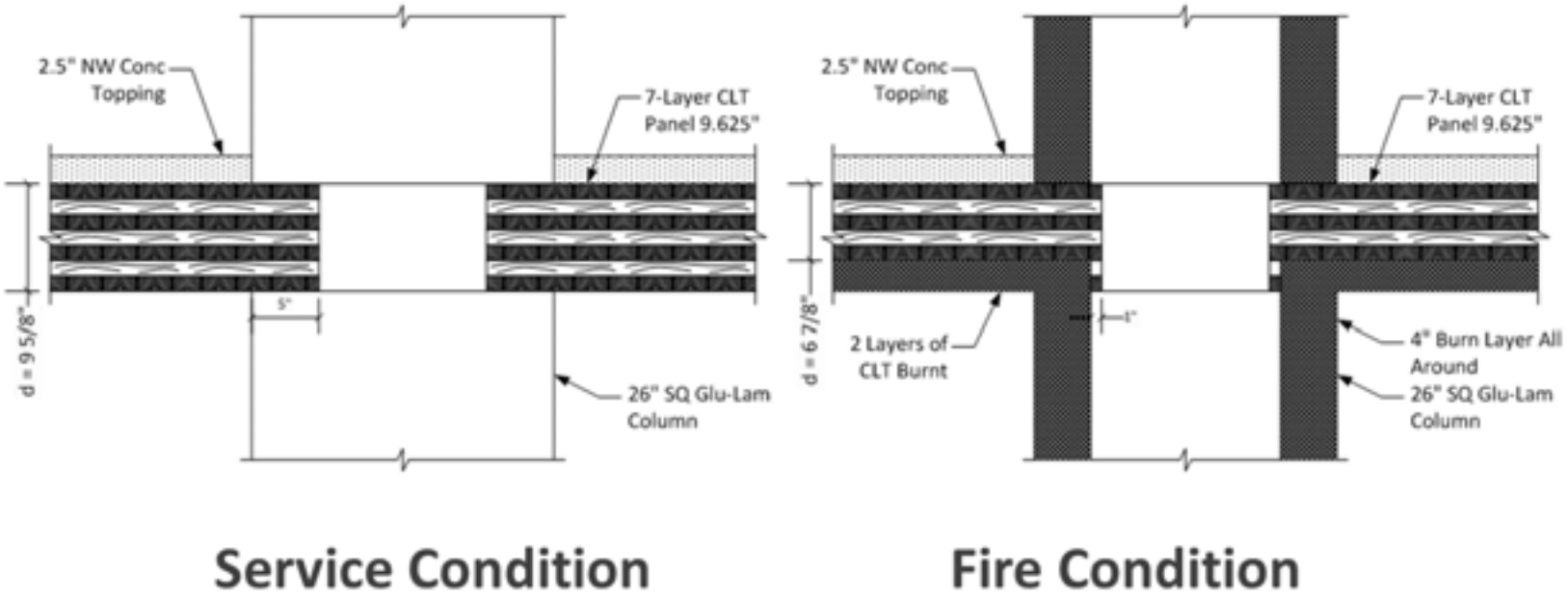


Noncombustible protection	Protection Contribution
½-inch Type X Gypsum Board	25 min
5/8-inch Type X Gypsum Board	40 min

NDS Chp. 16: CLT

- Fire performance is dependent on manufactured system
- Char rate for CLT is increased as a result of the glue interface at laminations

E.g.: CLT panel with 1-3/8” laminates results in 1.9” char depth after 1-HR exposure



NDS – 16 : Char Rate

NLT

1.5”/HR

DLT

1.5”/ HR

CLT

1.9”/HR

GLULAM

1.5”/ HR

LVL

1.5”/ HR

LSL

1.5”/ HR

*Per NDS 2018

Connection Fire-Resistance Rating

FRR for connections in Type IV-A IV-B, or IV-C construction shall be determined by one of the following:

- Testing in accordance with Section 703.2 where the connection is part of the fire resistance test.

- Engineering analysis that demonstrates that:

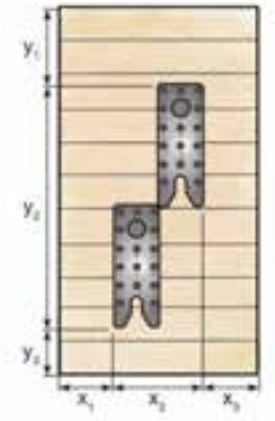
  - Average temperature rise at any portion of the connection is limited to 250°F (139°C); and

  - Maximum temperature rise of 325°F (181°C)

  - For the duration of the required rating

- Includes connectors, fasteners and portions of wood members included in the structural design of the connection.

Concealed connection



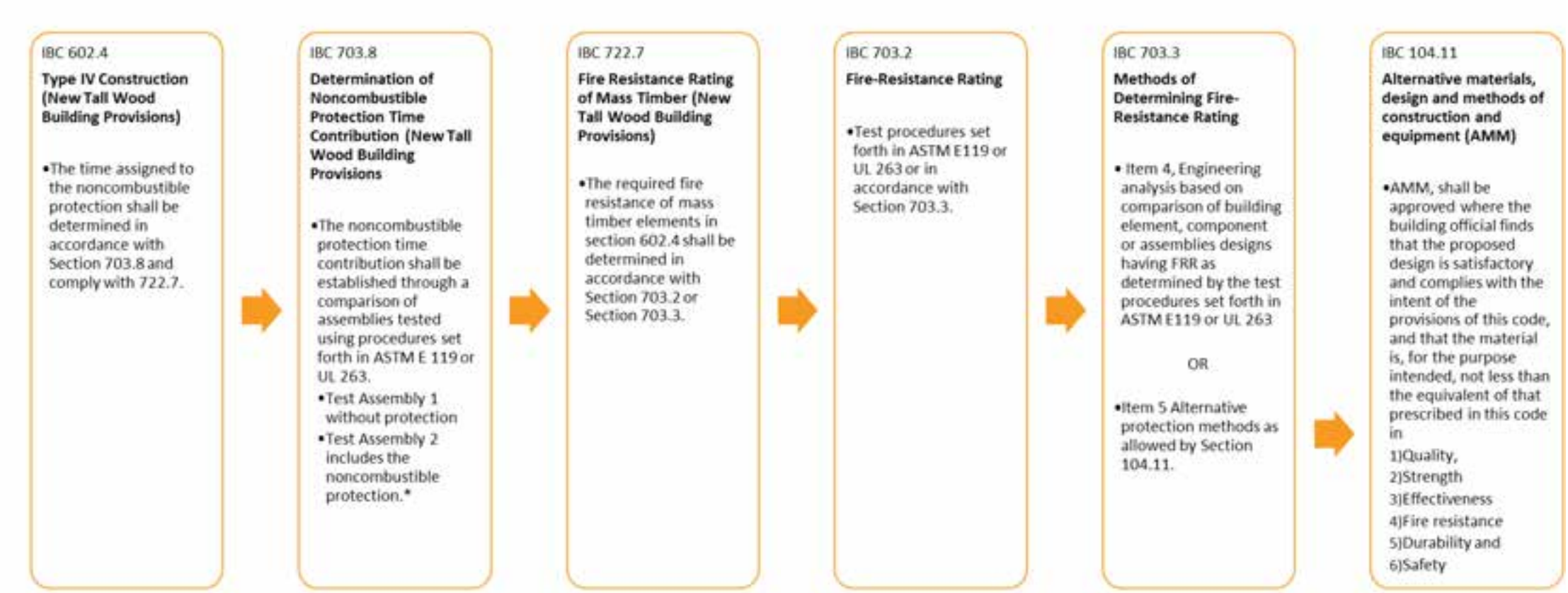
Connection with exposed steel

Full Scale Furnace Testing

- Most North American Manufacturer’s have ASTM E119 tested assemblies, some with UL listings.
- Floor and wall assemblies up to 2-HR ratings.
- Loading is client/manufacturer specified, typically a reduced load case to represent fire limit state conditions
    - E.g.: Live load of 75 psf
    - E.g.: 50% maximum allowable bending moment
- If design requires greater structural demand in fire, then engineering judgement and/or additional fire protection (more thickness for charring) may be required.
- Important to note the limitations of test assemblies vs actual structural condition (beam supported vs point load condition)

Value Added Design

Alternative Means & Methods

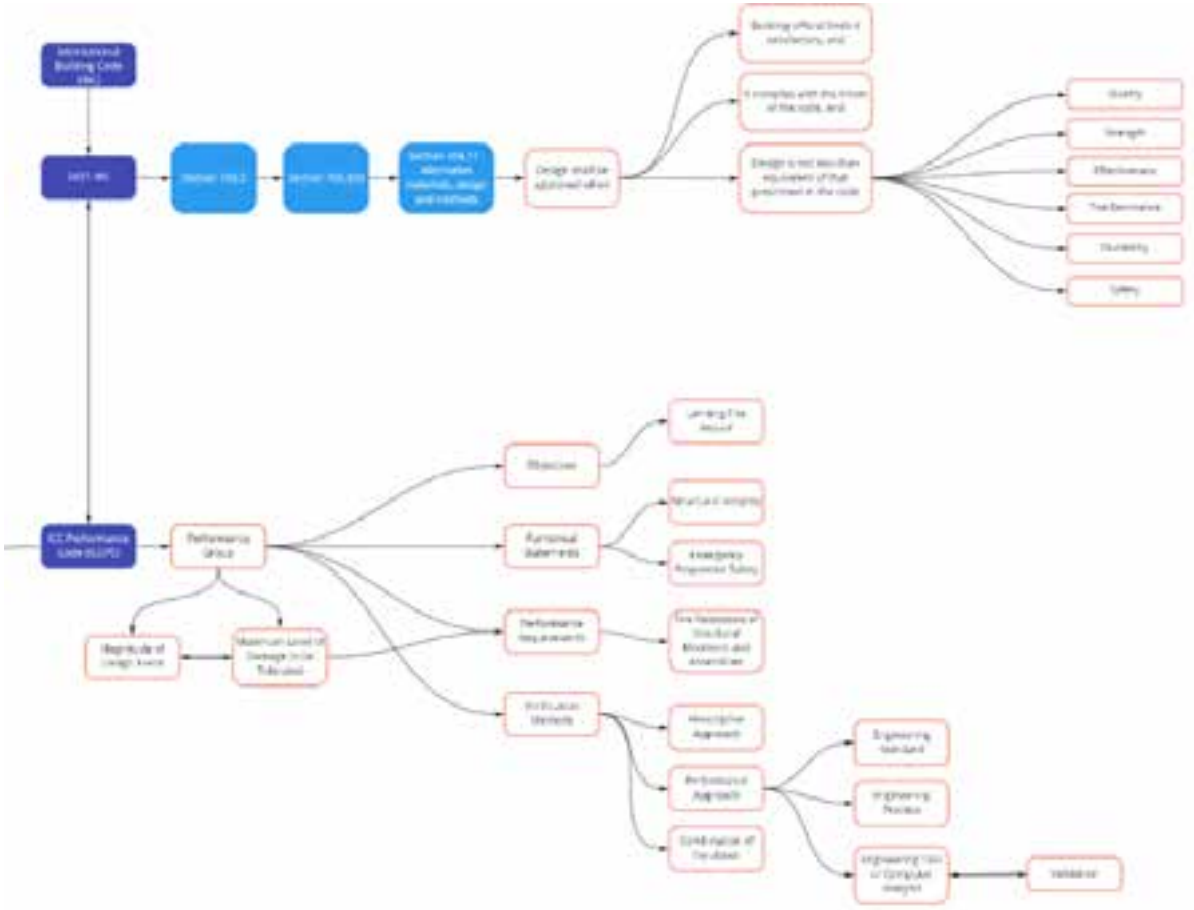


*Noncombustible protection time contribution is determined by subtracting the fire resistance time of Test Assembly 1 from the fire resistance time of Test Assembly 2.

Performance Based Design: Overview

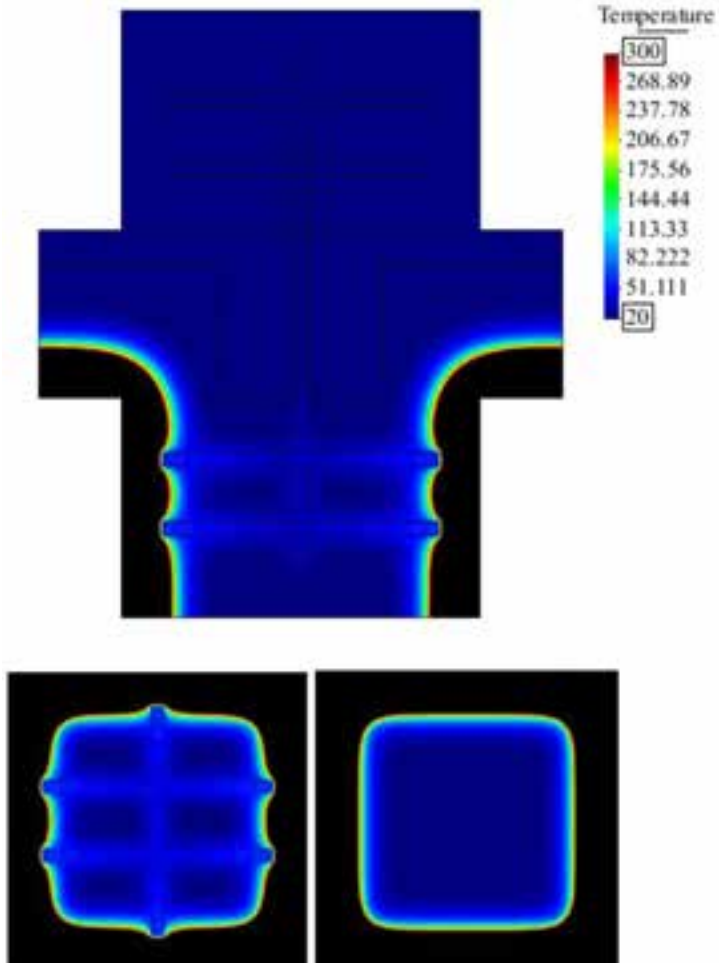
Performance based design can be used to support *alternate solutions* to prescriptive code. The methodology of CBC Section 104.11 is applied, however, little guidance is provided.

Through agreement with authorities the ICC Performance Code (ICCPC) can be applied which outlines performance/acceptance criteria in order to achieve compliance.



Performance Based Analysis

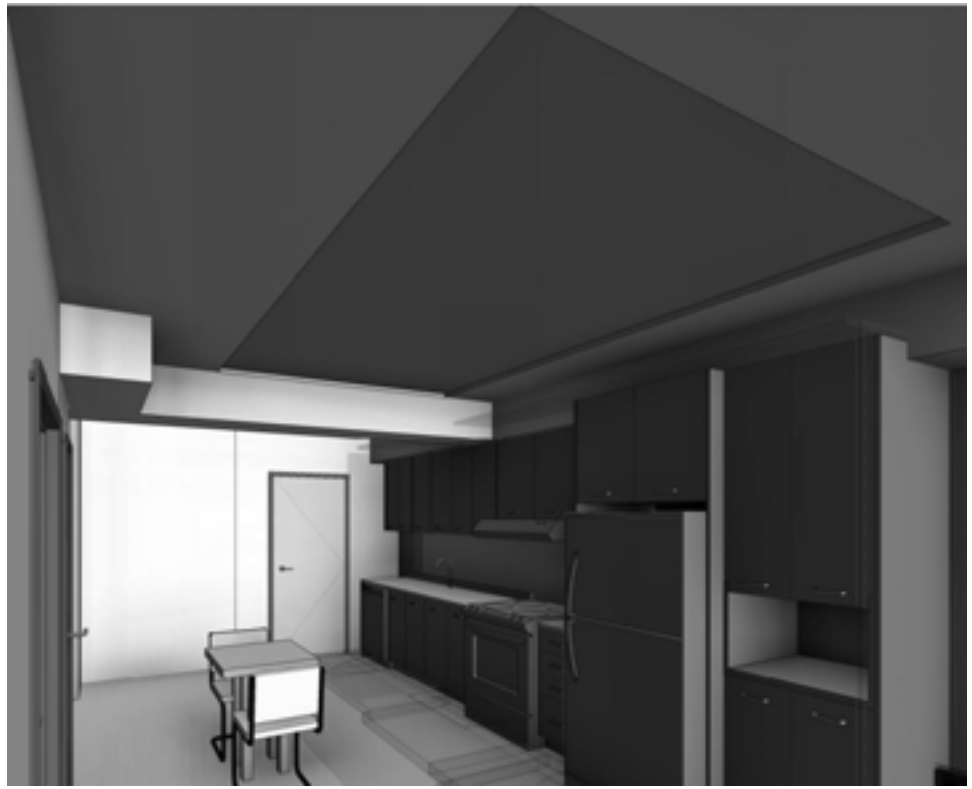
- Thermal-finite element assessment of assemblies
- Support engineering judgement of untested systems/assemblies
- Protection details for connections, exposure of mass timber
- Furnace and realistic building fires



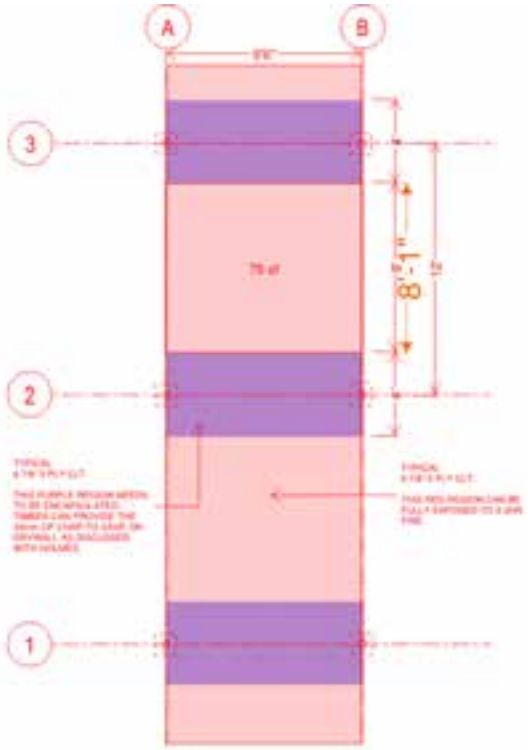
McEvoy & Dupont Apartments

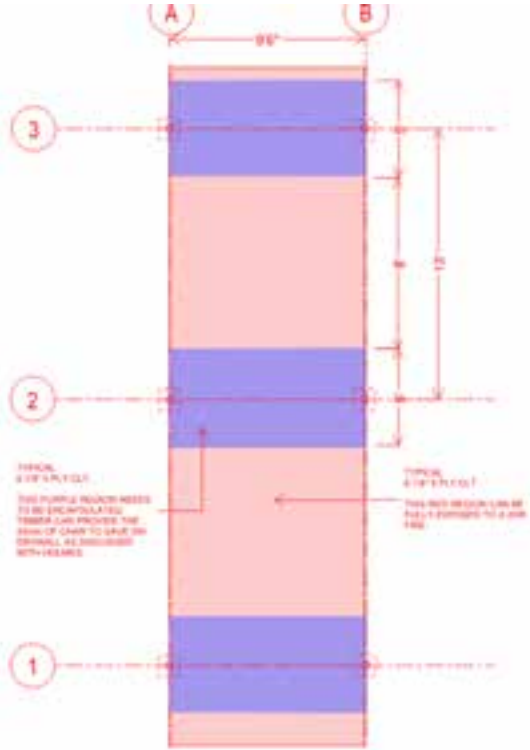
280 McEvoy, California – Proposed Design

- Two 12-story residential Type IV-B towers on I-A podium
- Columns designed for 2-hr FRR by encapsulation and char (column + slab system)
- 5-ply CLT strategically protected with 2 layers gypsum board to achieve 2-hr FRR
- Compartmentation provided
- Design goal to achieve increased exposed mass timber in units



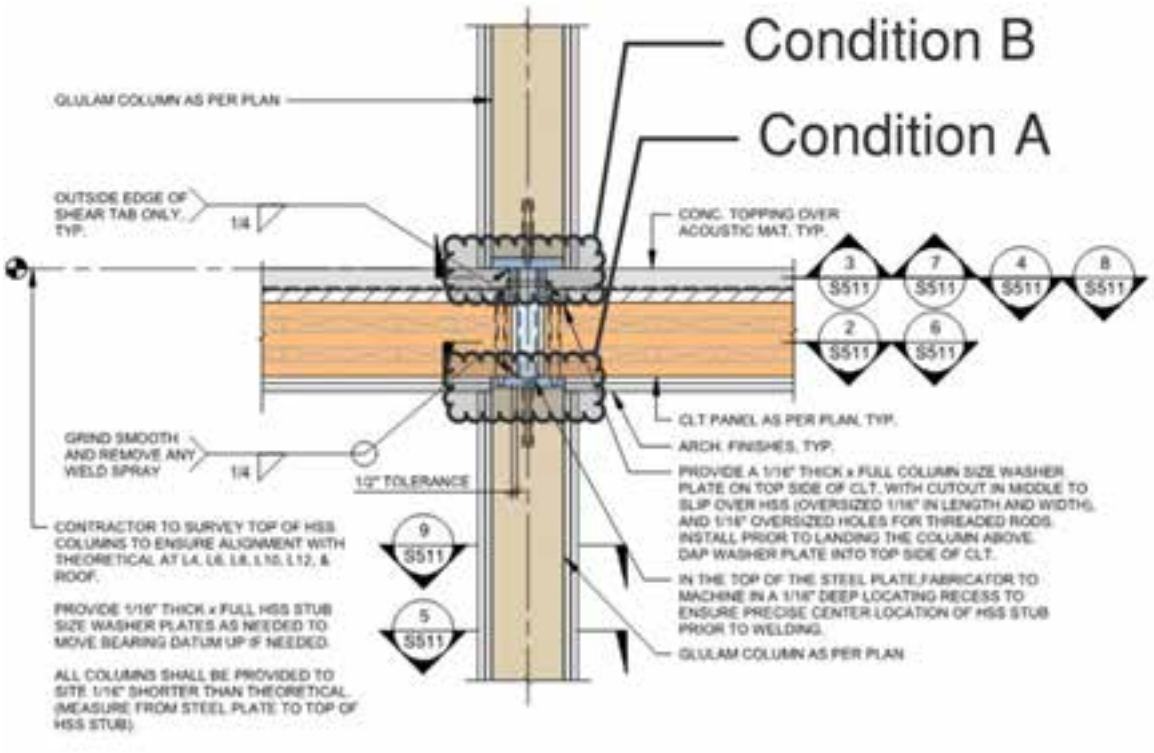
50% Exposed Mass Timber





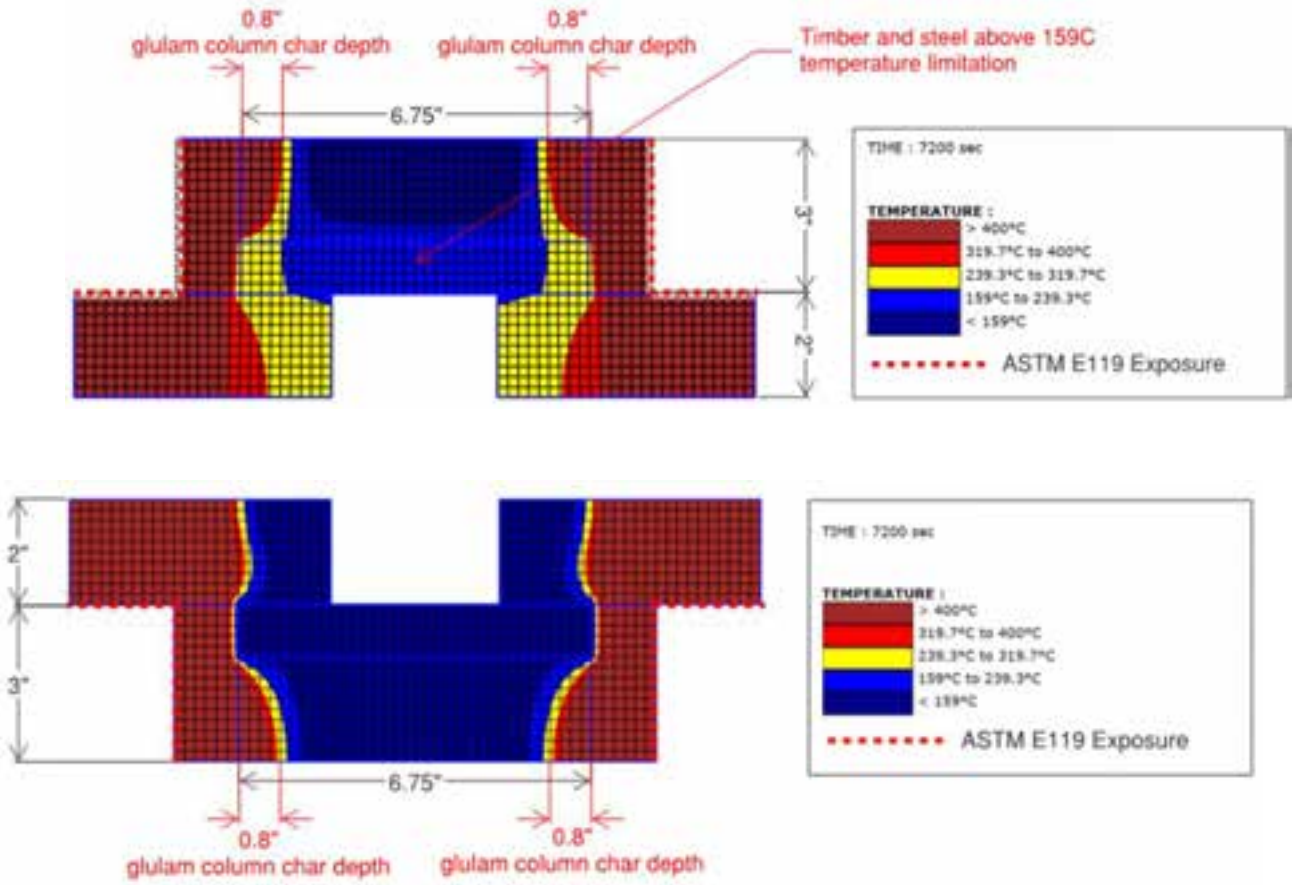
Gypsum protection at column lines and weak axis of CLT span.

Connection Protection



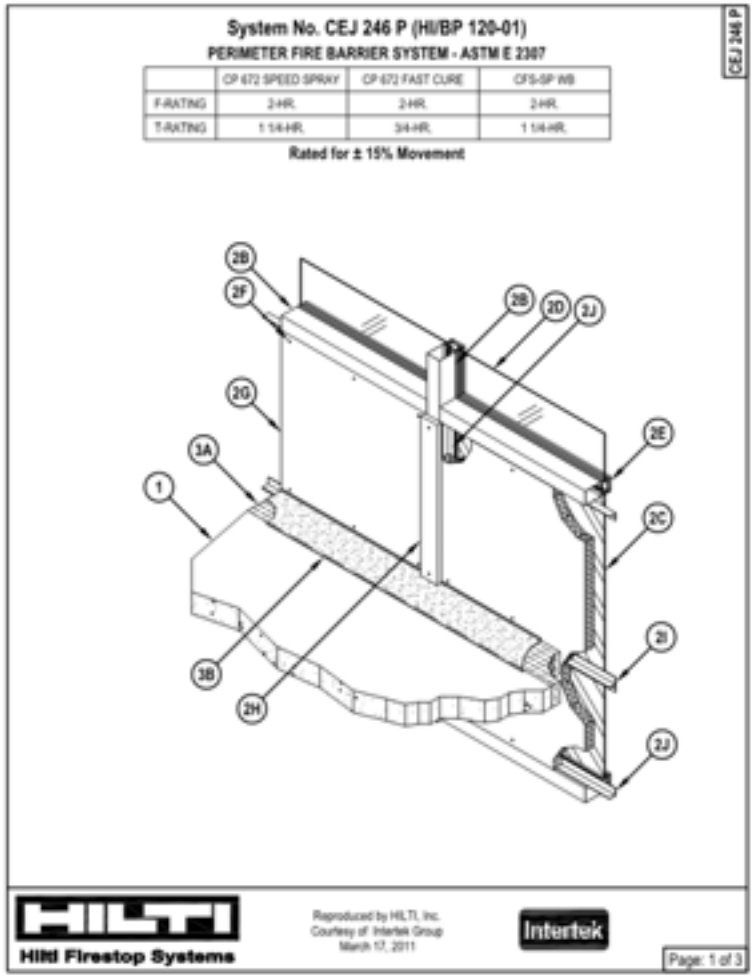
Finite Element Assessment

- Thermal-finite element assessment to ASTM E119 temperature curve for 2-hour duration.
- Indicated additional protection was required to bottom bearing plate to mitigate accelerated charring at bottom of column.
- Solution: Recessed steel bearing plates further into floor assembly to increase thermal mass (protection).



TOP and BOTTOM sections of column-floor-column joint (thermal analysis)

Edge of Slab Detailing



System No. CEJ 246 P (HI/BP 120-01)

PERIMETER FIRE BARRIER SYSTEM - ASTM E 2307

CEJ 246 P

	CP 672 SPEED SPRAY	CP 672 FAST CURE	CFS-SP WB
F-RATING	2-HR.	2-HR.	2-HR.
T-RATING	1 1/4-HR.	3/4-HR.	1 1/4-HR.

Rated for ± 15% Movement

HILTI

Hilti Firestop Systems

Reproduced by HILTI, Inc.
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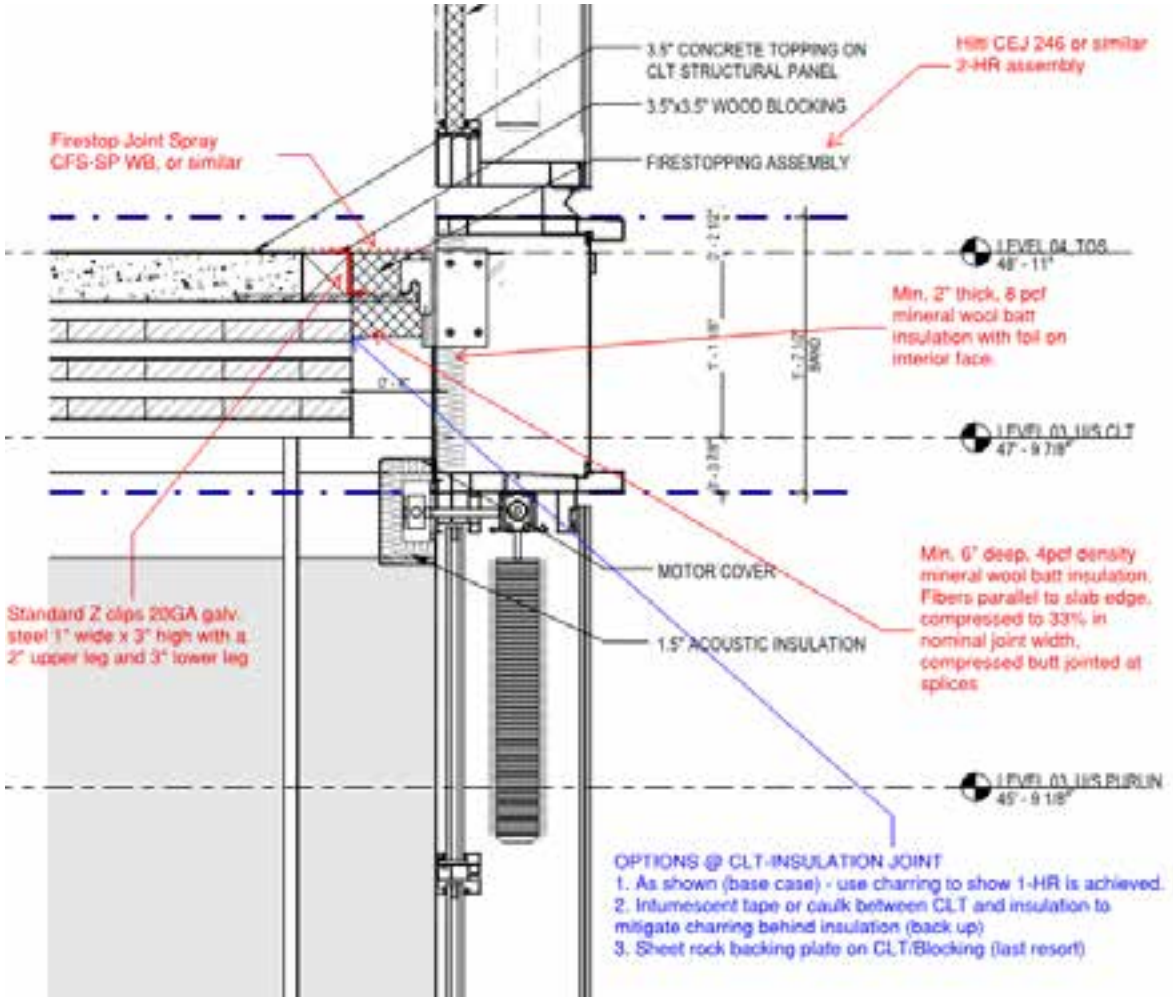
March 17, 2011

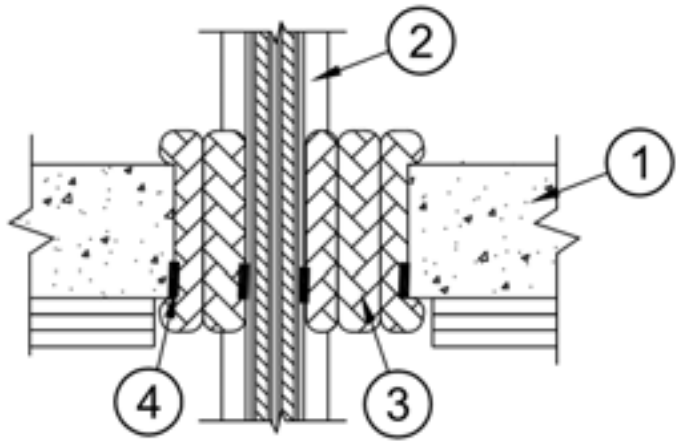
Intertek

Page: 1 of 3



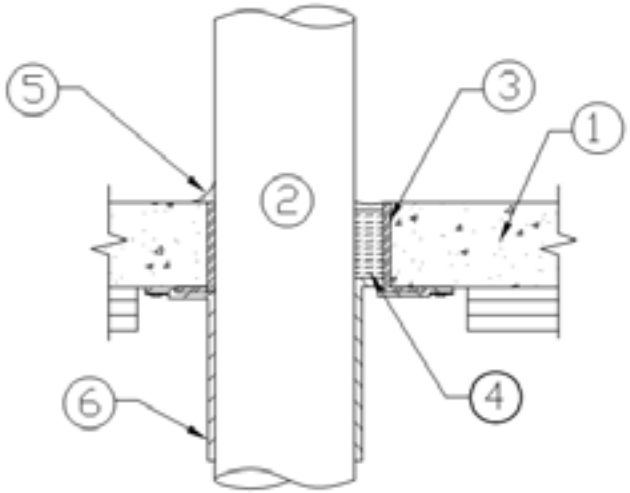
Floor Penetrations

3M ENGINEERING JUDGEMENT NO. 615658
MODIFIED SYSTEM NO. C-AJ-6041 DEPICTED
REQUESTED RATING - 1 HR / F
OBTAINABLE RATING: SEE BELOW*



1. CONCRETE FLOOR/CROSS-LAMINATED TIMBER.
2. PENETRATING ITEM PER APPROPRIATE VERSION OF CORRESPONDING EJ.
3. 3M FIRE BARRIER PILLOWS/3M FIRE BARRIER SELF LOCKING PILLOWS.
4. MP+ MOLDABLE PUTTY

3M ENGINEERING JUDGEMENT NO. 607991 REV 3
MODIFIED SYSTEM NO. C-AJ-1427, F-A-1057
REQUESTED RATING - 1 HR / F AND T
OBTAINABLE RATING (*SEE BELOW)



1. CONCRETE AND CROSS LAMINATED TIMBER FLOOR.
2. PENETRATING ITEM PER APPROPRIATE VERSION OF CORRESPONDING EJ.
3. STEEL SLEEVE. (WITH OPTIONAL SQUARE BASE)
4. 4 PCF MINERAL WOOL INSTALLED INTO ANNULAR SPACE AS OUTLINED IN APPROPRIATE VERSION OF CORRESPONDING EJ.
5. FIRESTOP SEALANT AS OUTLINED IN APPROPRIATE VERSION OF CORRESPONDING EJ.
6. 3M DUCT WRAP 615+

Process

Exposed Mass Timber
(Analysis and Justification)

Mitigation Measures

Recent Testing

Performance Based Engineering

Previous Test Results

- Series of full-scale compartment tests
- Multi-story compartment used for the test series, consisted CLT walls and floors
- Complete burnout of the fuel load without contribution of the mass timber elements
- No automatic fire sprinklers

Mass Timber Material Testing Development

- ICC Tall Wood Building provisions based on testing to PRG-320 (2015)
  - Adhesives not thermally resistant
  - Resulted in CLT delamination

- Current panels manufactured to PRG-320 (2018)
  - Thermally resistant PUR (Polyurethane Reactive) adhesives
  - No delamination expected
  - Additional testing (AWC) just completed

- Self-extinguishment is expected to improve within Commercial spaces (compared to residential configuration):
  - Reduced re-radiation effects
  - Increased ventilation (reduced fire severity)
  - Glulam Columns tested > 3hr FRR

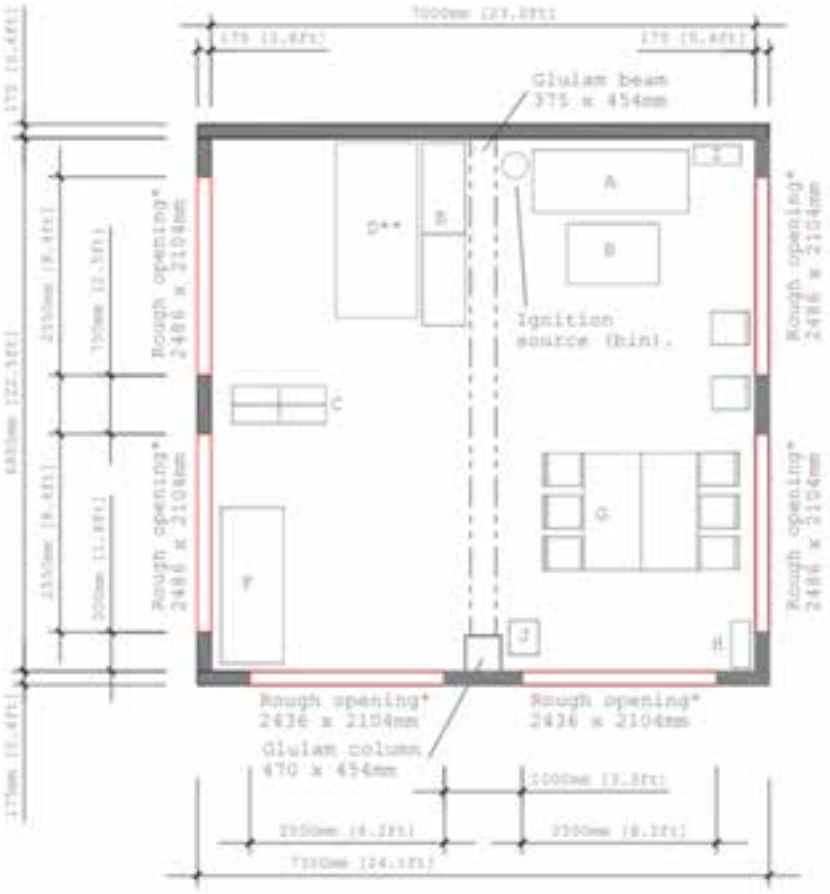
- High rise projects approved within Canada and US with increased exposed mass timber: INTRO Market Square office building, ASCENT residential project

FPL Test Results

- Series of 4 compartment tests (residential compartment and fuel load).
- In all tests with exposed mass timber, the peak room temperatures were similar to fully encapsulated test. The fully developed fire stages were longer than the baseline as the exposed timber added more fuel load to the rooms.
- Glulam columns sized to 3-HR FRR per NDS 16, achieved > 4-hrs FRR.

RISE Test Results

- Five compartment fire experiments were performed for this study.
- One of the tests were undertaken with portions of exposed mass timber panels up to 100% exposed ceilings, with various window opening areas.
- ANSI/APA PRG 320, 2018 compliant panels.
- Only back wall protected (2 x Type X GWB).



Fire Load Energy Density Assessment (FLED)

RISE Test Results

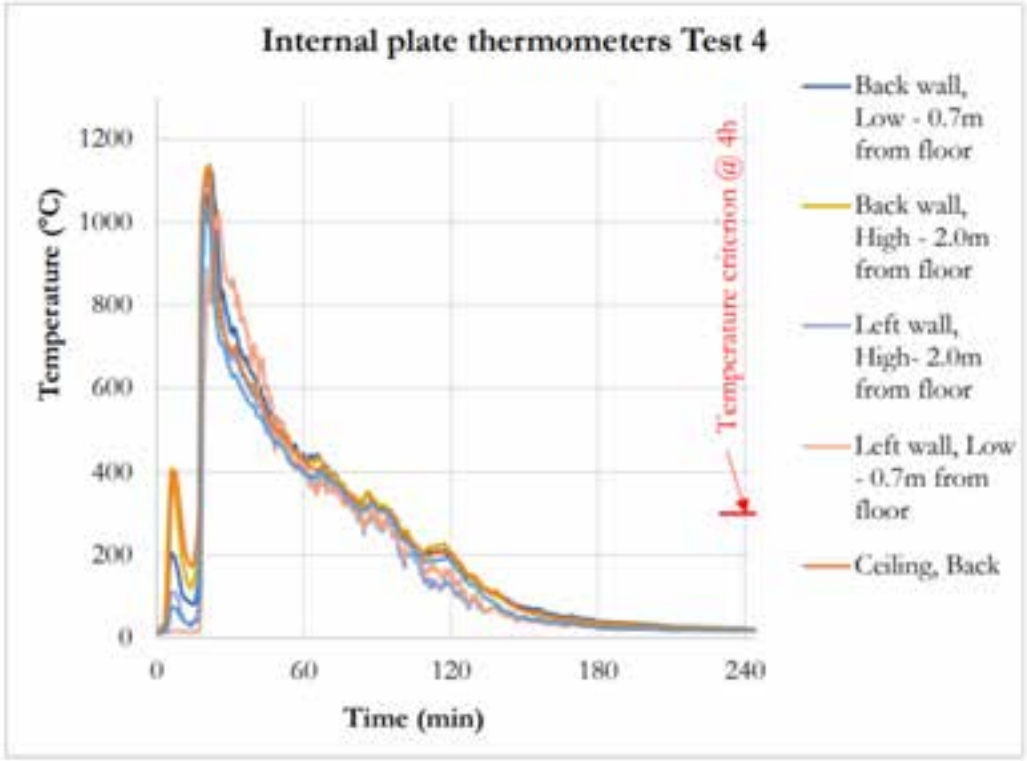
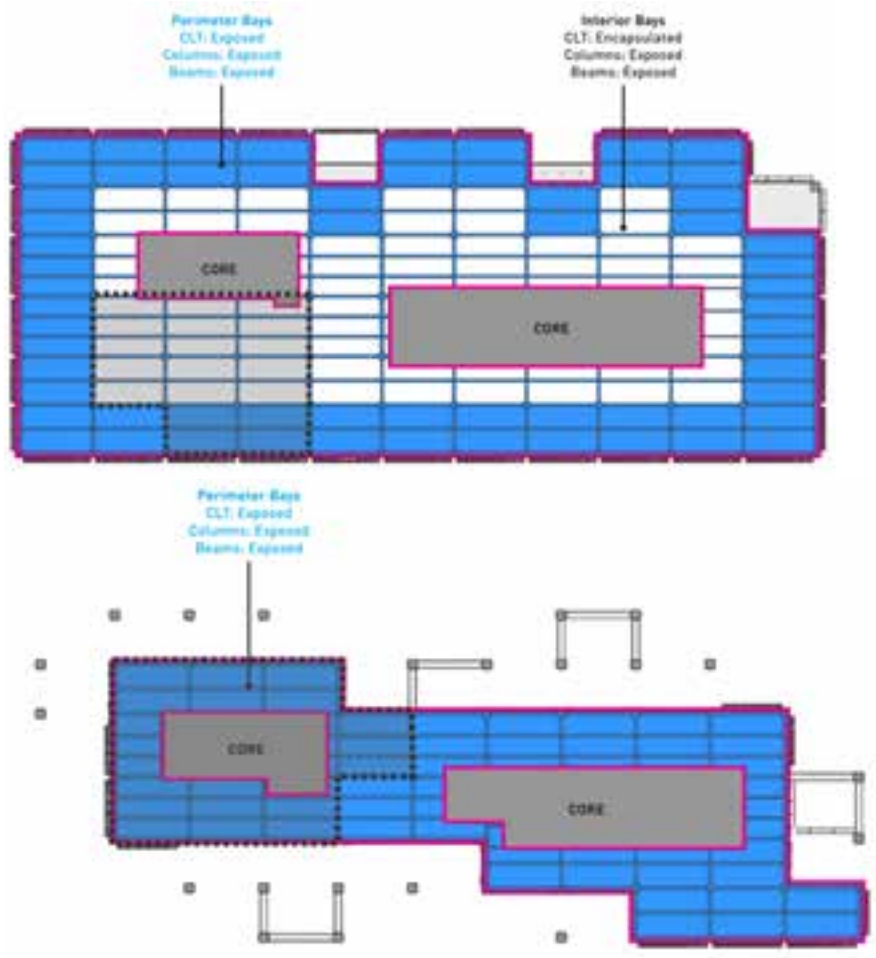
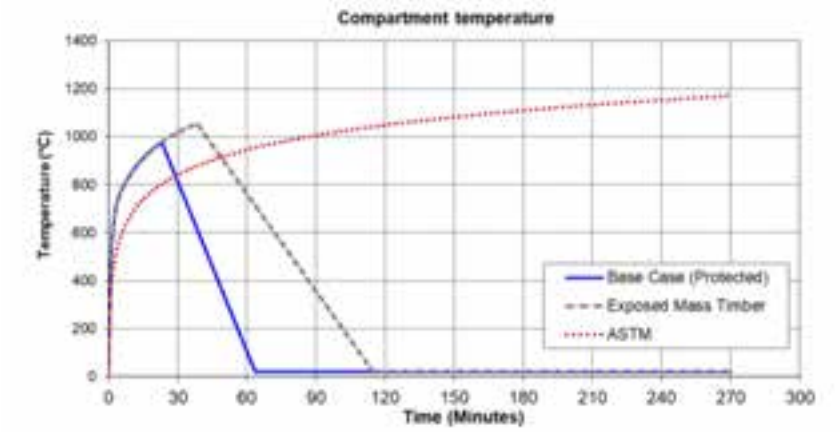
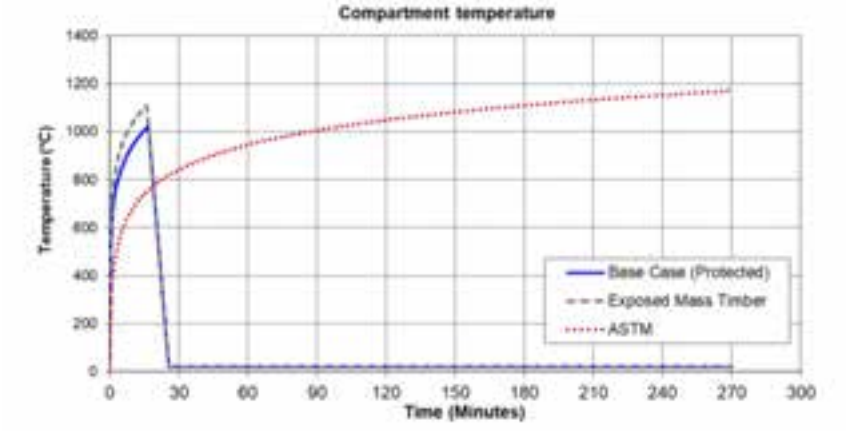


Figure 43: Internal plate thermometer measurements of Test 4

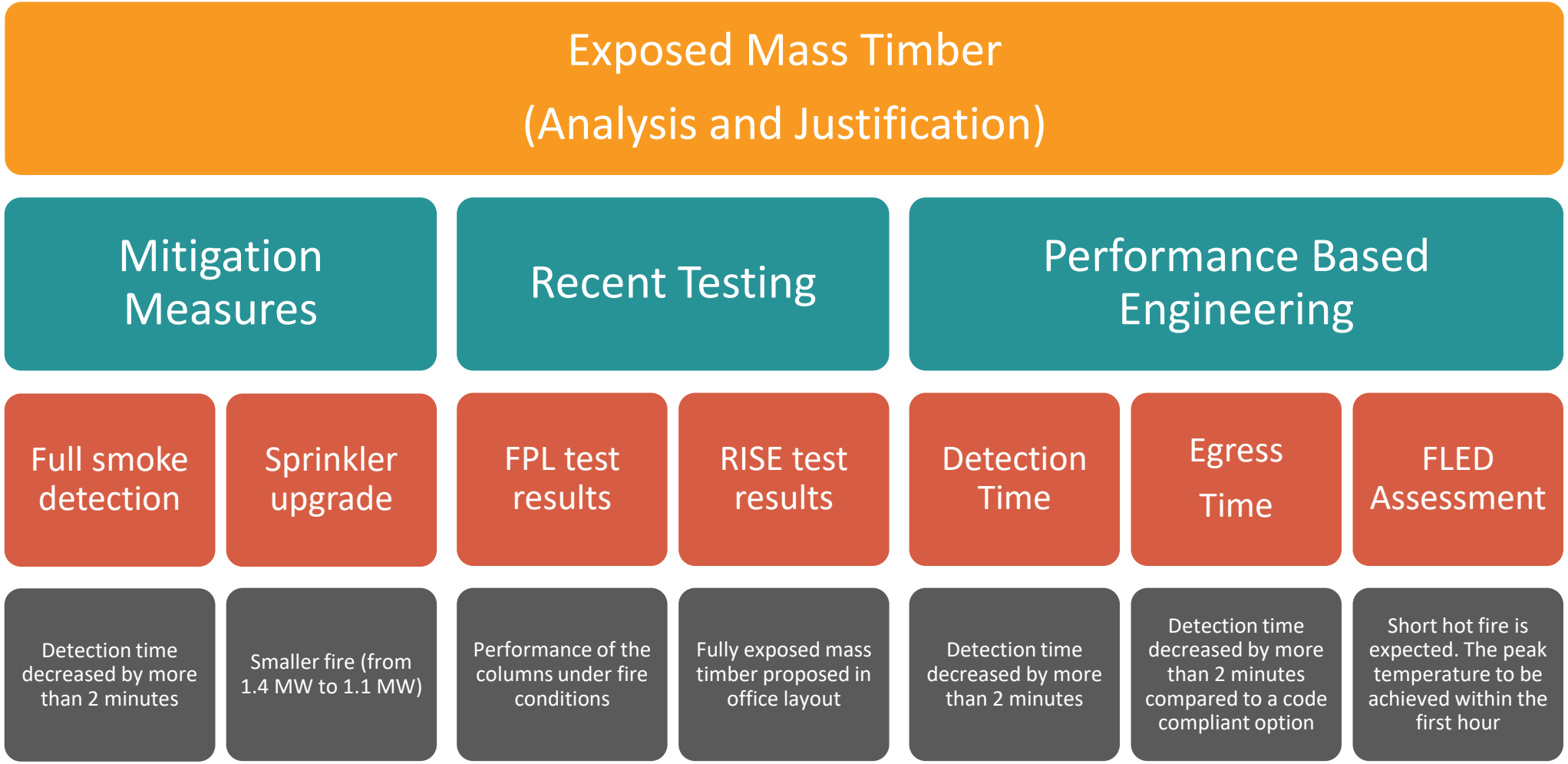
Fire Load Density Assessment (FLED)



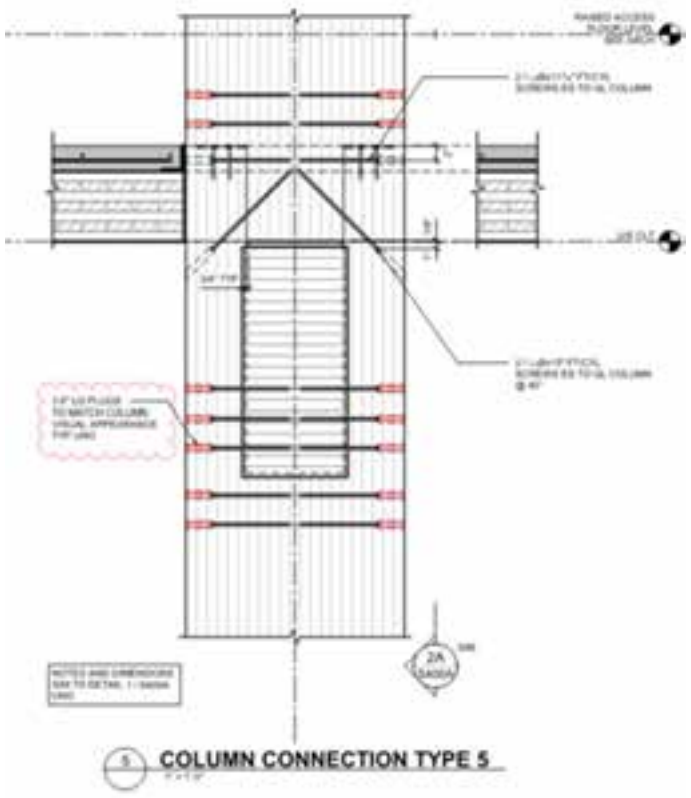




Summary


Exposed Mass Timber
(Analysis and Justification)
Mitigation Measures
Recent Testing
Performance Based Engineering
Full smoke detection
Sprinkler upgrade
FPL test results
RISE test results
Detection Time
Egress Time
FLED Assessment
Detection time decreased by more than 2 minutes
Smaller fire (from 1.4 MW to 1.1 MW)
Performance of the columns under fire conditions
Fully exposed mass timber proposed in office layout
Detection time decreased by more than 2 minutes
Detection time decreased by more than 2 minutes compared to a code compliant option
Short hot fire is expected. The peak temperature to be achieved within the first hour

Beam-Column Joint



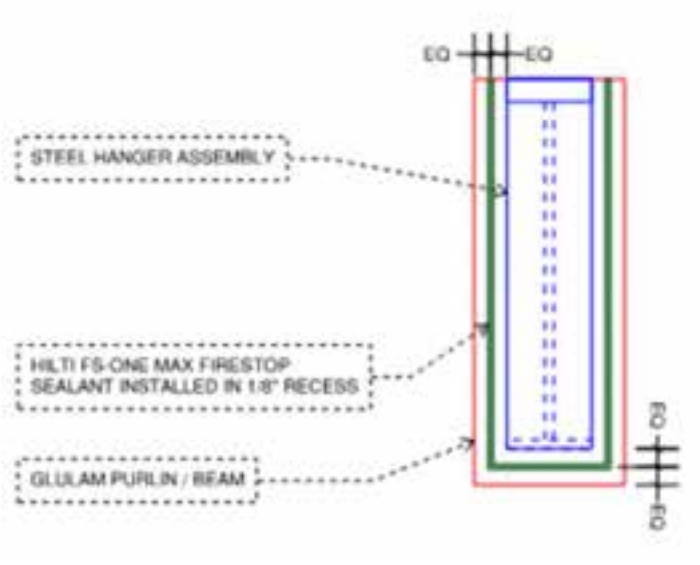


Figure A-3. Column Prepped.

Figure A-4. Column and Beam Connection.

QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

Bevan Jones

bevan.jones@holmes.us

holmes.us