Timber Office Buildings: Everything Old is New Again

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Brock Commons Vancouver, completed 2017

Acton Ostry

Fast+Epp

18 storeys (17 wood +1 concrete); 54 metres; 162,700 sqft.

Time for Canadian & U.S. Forests to grow the timber used: 6 minutes

Time to erect 17 floors: less than 70 days with a crew of 9 or 10

1,753 tonnes of CO_2 sequestered

Tallest modern timber tower until…

Photo: Fast & Epp

Mjøsa Tower

Brumunddal, Norway

18 storeys/85.4m

11,300 m^2 (121,570sqft.)

Offices, hotel and apartments

images: Moelven

Wood as a resource

- Canad % of the global
- Comp
- In 201
- To cor M hectar
- Forest 200,000 jobs
- 7% of
- **94% o d**

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- Why wood?
  - Grown by the sun
  - Light weight relative to its strength
  - Low carbon footprint
    - On a recent study for a 15 storey office building we estimate 3250 tonnes of CO_2 saved in switching from the steel to wood, roughly the annual output of 200 average Canadians
  - Prefabricated – accelerated construction
  - Aesthetically pleasing – exposed to view

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Biophilia

- exposed wood has positive health and well-being benefits on occupants
  - Studies: D. Fell (UBC); Rice *et al*. (FPInnovation); Kelz *et al*. (Austria); Sakuragawa *et al*. (Japan)

In offices:

- Higher rental rates
- Faster to rent
- High profile tenants (i.e. knowledge economy)
- More likely to stay rented during economic downturns

In hospitals (Credit Valley Hospital Atrium):

- Notable reduction in cancer centre staff sick days

In barns:

- Cows produce more milk in barns with exposed wood

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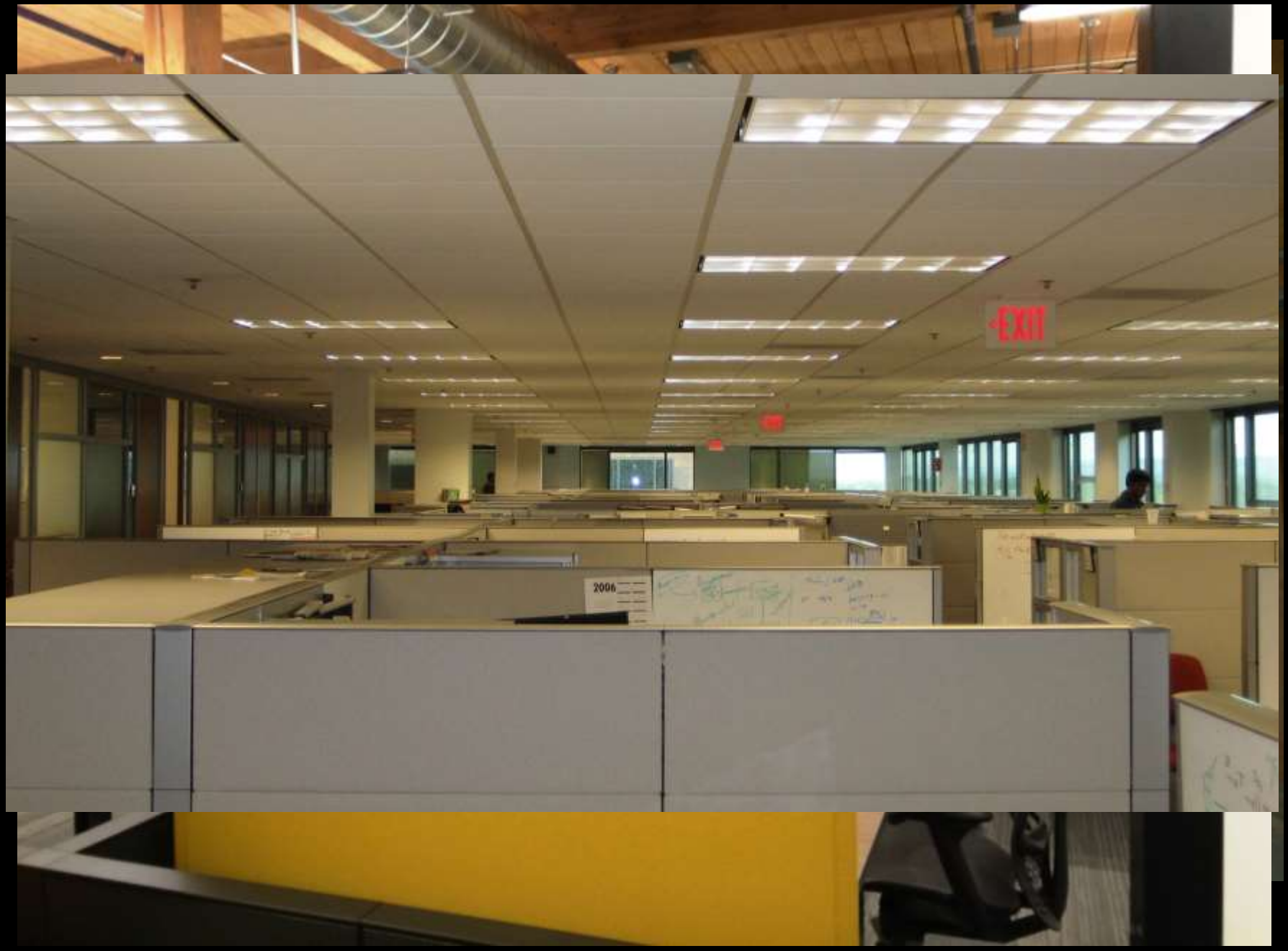

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Mass Timber

Glulam (Glue Laminated Timber)
NLT (Nail Laminated Timber)
DLT (Dowel Laminated Timber)
CLT (Cross Laminated Timber)
LVL (Laminated Veneer Lumber)
LSL (Laminated Strand Lumber)
Plywood

Glulam

Photo: Guardian Bridge
Photo: Art Thureson Inc.

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NLT (Nail Laminated Timber)

Photo: Structurecraft

DLT (Dowel Laminated Timber)

Image: Structurecraft

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CLT (Cross Laminated Timber)

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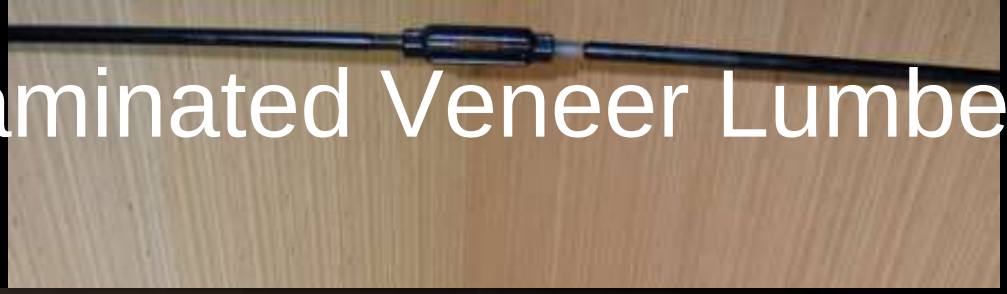
LVL (Laminated Veneer Lumber)



Photos: Brisco Manufacturing Ltd.

LSL (Laminated Strand Lumber)

Photo: Equilibrium

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Plywood

Photo: Freres Lumber

Mass plywood: up to 300mm thick; 3.6m x 14.5m

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- Special design considerations for mass timber buildings
  - Fire
  - Water
  - Dimensional stability
  - Connections

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Fire

- Rule #1: Wood burns; get over it
- char
- on

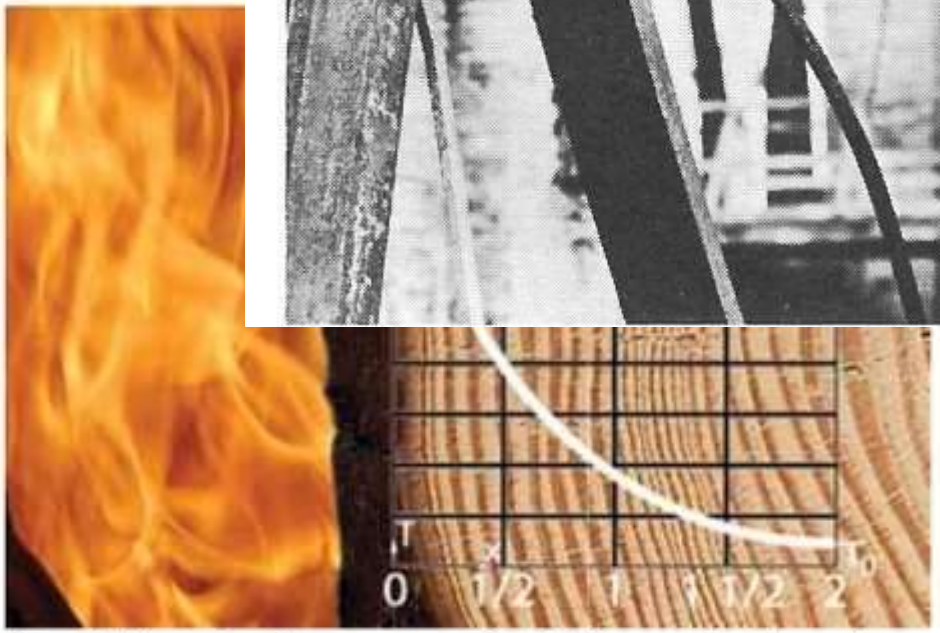


Figure 3: Illustration of temperature gradient in fire-exposed wood member.

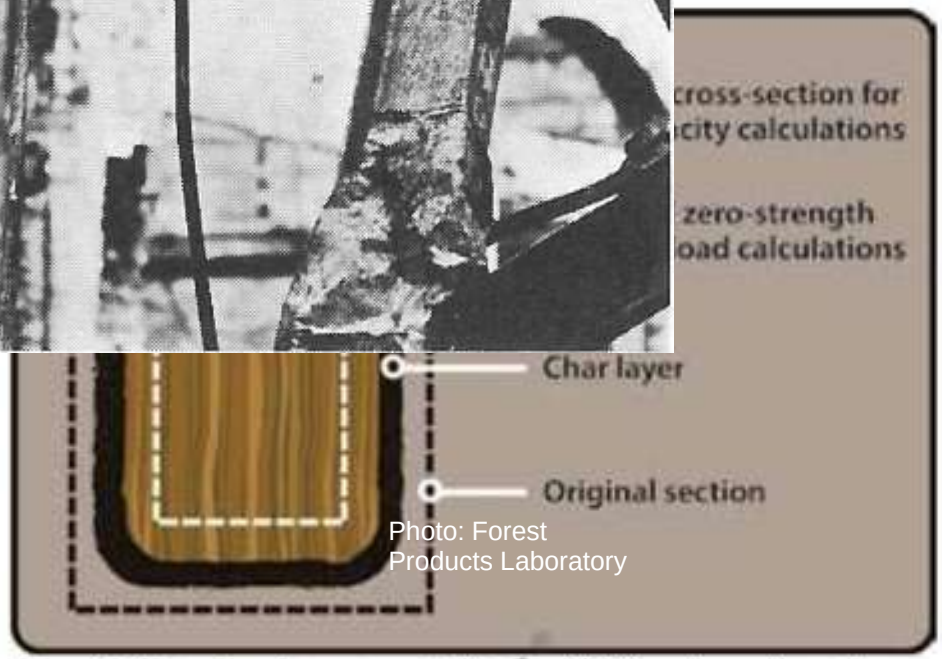


Photo: Forest Products Laboratory

Figure 4: Illustration of zero-strength layer model of fire-damaged wood beam.

- M-Building, Kanazawa City, Japan
  - Composite steel-timber structural system
  - Timber contributes to structure and protects steel

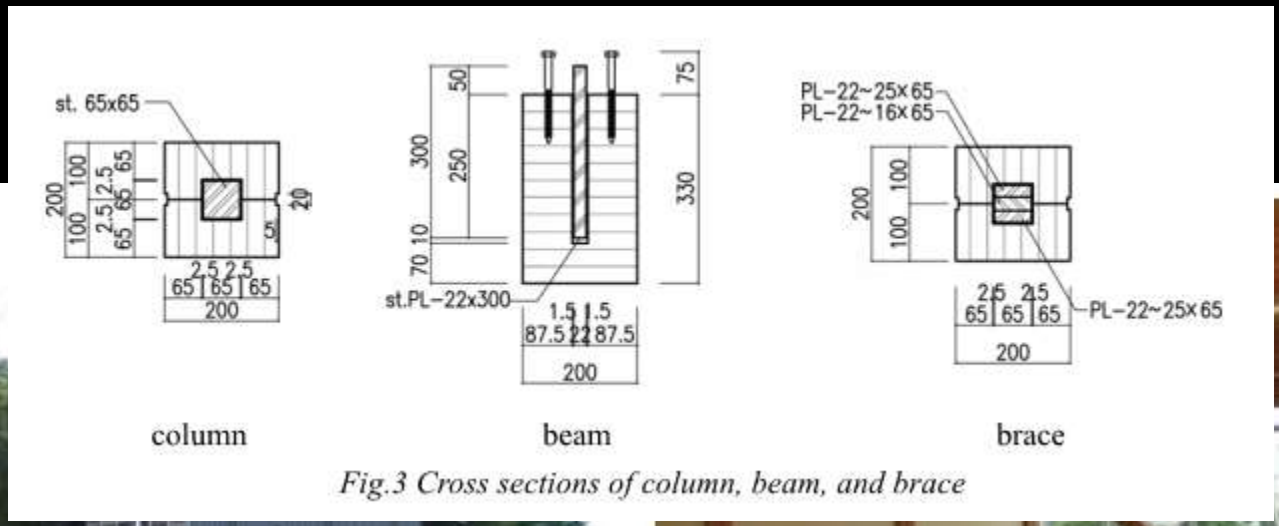
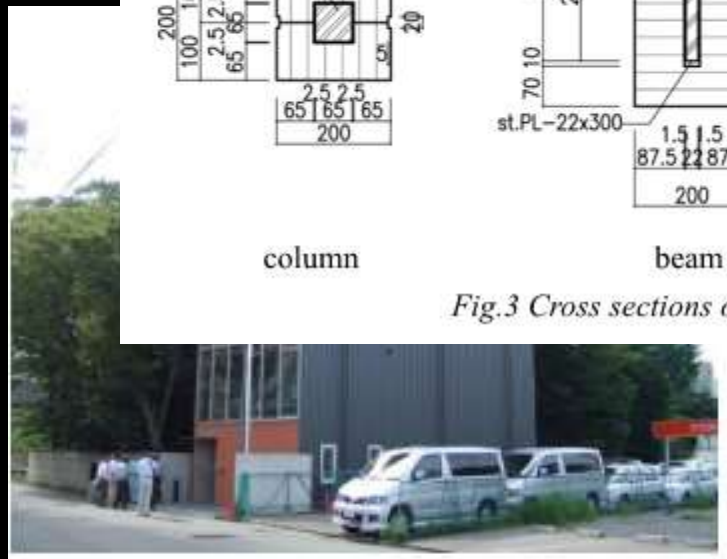


Fig.3 Cross sections of column, beam, and brace



Images: Koshihara et al.

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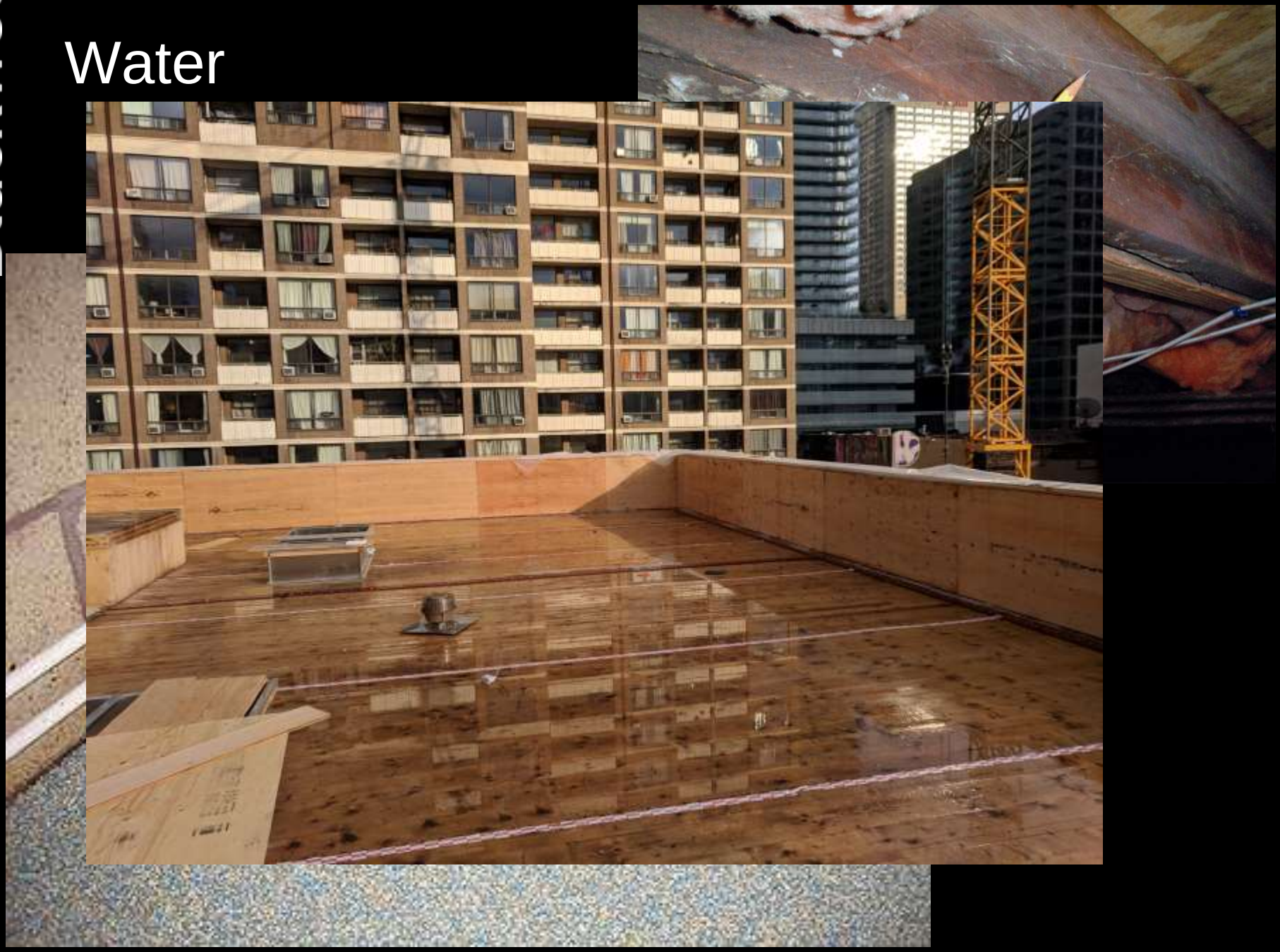
Water



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Other materials are not immune

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Shrinkage

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Wood Connections

Wood Connections

MEZZANINE LEVEL: SCHEDULE OF BEAMS AND BEAM DESIGN REACTIONS

BEAM MARK	BEAM SECTION (w x d)	GRADE	REACTIONS		REMARKS
			LEFT END REACTION	RIGHT END REACTION	
MB1	5⅛" x 18"	24f-E D.FIR	95 kN	95 kN	SUGGESTED CONNECTOR: KNAPP MEGANT 520x60x40 (REQUIRES MINIMUM SECTION DEPTH OF 24")
MB2	5⅛" x 18"	24f-E D.FIR	80 kN	80 kN	SUGGESTED CONNECTOR: KNAPP MEGANT 405x60x40 (REQUIRES MINIMUM SECTION DEPTH OF 20½")
MB3	5⅛" x 16½"	24f-E D.FIR	65 kN	65 kN	SUGGESTED CONNECTOR: KNAPP MEGANT 405x60x40 (REQUIRES MINIMUM SECTION DEPTH OF 19")
MB3a	5⅛" x 16½"	24f-E D.FIR	75 kN	75 kN	SUGGESTED CONNECTOR: KNAPP MEGANT 405x60x40 (REQUIRES MINIMUM SECTION DEPTH OF 20½")
MB4	5⅛" x 19½"	24f-E D.FIR	50 kN	50 kN	SUGGESTED CONNECTOR: KNAPP MEGANT 405x60x40 (REQUIRES MINIMUM SECTION DEPTH OF 19")
MB5	5⅛" x 24"	24f-E D.FIR	90 kN	90 kN	SUGGESTED CONNECTOR: KNAPP MEGANT 520x60x40 (REQUIRES MINIMUM SECTION DEPTH OF 24")
MB5a	5⅛" x 16½"	24f-E D.FIR	10 kN	10 kN	SUGGESTED CONNECTOR: KNAPP MEGANT 290x60x40 (REQUIRES MINIMUM SECTION DEPTH OF 15")
MB6	5⅛" x 22½"	24f-E D.FIR	65 kN	90 kN	SUGGESTED CONNECTOR: KNAPP MEGANT 520x60x40 (REQUIRES MINIMUM SECTION DEPTH OF 24")

Images: Wiehag

Image: A. Schreyer

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Precedents

- Horyuji – Nara Japan, 700 AD, 37m

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- 312 Adelaide West, Toronto – 1895, 8 Levels Post and Beam

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McEwen Architecture at Laurentian
(LGA)

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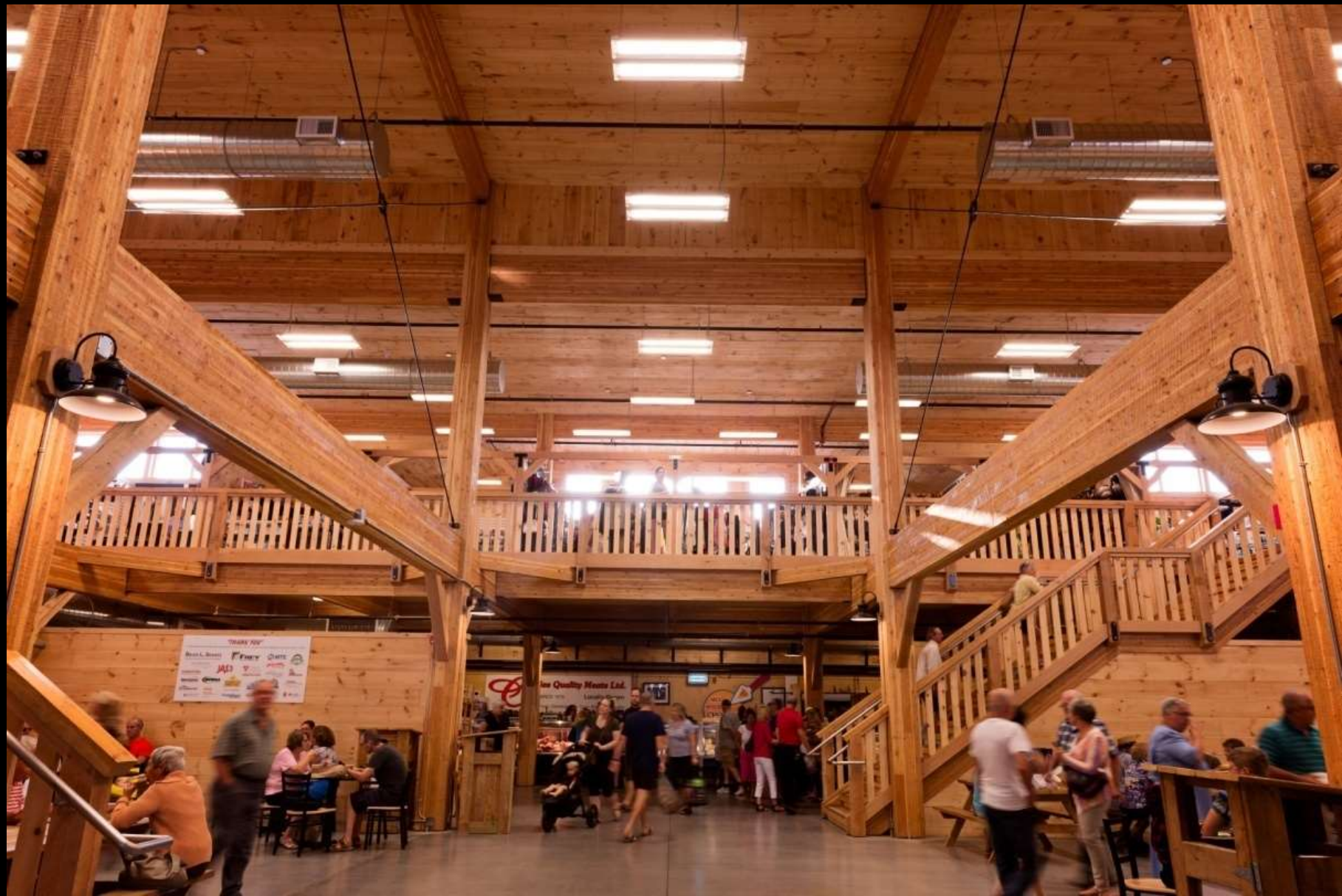
St. Jacobs Farmers' Market

(Architecture Incorporated)



Shoppers Drug Mart, Yonge St.

(Brook McIlroy)

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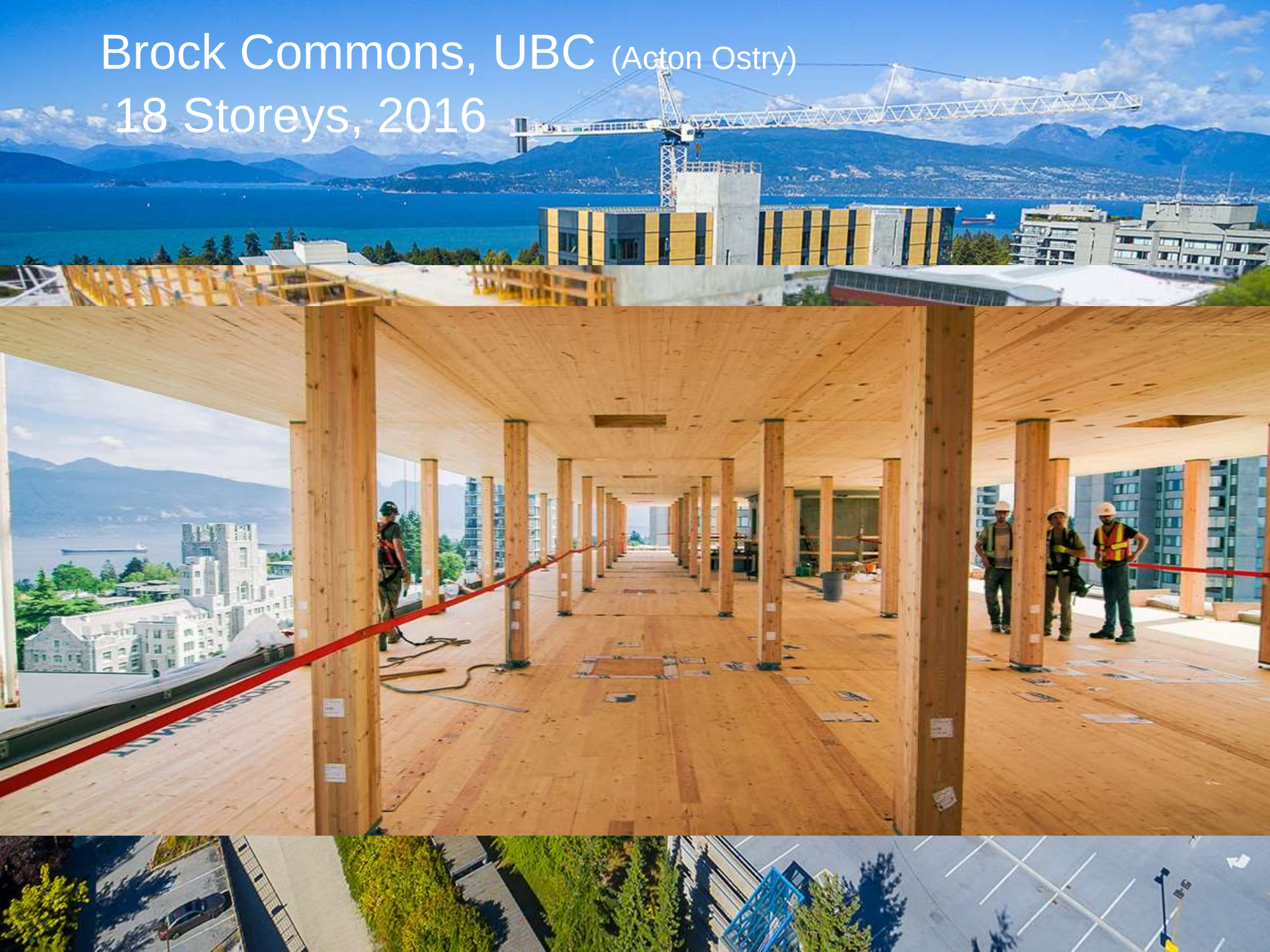
Treet – Bergen, Norway (Artec), 14 Levels, 2015

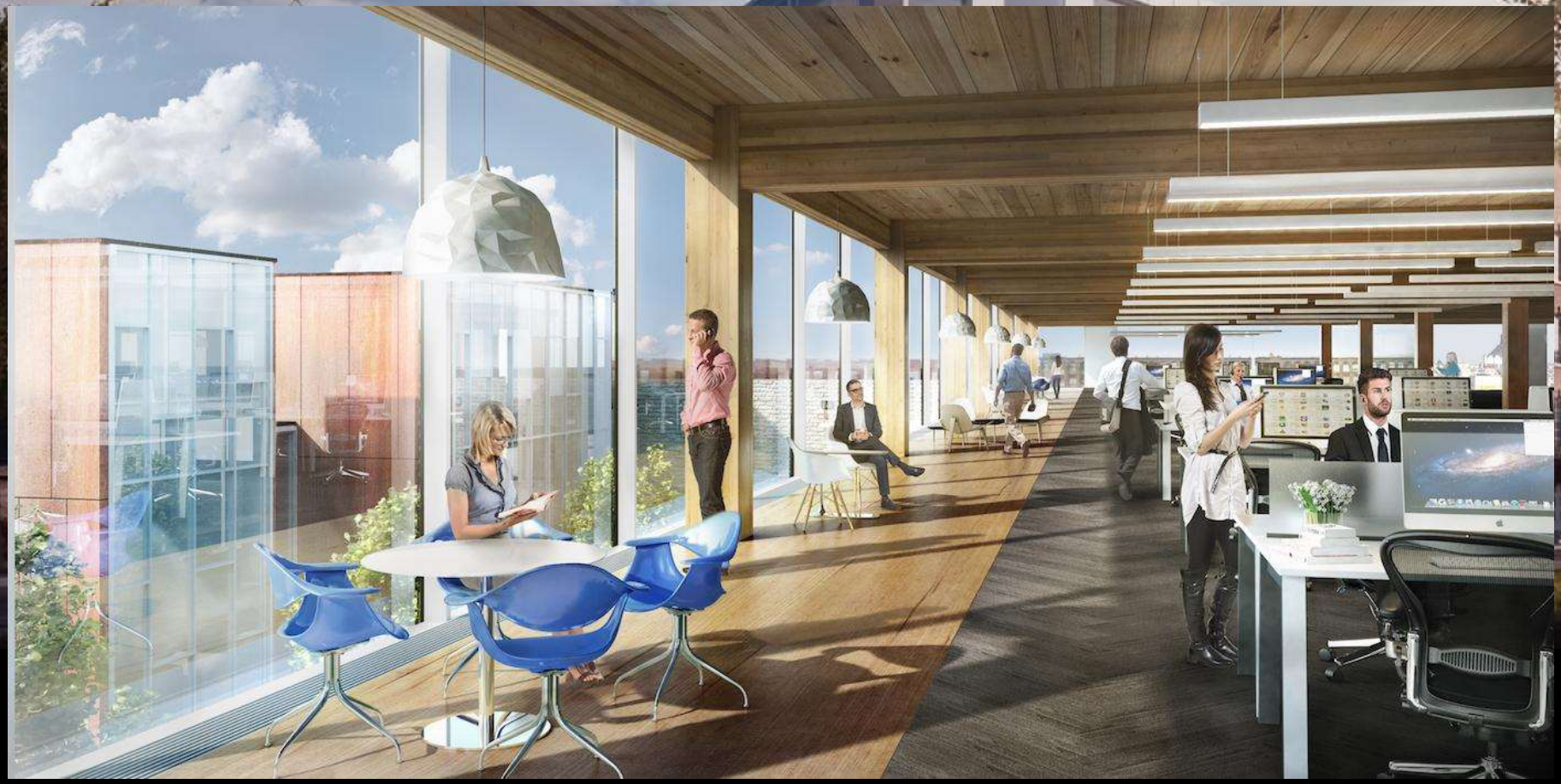
Brock Commons, UBC (Acton Ostry)
18 Storeys, 2016



Terrace House (Shigeru Ban)

80 Atlantic

(Quadrangle)



MEC Headquarters

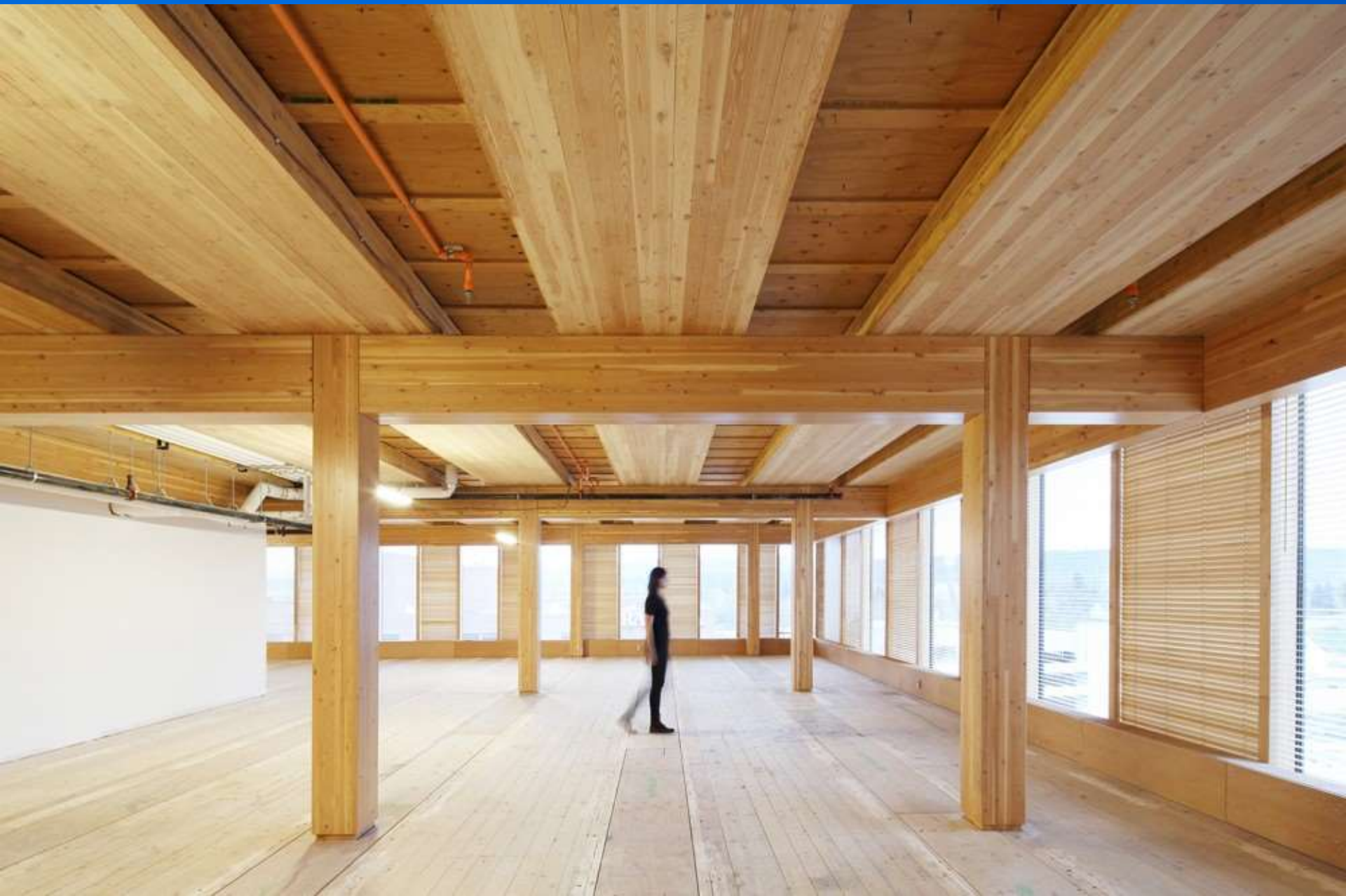
(Proscenium Architecture)

UMass Design Building

(Leers Weinzapfel Associates)

Wood Innovations Centre – Prince George (MGA)

7 Levels, 2014



T3 Minneapolis (MGA)

7 stories

Residential

Minimising floor-to-floor height and assembly thickness is desirable

- Smaller rooms /demising walls result in smaller spans and can result in modest structural depth
- Frequently fire rating is achieved through gypsum in residential applications

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Commercial/Institutional

Minimising floor assembly thickness is desirable

Mechanical requirements are more significant – adds to depth of assembly

Long spans are preferred – 9m± is gold standard for office space

Exposed timber is preferred

- Beam depth increases with span
- Fire-rating may drive up timber sizes in order to expose structure

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Systems for long spans

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Composite vs. Non-composite

- Less Timber
- Shear Transfer (Cost & Complication)
- Heavier

- More Timber
- Floating Topping (if used)
- Lighter Weight (if no topping)
- Faster

HBV Connector

SFS Holz-Beton-Verbundsystem

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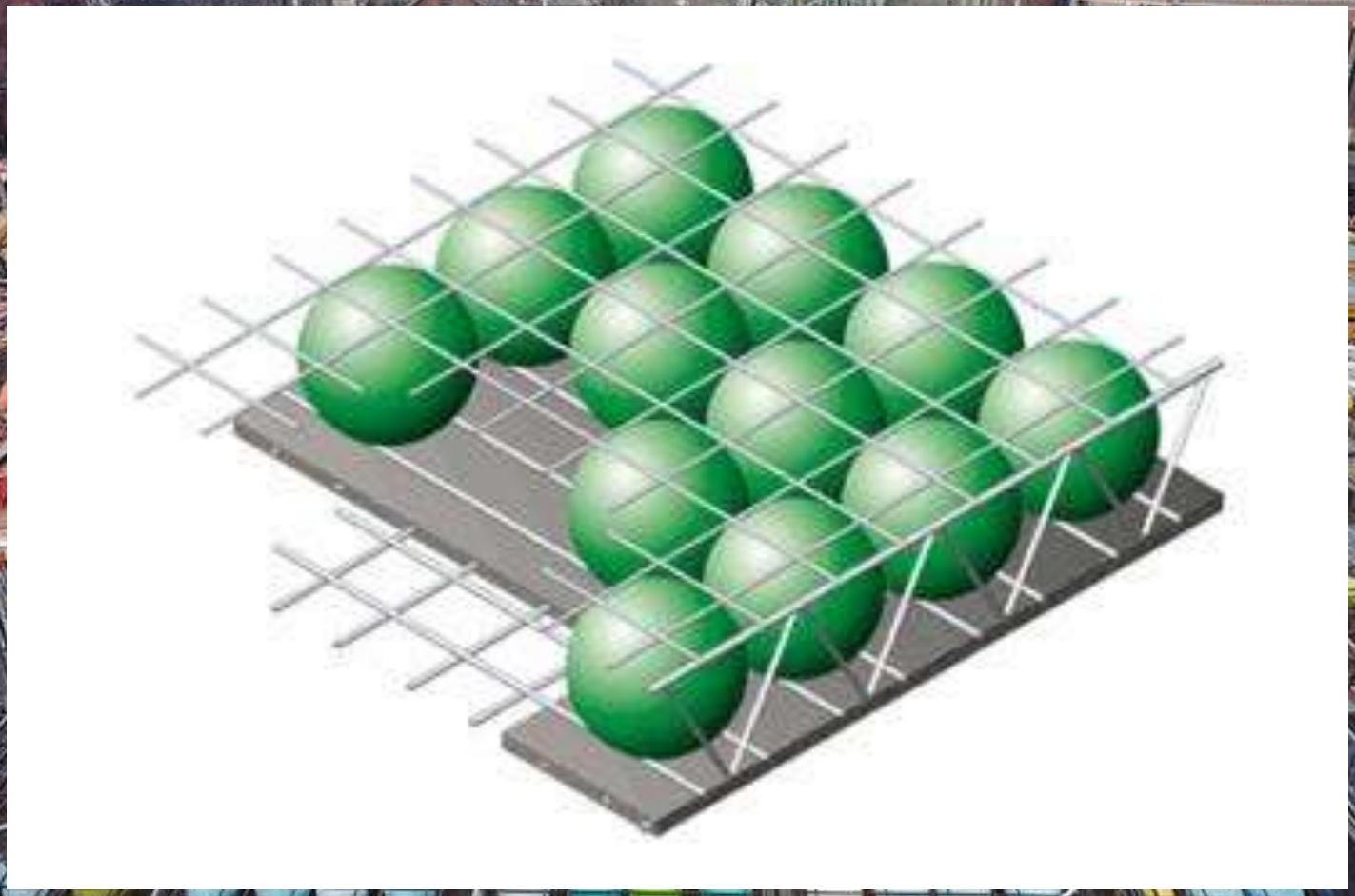

Bubbledeck

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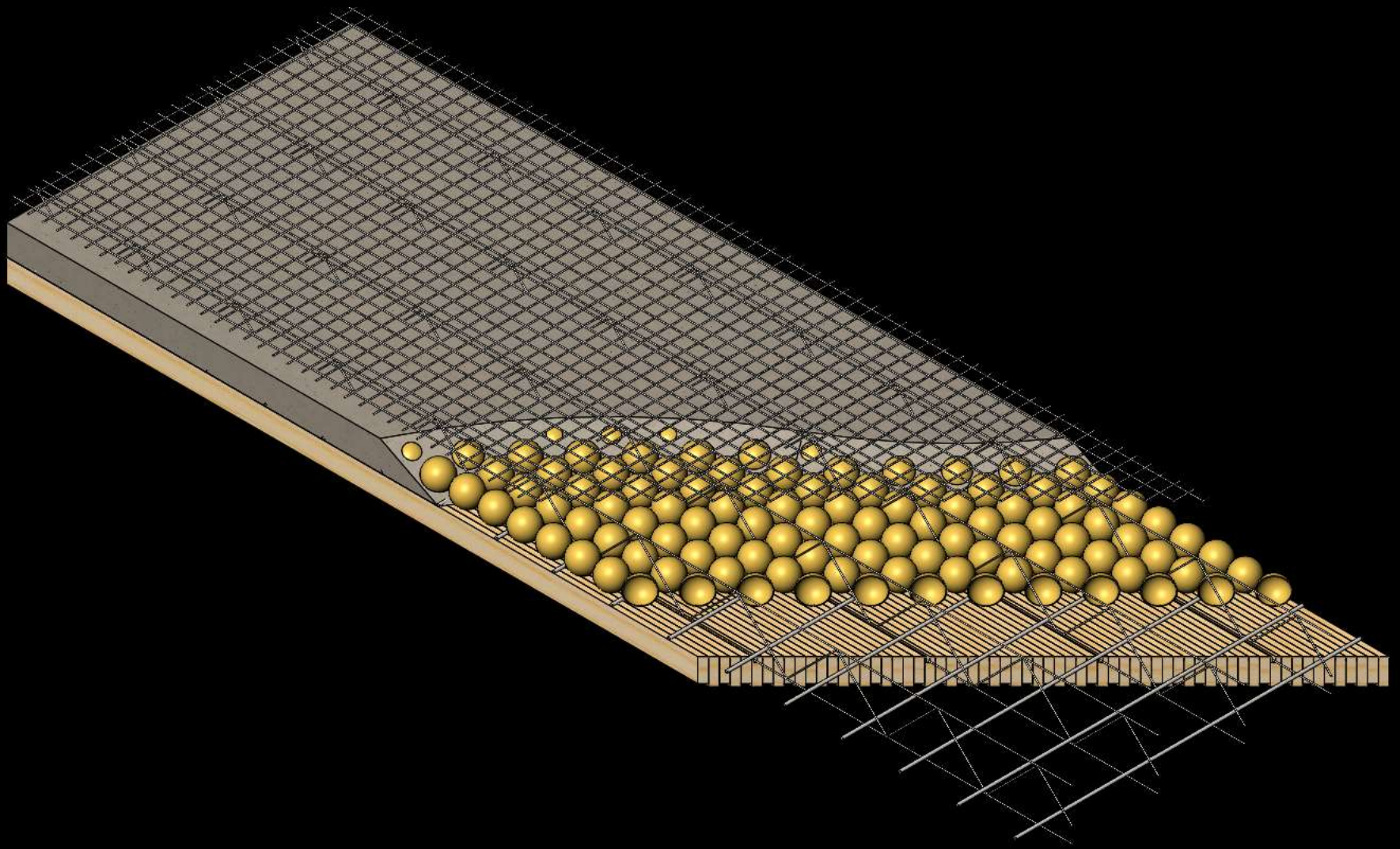

BubbleLam

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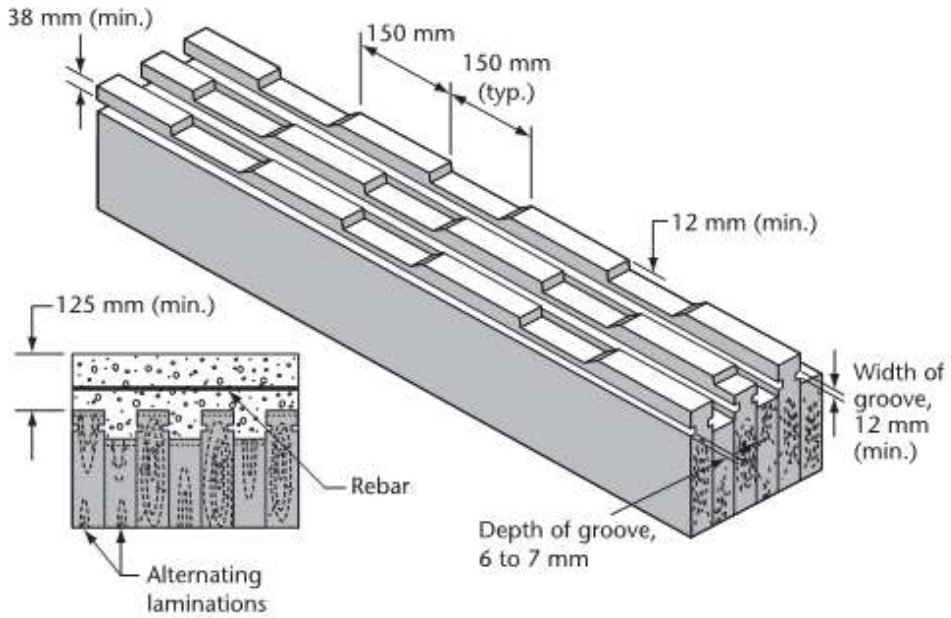


Figure 9.3
Details of wood-concrete interface
(See Clause 9.22.4.)

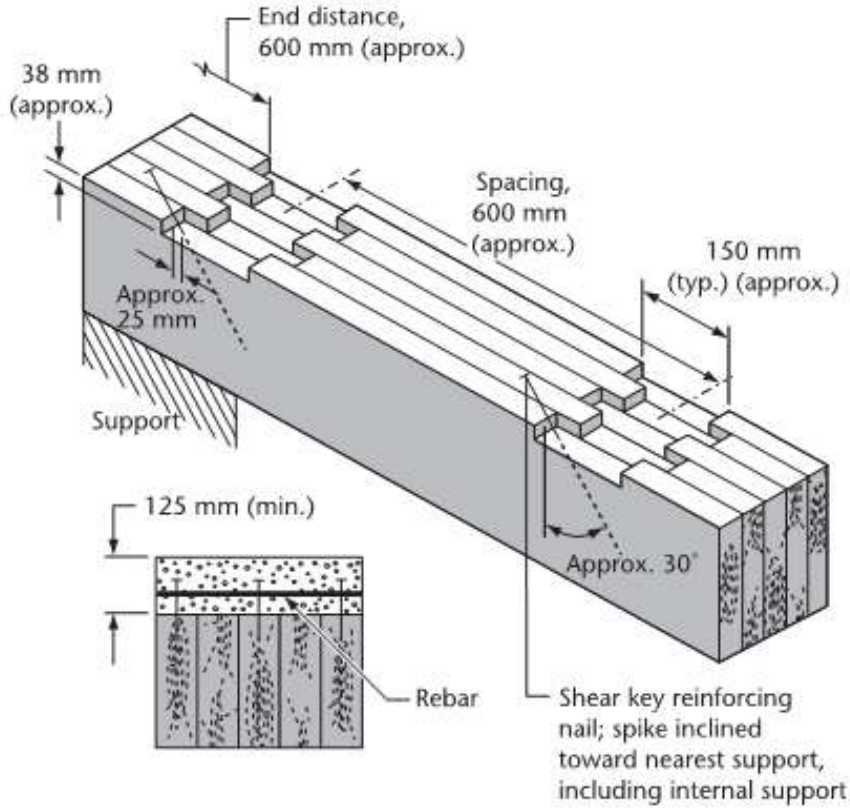
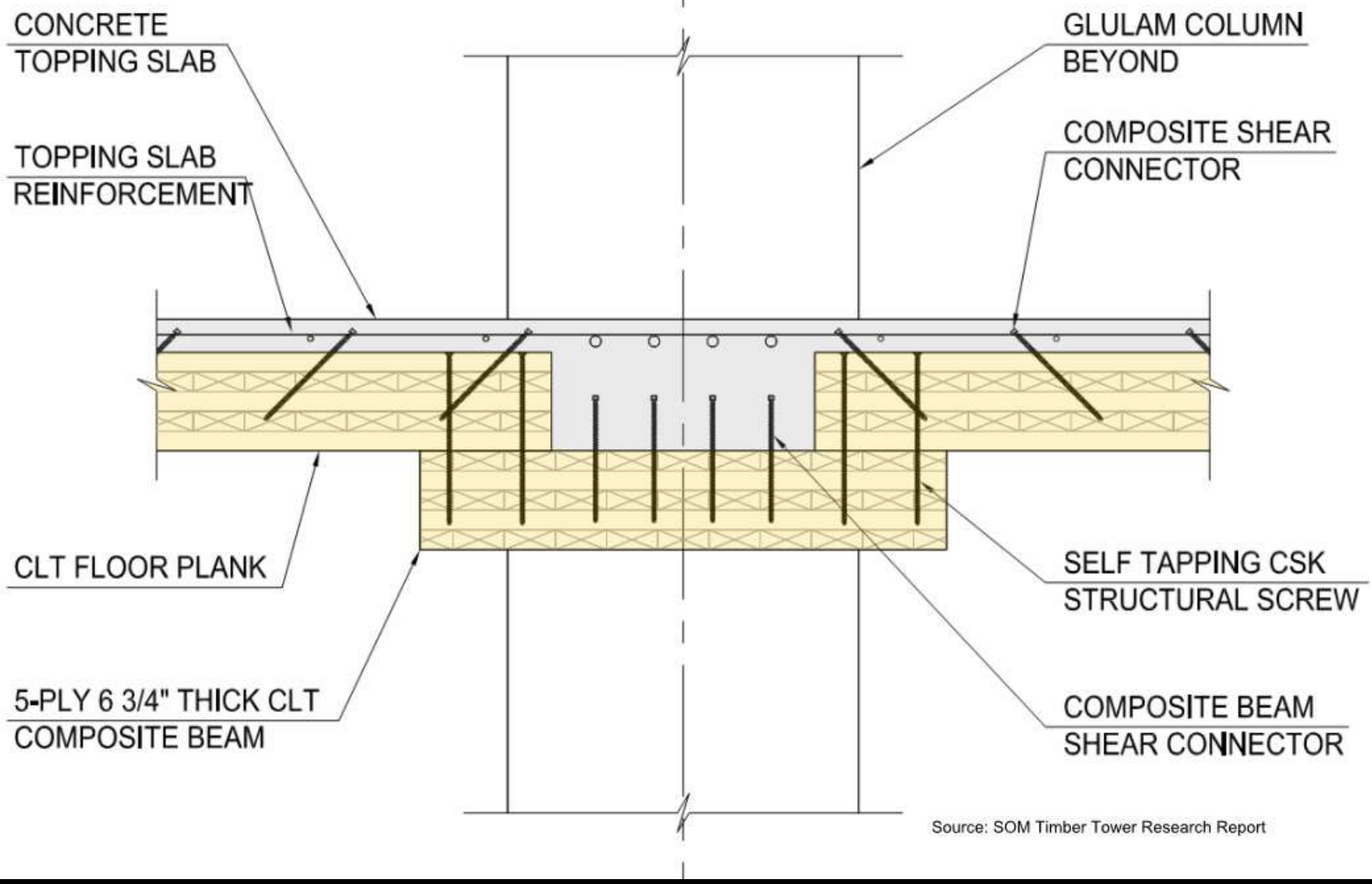


Figure 9.4
Alternative details of wood-concrete interface
(See Clauses 9.22.3.3 and 9.22.4.)


CONCRETE
TOPPING SLAB
TOPPING SLAB
REINFORCEMENT
CLT FLOOR PLANK
5-PLY 6 3/4" THICK CLT
COMPOSITE BEAM
GLULAM COLUMN
BEYOND
COMPOSITE SHEAR
CONNECTOR
SELF TAPPING CSK
STRUCTURAL SCREW
COMPOSITE BEAM
SHEAR CONNECTOR
Source: SOM Timber Tower Research Report

Hybrid assembly

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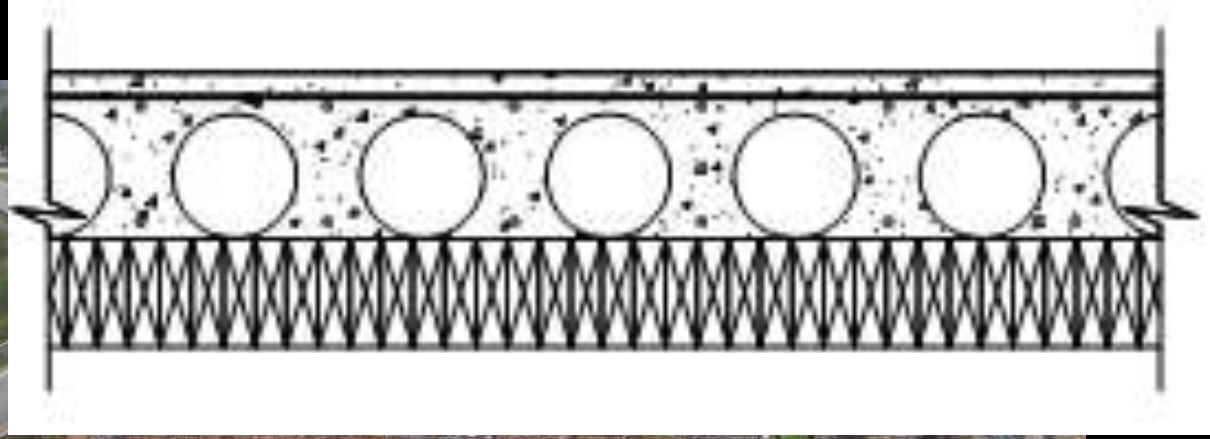

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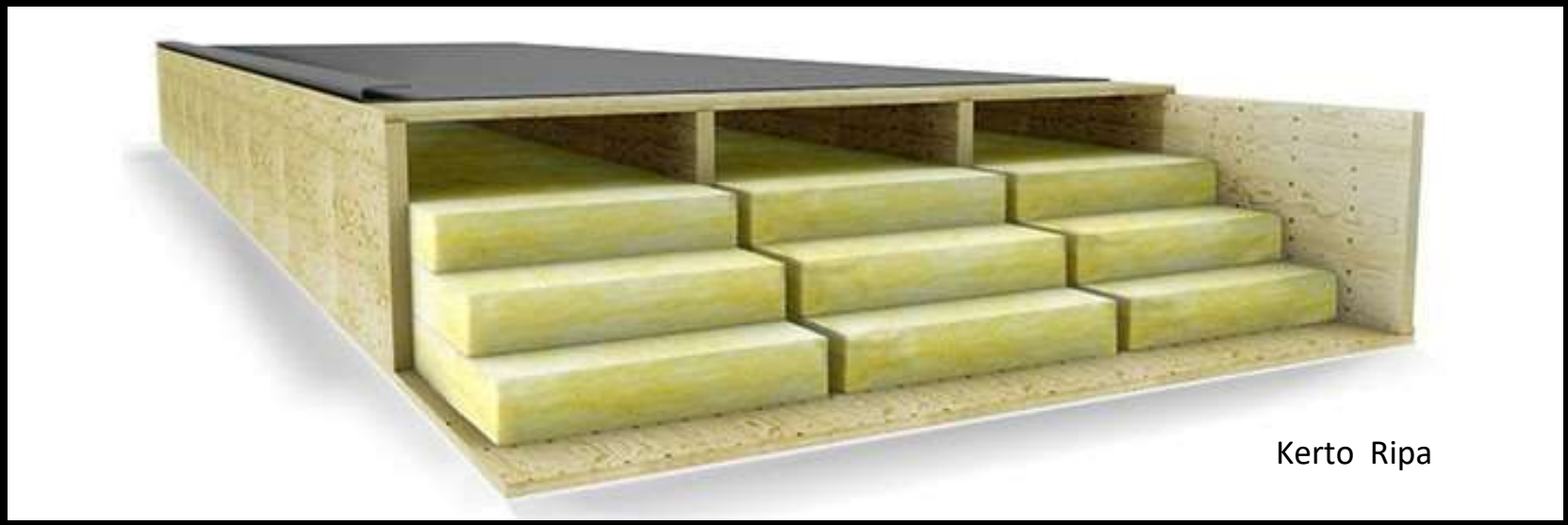
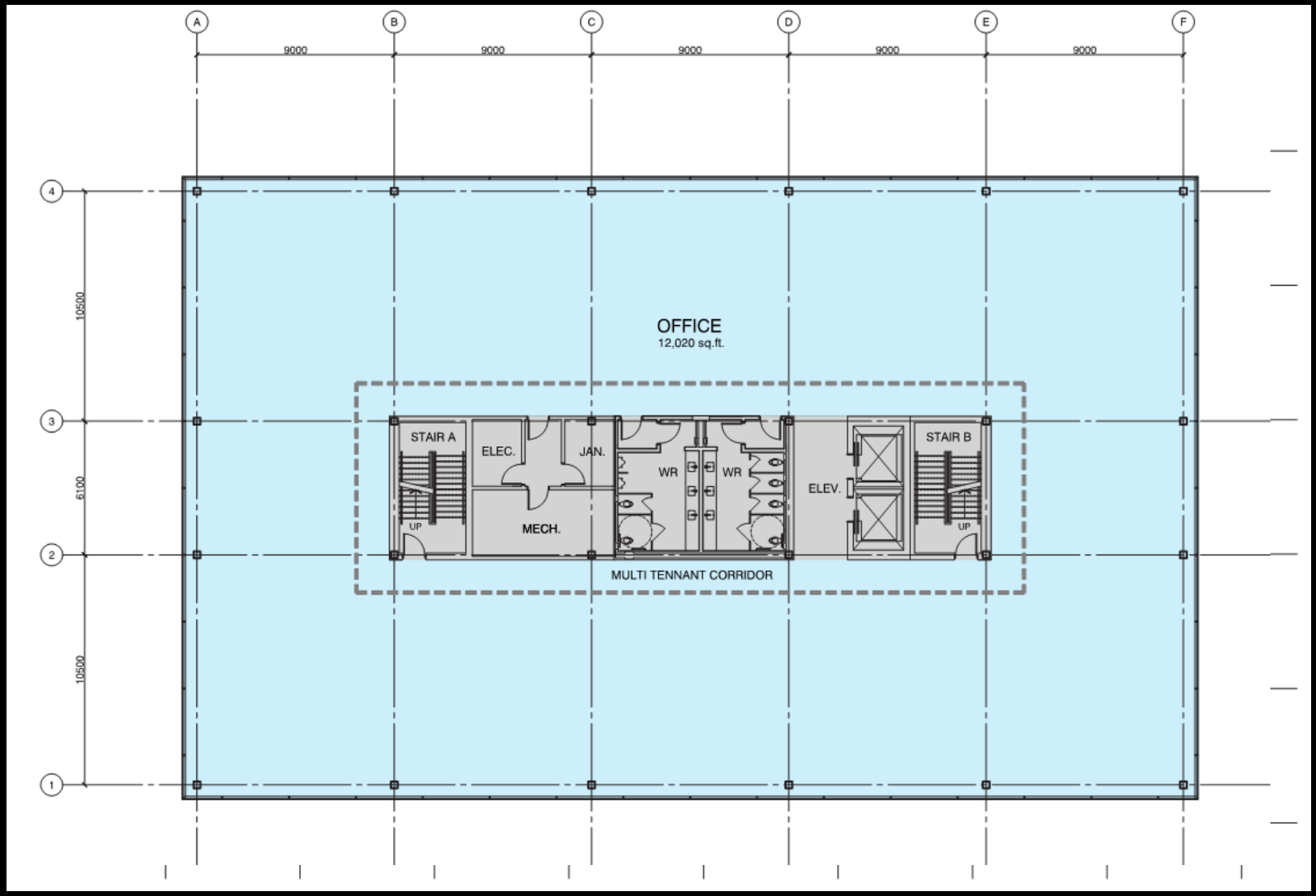


Kerto Ripa

Schneider Holz

Prototype office comparison



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Prototype office comparison

Results:

- Costs normalized to ~85,000sqft timber option
- Mostly “apple to apple” comparison
  - Did not consider schedule impact
  - Did not consider mechanical impact (exposed vs. concealed ducts)
  - Included ceiling and fireproofing for precast/steel option
- Timber option ~10% higher than precast-steel option
  - Only considered costs related to structure – not total construction costs

7 Storey office, Toronto

Image: Bogdan Newman Caranci Inc.

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PEIKKO DELTABEAM

Alternative Solution Strategy

- Above 6 storeys but not a tall building
- 2 hour rating required for structure
- Provision of firefighter's elevator and isolated elevator lobbies
- Pressurized exit stairs
- Total area, and area per compartment is lower than that allowed by code for 6-storey
- ~20% of soffit will be non-combustible; flame spread of combustible material ~1/3 of that allowed by code (49 for Black Spruce vs. 150)
- Emergency power provided for 1 hour instead of 30min.
- Sprinkler reliability will be increased – 2 standpipes

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14 Storeys, 80m

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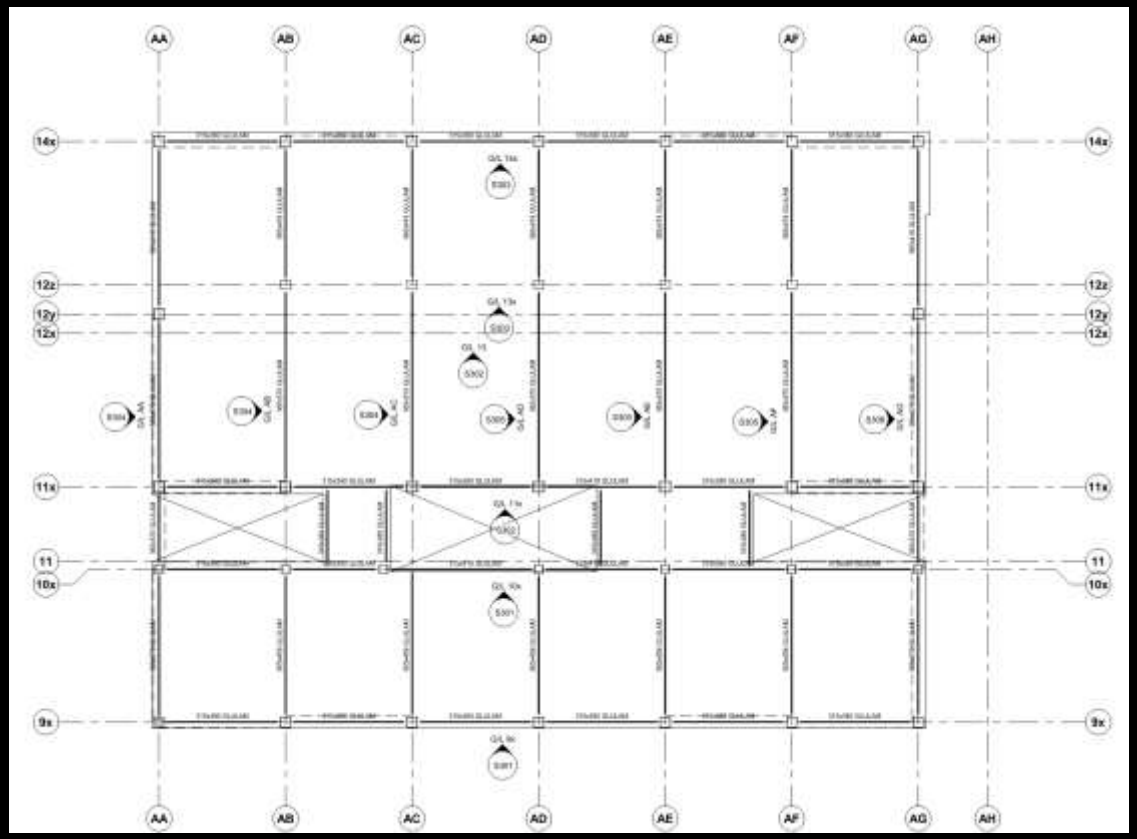
Academic Wood Tower



- Post and beam floor plans
- Simple connections throughout
- Columns 265x266 – 532x845

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Academic Wood Tower

- Optimal design optimizes deck.
- Bay spacing designed to maximize slab span
  - 175 Glulam slab required for inherent 2 hr fire resistance
- Mid span columns required to maintain floor to floor heights

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Academic Wood Tower

- Comparison with steel sizes
  - Typical beam depth:
    - Timber - 570
    - Steel - 460

$\Delta = 110$

  - Typical structural floor assembly
    - Timber - 795
    - Steel - 560

$\Delta = 235$

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Lateral System

- Wind controls design
- Seismic to be addressed through time-history analysis - strategy to reduce the need for ductility in compression/bearing connections

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Code compliance

- Current Canadian building codes only recognize up to 6 storeys (Quebec has special provisions for up to 12 storeys)
- Encapsulation is effective in pursuing alternative solution submission to meet objectives of code
    - 2020 NBCC will have provisions for 12-storey mass timber
- But if exposed timber is preferred, need to pursue alternate means
    - Enhanced sprinkler reliability/redundancy
    - Fire-fighting lobby/non-combustible core
    - Comparison with combustible material allowances in current non-combustible building code provisions
- FRR: NBCC vs. O86-14 Annex B

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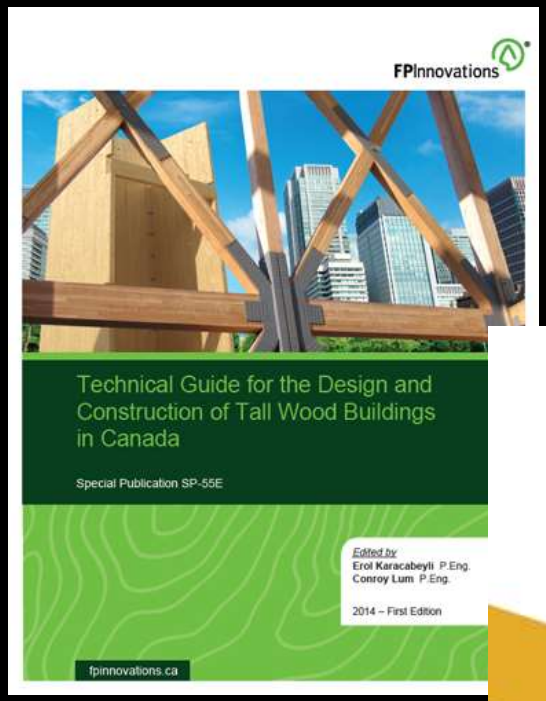
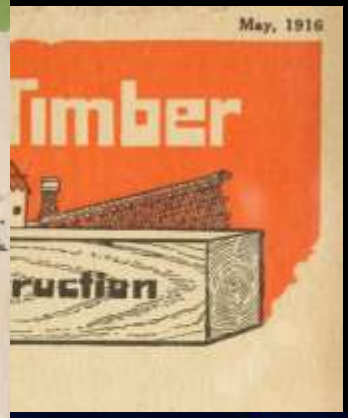
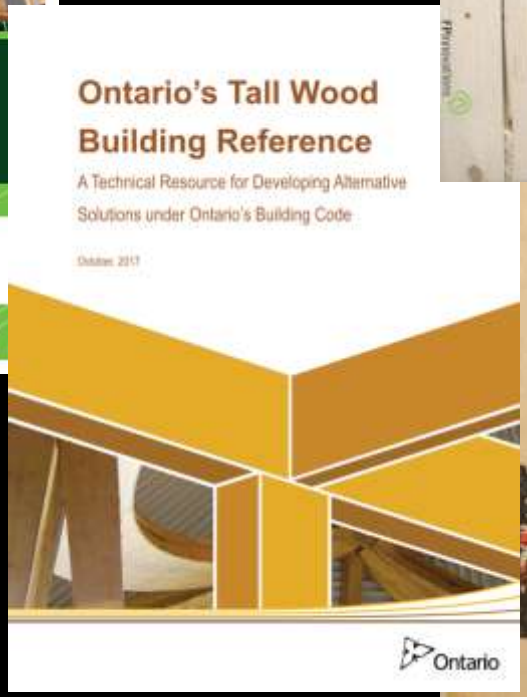
Design Resources







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Tallest multi-storey wood building in the world:

Fogong Temple Pagoda

circa 1056

67.3m