

PAST / CURRENT / FUTURE WORK RELATED TO FIRE PERFORMANCE OF TIMBER SYSTEMS

WoodRise Alliance – Fire Performance of Taller Timber Buildings

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FPInnovations

WOODRISE

OUTLINE

- Past work (more than 5 years ago)
- Current work (from the past ±5 years, until now)
- Future work (next 5-10 years)
- Conclusions

PAST CURRENT FUTURE

PAST WORK ON FIRE PERFORMANCE

WOOD-FRAME CONSTRUCTION (i.e., *LIGHT-WEIGHT WOOD*)

- Dominant system in North America for residential buildings
  - 1 to 4 storeys: 97% in Canada and 94% in United States in 2018
  - 5 and 6 storeys: strong increase from 26% in 2014 to 65% in 2018 (Canada)
- Numerous products available
  - Sawn lumber (dimensional lumber, 2x4, etc.)
  - Prefabricated wood I-joists
  - Metal plate wood trusses
  - Open web wood trusses
  - Structural composite lumber (LVL, PSL, LSL, OSL)

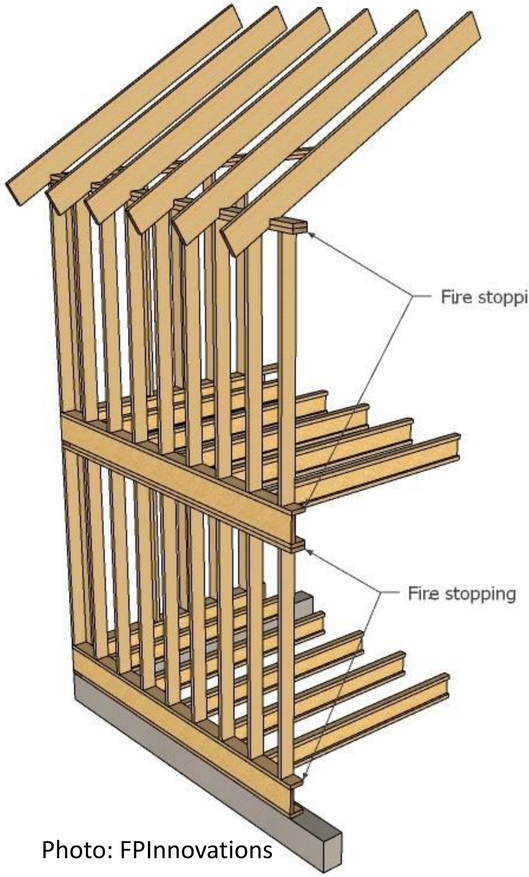


Photo: FPInnovations

Photo: cecobois

Photo: Louisiana-Pacific

Photo: Louisiana-Pacific

PAST WORK ON FIRE PERFORMANCE

WOOD-FRAME CONSTRUCTION (i.e., *LIGHT-WEIGHT WOOD*)

- Several assemblies have been tested to demonstrate their performance
  - Standard fire exposure (ISO 834-1, etc.)
  - Compartment fires / fire dynamics
- Tests allowed to evaluate the effects of various parameters
  - Gypsum boards: Type X (or F)
  - Resilient channels
  - Insulation: cellulose, fiberglass and mineral wool
- Wood-frame can provide significant fire resistance (> 2 hrs.)
  - Construction methods and details are fundamentals (e.g., joints, protection of service penetrations, etc.)
- Manufacturers and Associations have a long list of tested assemblies available to designers

Photo: cecobois

Photo: FPInnovations

PAST WORK ON FIRE PERFORMANCE

WOOD-FRAME CONSTRUCTION (i.e., *LIGHT-WEIGHT WOOD*)

- Calculation methods have been developed over the years
  - Component Additive Method (US and Canada)
    - Limited to 90 minutes
    - Time contributions are assigned to the assembly's components
  - EN1995-1-2:2004 – Section 5
    - Limited to 60 minutes
    - Methods for load-bearing function (charring) and separating function

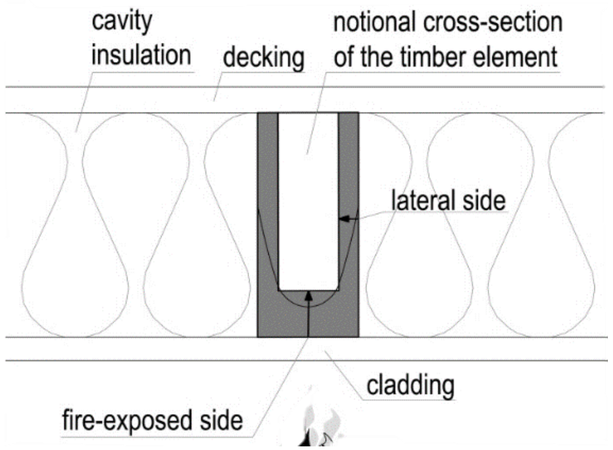


Table D-2.3.4.-B
Time Assigned to Gypsum Board Membranes on Fire-Exposed Side of Floors

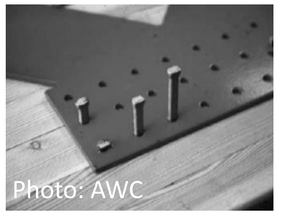
Description of Finish	Resilient Metal Channels[1]	Time, min	
		Floors with Wood or Steel Joists	Floors with Open-Web Steel Joists
12.7 mm Type X gypsum board	Spaced ≤ 400 mm o.c.[2]	25[3]	—
15.9 mm Type X gypsum board		40	—
12.7 mm Type X gypsum board	—	25[4]	25
15.9 mm Type X gypsum board		40[4]	40
Double 12.7 mm Type X gypsum board	Spaced ≤ 400 mm o.c.[5]	50[3]	—
Double 12.7 mm Type X gypsum board	Spaced at 600 mm o.c.[6]	45[3]	—
Double 15.9 mm Type X gypsum board	Spaced ≤ 600 mm o.c.[6]	60[3]	—

Photo: National Building Code of Canada 2015

PAST WORK ON FIRE PERFORMANCE

POST-&-BEAM / MASS TIMBER CONSTRUCTION

- Elements of large cross-section
  - Formerly used for large industrial buildings, now almost all buildings
  - Provide an inherent fire resistance
- Numerous products available
  - Sawn timber (*heavy timber*)
  - Glue-laminated timber
  - Structural composite lumber (LVL, PSL, LSL, OSL)
  - Cross-laminated timber (CLT)
- Connections using traditional fasteners
  - Steel or iron caps
  - Wood pegs and dovetails
  - Bolts, dowels, rivets, metal plates, split rings



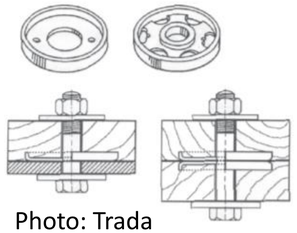


Photo: Trada

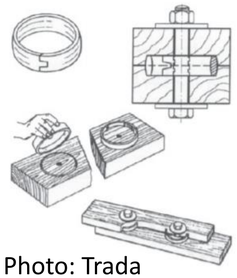


Photo: Trada

PAST WORK ON FIRE PERFORMANCE

POST-&-BEAM / MASS TIMBER CONSTRUCTION

- Several products have been tested to demonstrate their performance
  - Standard fire exposure (ISO 834-1, etc.)
  - Compartment fires / fire dynamics vs. exposed surfaces
- Tests allowed to evaluate the effects of various parameters
  - Charring rate – density, moisture content, heat exposure, thermal gradient
  - Thermal properties (density, specific heat and thermal conductivity)
  - Combustion properties (e.g., ignition, pyrolysis, mass loss, heat of combustion)
  - Performance of connections (bolts & dowels of short duration)
- Post-&-Beam / Mass timber can provide significant fire resistance (> 2 hrs.)
  - Easy to calculate based on charring rate
  - Connections may be the weak point (i.e., need to protect metallic fasteners)

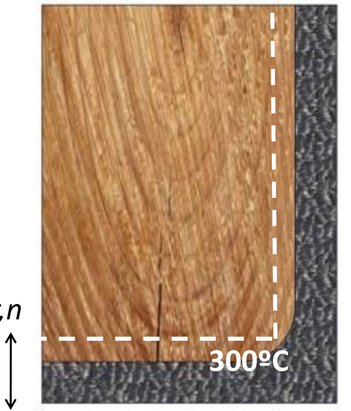
Image : SP Trätek

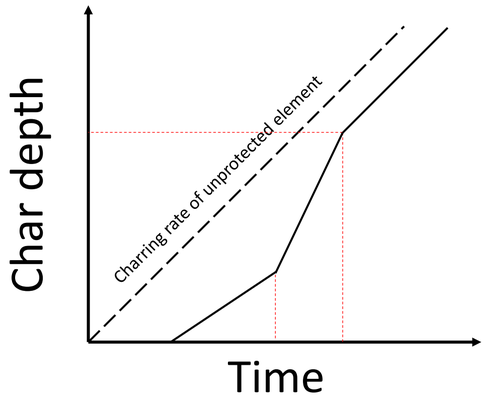
Photo: A.Frangi

PAST WORK ON FIRE PERFORMANCE

POST-&-BEAM / MASS TIMBER CONSTRUCTION

- Calculation methods have been developed over the years
  - National Building Code of Canada (Canada)
    - T. T. Lie equations (1977) applicable to glulam only
    - CSA O86 applicable to timber, glulam, SCL and CLT exposed to standard fire CAN/ULC S101
    - Generic charring rates, time contribution of gypsum boards
  - International Building Code (US)
    - T. T. Lie equations (1977) applicable to glulam and timber only
    - NDS and Technical Report 10 applicable to timber, glulam, SCL and CLT exposed to standard fire ASTM E119
    - Limited to 2 hrs.
    - Generic charring rates, time contribution of gypsum boards
  - EN1995-1-2:2004
    - Applicable to timber, glulam and LVL exposed to standard fire ISO 834-1
    - Generic charring rates, effect of gypsum boards
    - Provisions for connections (up to 1 hr.)
    - Provisions for advanced modeling



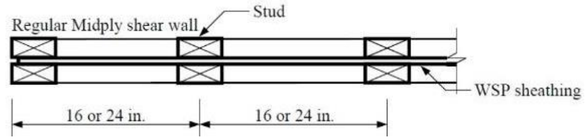


CURRENT WORK ON FIRE PERFORMANCE

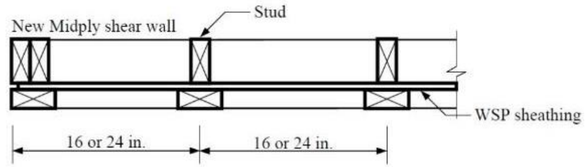
WOOD-FRAME CONSTRUCTION (i.e., *LIGHT-WEIGHT WOOD*)

- Evaluation of new materials and systems
  - Combustion properties, fire-resistance, etc.
- New insulation materials
  - Bio-based materials
  - Straw bale
- New membrane protection (vs. gypsum board)
  - Fiber cement board
  - Magnesium oxide (MgO) board
- New lateral load resisting systems (e.g., Mid-Ply)
  - Useful for mid-rise construction in high-seismic areas
  - Enhanced axial compression resistance
  - Enhanced acoustic performance

Photo: F.Blondin / CIRCERB



Original design

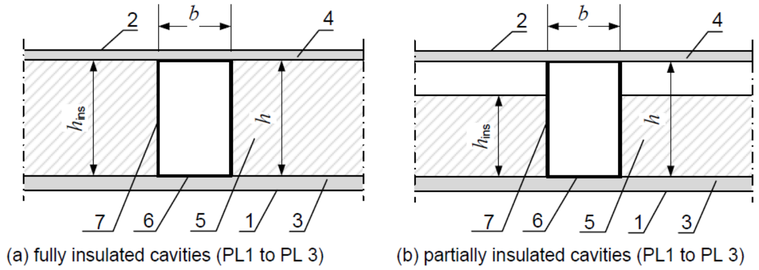


New design

CURRENT WORK ON FIRE PERFORMANCE

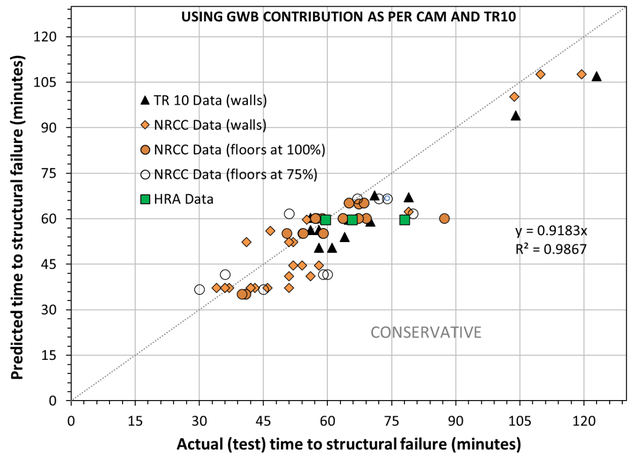
WOOD-FRAME CONSTRUCTION (i.e., *LIGHT-WEIGHT WOOD*)

- New load-bearing wall assemblies
  - Energy-efficient exterior walls
  - High-capacity walls using staggered studs
  - Walls using engineered wood-based studs
  - Walls with enhanced acoustical performance
- Refinement of calculation methods
  - Refinement of EN1995-1-2 methods (for 2025-2027)
    - Thermal properties of insulation and gypsum boards
    - Review of effect of insulation on stud onset of charring
    - And many more!
  - Revised methods in the US (industry standard coming soon by AWC)
  - Review of applicability of CSA O86 method to wood-frame assemblies



(a) fully insulated cavities (PL1 to PL 3) (b) partially insulated cavities (PL1 to PL 3)

Photo: Draft EN1995-1-2:2020



CURRENT WORK ON FIRE PERFORMANCE

POST-&-BEAM / MASS TIMBER CONSTRUCTION

- Cross-laminated timber (CLT)
  - Adhesive performance (heat delamination)
- Mechanically-laminated timber (MLT)
  - Nail-laminated timber (NLT) – charring rate and effect of gaps
  - Dowel-laminated timber (DLT) – charring rate
  - Screw-laminated timber (SLT) – charring rate
  - Review of applicability of current methods to MLT
- Connections
  - Innovative fasteners (e.g., self-tapping screws) and beam-column assemblies
  - Calculation methods (> 60 min)
- Encapsulation methods
  - Single, double and triple layers of gypsum board
  - Alternative/Innovative materials (vs. gypsum board)

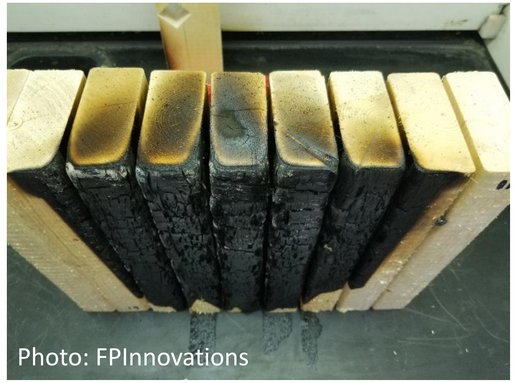


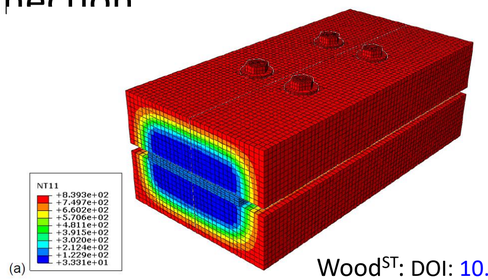
Photo: FPInnovations

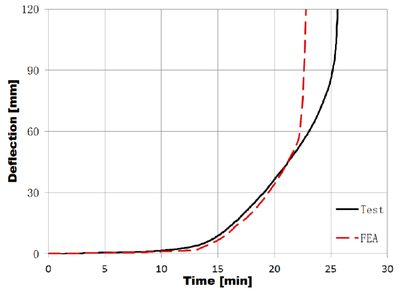
Photo: M. L.-Gagnon / CIRCERB

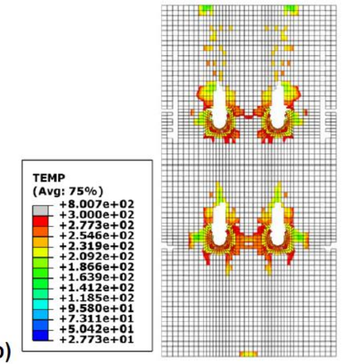
CURRENT WORK ON FIRE PERFORMANCE

ALL TIMBER CONSTRUCTION

- Compartment fires
  - Exposed surfaces vs. Fire dynamics vs. Fuel burn-out
  - Effect from “non-delaminating” products
- Fire safety engineering
  - General principles applicable to timber construction
- Thermo-structural models
  - Mostly sequential coupling (vs. 2-way coupling)
  - Single elements
  - Limited types of connection





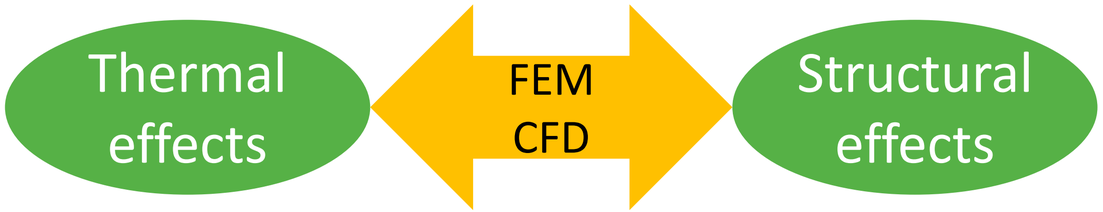


Wood[ST]: DOI: 10.1061/(ASCE)ST.1943-541X.0002524

FUTURE WORK ON FIRE PERFORMANCE

ALL TIMBER CONSTRUCTION

- Fire safety engineering
  - General principles applicable to timber construction
  - Fire dynamics in large open-space floor design (e.g., offices)
  - Charring rate (vs. those for standard fire exposure)
  - Thermal properties (vs. those for standard fire exposure)
  - Timber contribution in advanced modeling (e.g., CFD)
  - Shift to performance-based design
    (let go of “combustibility” classification)
- Thermo-structural models
  - 2-way coupling (vs. sequential)
  - Systems (vs. single elements)
  - Modern connections (vs. traditional)



FUTURE WORK ON FIRE PERFORMANCE

ALL TIMBER CONSTRUCTION

- Rehabilitation post-fire
  - Sprinkler discharge / water damage
  - Structural rehabilitation methods
- Connections
  - Standard fire tests on modern connections
- Hybrid systems – calculation methods
  - Steel-timber
  - Concrete-timber
  - Others? (Aluminum?)
- Fire safety of facades
  - Test methods
  - Risk mitigation strategies

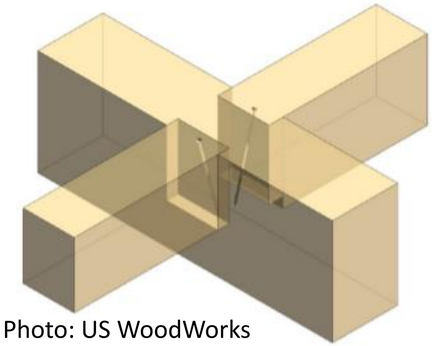


Photo: US WoodWorks

Photo: MTC Solutions

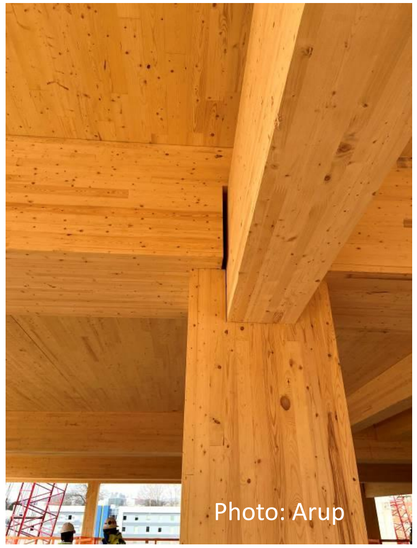


Photo: Arup

Photo: https://www.structuremag.org/

Photo: RISE

CONCLUDING REMARKS

- Wood-frame construction is very well-understood
  - Numerous standard fire tests to demonstrate Code compliance
  - Calculation methods have proven to be efficient over the past decades
  - New systems and wood-based materials are being developed and need to be evaluated
- Post-&-Beam construction / Mass timber construction is relatively well-understood
  - Mass timber is a viable and safe option in areas traditionally dominated by steel and concrete
  - Significant efforts in past years to demonstrate Code compliance…and beyond Code compliance…
  - Applicability of existing calculation methods have proven to be efficient
  - Still major drawbacks from Code perspective, building officials, fire fighters and insurance
- Many key aspects are still misunderstood by design community, building officials, etc.
  - Education/dissemination to wider audience is key for societal acceptance
- Performance-based design is gaining popularity
  - Several design properties and methods remain to be studied and developed
  - Advanced modeling is strongly needed

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GET IN TOUCH

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