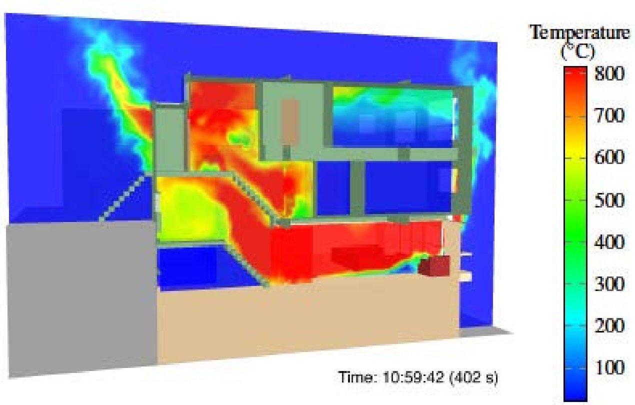
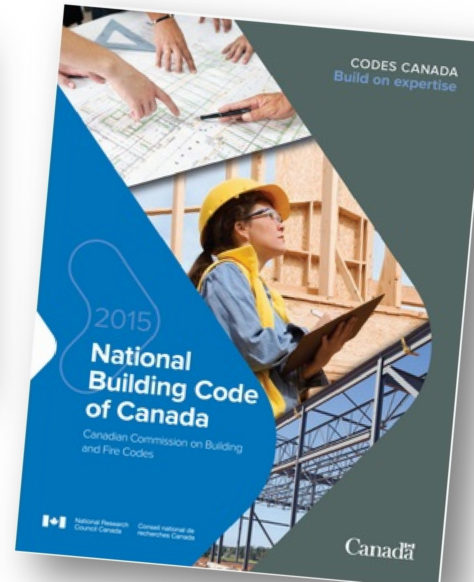
Wood Construction and Part 3 of the NBC

Past Successes and Future Opportunities





Charlottetown, PE and Fredericton, NB

September 14th - 15th, 2016

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HOUSEKEEPING

Cell Phones

Fire / Emergencies

Questions

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AGENDA

- Wood Construction and the NBC/NFC
- Past Successes (Alternative Solutions)
- Future Opportunities
- Available Tools and Calculations
- Questions

WHO WE ARE

ESTABLISHEED 1987

Fredericton & Halifax

- Fire Protection Engineering
- Building & Fire Code Consulting
- Fire Safety Planning
- Forensic Investigations

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Where we Work

Provinces include:

Newfoundland

Nova Scotia

Prince Edward Island

New Brunswick

Quebec

Ontario

Manitoba

Saskatchewan

Alberta

British Columbia

Territories include:

Nunavut

Northwest Territories

States include:

Maine

Pennsylvania

Maryland

New York

Massachusetts

New Hampshire

Georgia

Florida

Washington DC

Illinois

California

North Carolina

Seattle

International:

Barbados | United Kingdom

Bermuda | Germany

Brief Biography

Ben Coles, M.Sc.Eng., MBA, P.Eng., PE
Project Coordinator

- Fire Protection Engineering
- Building & Fire Code Consulting
- 13 years experience

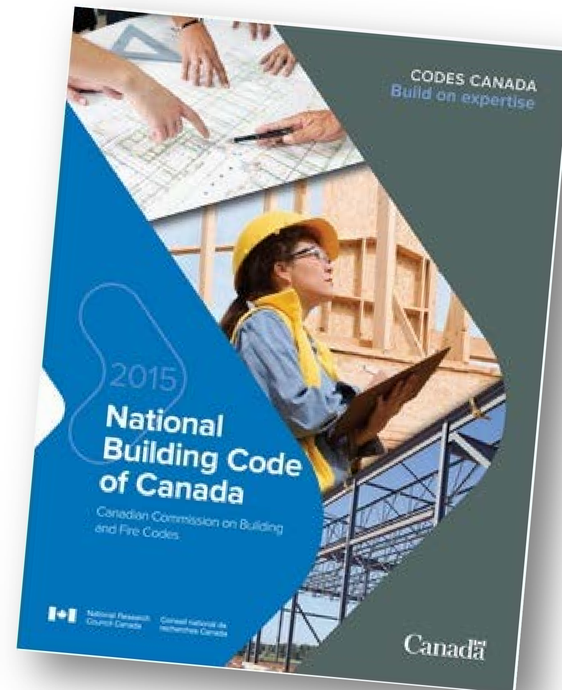
B.Sc. Mechanical Engineering (UNB 2003)
M.Sc. Fire Protection Engineering (WPI 2009)
MBA in Engineering Management (UNB 2011)

WOOD CONSTRUCTION IN THE NBC

NBC CHANGES

Six-storey wood structures in 2015 NBC

- Safety
- Limitations are being lifted



Sprinkler/FAS buildings just as safe with wood construction
Non-combustible = better FLS is being challenged

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WOOD CONSTRUCTION IN THE NBC

NBC CHANGES

Six-storey wood structures in 2015 NBC

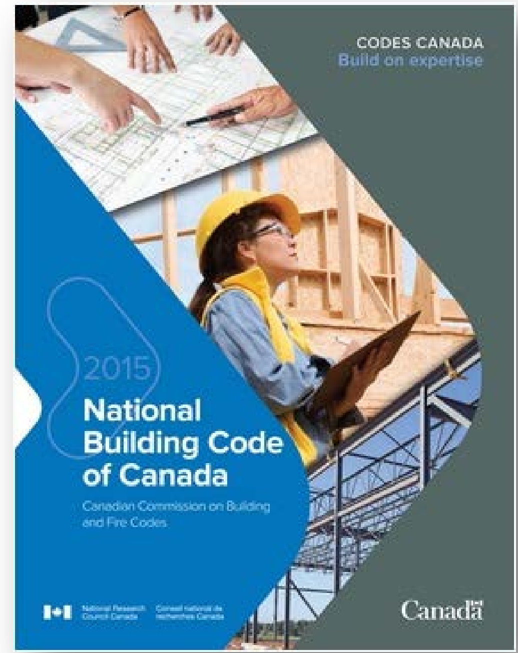
- Group C and D occupancies
- Changes address:
  - Sprinkler requirements
  - Area limitations

Wood Construction in the NBC

APPENDIX D
Fire-Performance Ratings

- Wood/Steel Framed Walls, Floors/Roofs
  - New materials and assemblies
  - Component Additive Method (CAM)
  - Time assignments for materials

- Fire test reports published by the NRC
  - Available online



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Wood Construction in the NBC

APPENDIX D

Fire-Performance Ratings

- Expansion and addition of tables in Appendix D-2.3.

Wood Construction in the NBC

Time Assigned for Contribution of Wood-Framed or Cold-Formed-Steel-Framed Walls

Description of Frame	Time, min	
	Loadbearing Walls	Non-Loadbearing Walls
Wood studs spaced ≤ 400 mm o.c.	20	
Wood studs spaced ≤ 600 mm o.c.	15	
Cold-formed-steel studs spaced ≤ 400 mm o.c.	10	
Cold-formed-steel studs spaced ≤ 600 mm o.c.	10	–

Time Assigned for Contribution of Wood or Steel Frame of Floors and Roofs

Description of Frame		Time, min
Type of Assembly	Structural Members	
Floor[1]	Wood joists, wood I-joists, wood trusses and cold-formed-steel joists spaced ≤ 600 mm o.c. Open-web steel joists with ceiling supports spaced ≤ 400 mm o.c.	10[2]
Roof	Wood joists spaced ≤ 400 mm o.c.	10
	Open-web steel joists with ceiling supports spaced ≤ 400 mm o.c.	10
	Wood truss assemblies [metal-plate-connected] spaced ≤ 600 mm o.c.	5

Wood Construction in the NBC

Table D-2.3.4.-A
Time Assigned to Protective Membranes on Fire-Exposed Side of Wood-Framed and Cold-Formed-Steel-Framed Walls

Description of Finish	Time, min	
	Loadbearing Walls	Non-Loadbearing Walls
11.0 mm Douglas Fir plywood phenolic bonded	–	10(1)
14.0 mm Douglas Fir plywood phenolic bonded	–	15(1)
12.7 mm Type X gypsum board	25(2)	25
15.9 mm Type X gypsum board	40(2)	40(3)
Double 12.7 mm Type X gypsum board(4)	50	80

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)	—

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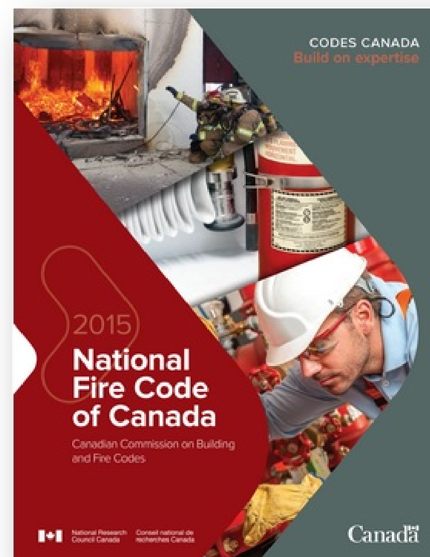
WOOD CONSTRUCTION IN THE NFC

SUBSECTION 5.6.3.
Add't Requirements for C & D Occupancies

- Additional measures during construction
  - Smoking restrictions
  - Signage requirements
  - Disposal specifications
  - Enhanced fencing, boarding and barricades



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Wood Construction in the NFC

SUBSECTION 5.6.3.
Firefighting Specifications

- Adequate water supply
  - Once combustible materials on site
- Hydrant Access
  - Clearly marked
  - Clearance not less than 2 m

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Wood Construction in the NFC

SUBSECTION 5.6.3.
Construction Access

- Stairway requirements
  - In accordance with NBC dimensions
  - Extended as each floor installed
  - Maintained during demolition

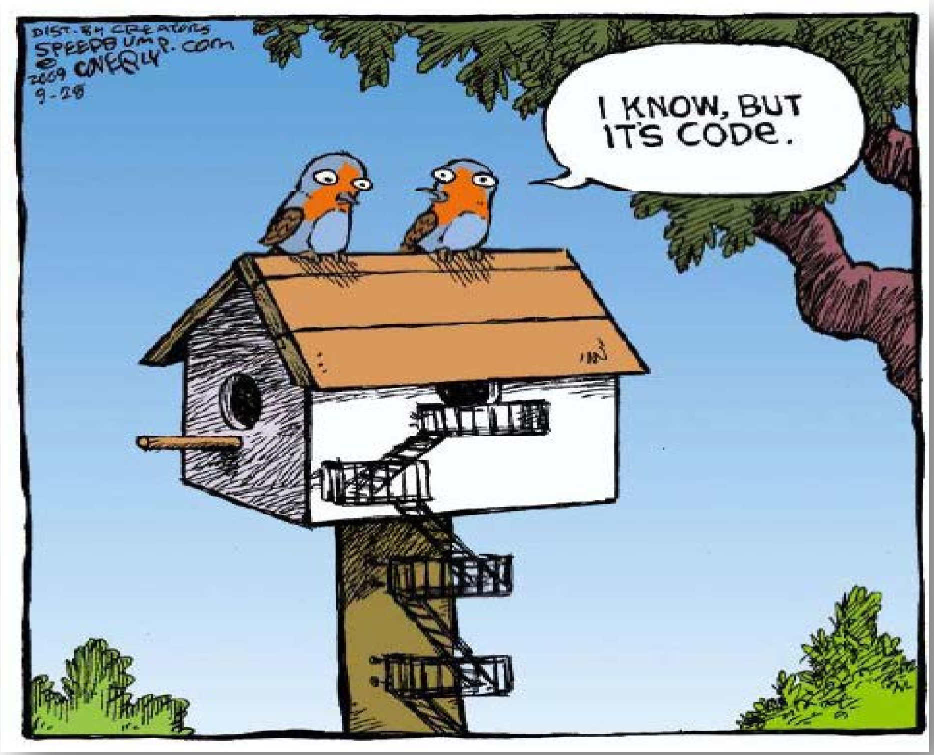
AGENDA

- Wood Construction and the NBC/NFC
- Past Successes (Alternative Solutions)
- Future Opportunities
- Available Tools and Calculations
- Questions

What is an Alternative Solution?

- The two methods of compliance are described in Article 1.2.1.1.
- a.) complying with the applicable **Acceptable Solutions** in Division B, or
- b.) using **Alternative Solutions** that will achieve at least the **minimum level of performance** required by Division B in the areas defined by the objectives and functional statements attributed to the applicable **Acceptable Solutions**.

What is an Alternative Solution?



What is an Alternative Solution?

- Increasing design complexity
- Is it practical to comply (eg. historic sites … Province House)

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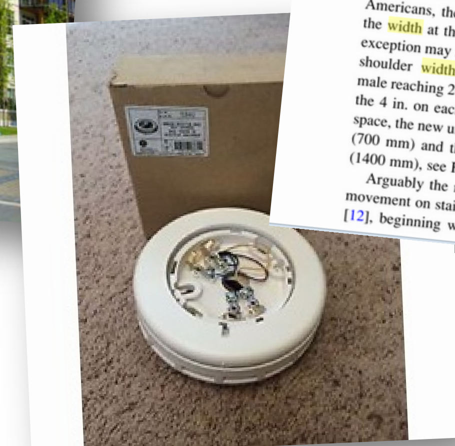
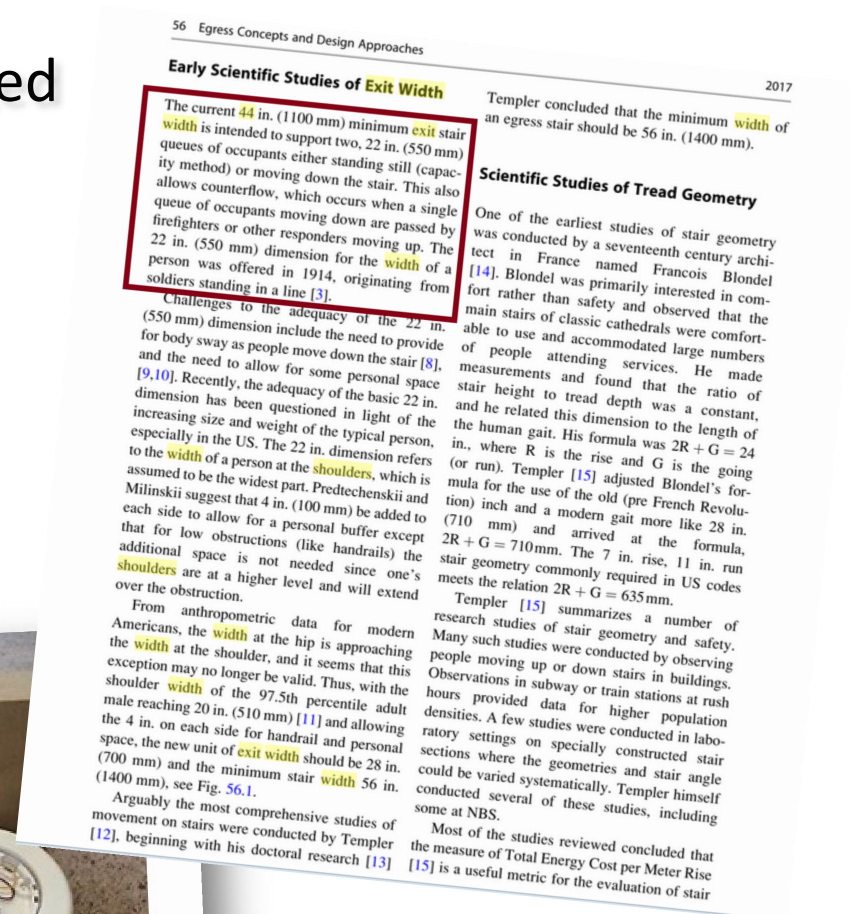
What is an Alternative Solution?

- Conventions are being challenged





Early Scientific Studies of Exit Width

The current 44 in. (1100 mm) minimum exit stair width is intended to support two, 22 in. (550 mm) queues of occupants either standing still (capacity method) or moving down the stair. This also allows counterflow, which occurs when a single queue of occupants moving down are passed by firefighters or other responders moving up. The 22 in. (550 mm) dimension for the width of a person was offered in 1914, originating from soldiers standing in a line [3].

Challenges to the adequacy of the 22 in. (550 mm) dimension include the need to provide for body sway as people move down the stair [8], and the need to allow for some personal space [9,10]. Recently, the adequacy of the basic 22 in. dimension has been questioned in light of the increasing size and weight of the typical person, especially in the US. The 22 in. dimension refers to the width of a person at the shoulders, which is assumed to be the widest part. Predtechenskii and Milinskii suggest that 4 in. (100 mm) be added to each side to allow for a personal buffer except that for low obstructions (like handrails) the additional space is not needed since one's shoulders are at a higher level and will extend over the obstruction.

From anthropometric data for modern Americans, the width at the hip is approaching the width at the shoulder, and it seems that this exception may no longer be valid. Thus, with the shoulder width of the 97.5th percentile adult male reaching 20 in. (510 mm) [11] and allowing the 4 in. on each side for handrail and personal space, the new unit of exit width should be 28 in. (700 mm) and the minimum stair width 56 in. (1400 mm), see Fig. 56.1.

Arguably the most comprehensive studies of movement on stairs were conducted by Templer [12], beginning with his doctoral research [13]

Templer concluded that the minimum width of an egress stair should be 56 in. (1400 mm).

Scientific Studies of Tread Geometry

One of the earliest studies of stair geometry was conducted by a seventeenth century architect in France named Francois Blondel [14]. Blondel was primarily interested in comfort rather than safety and observed that the main stairs of classic cathedrals were comfortable to use and accommodated large numbers of people attending services. He made measurements and found that the ratio of stair height to tread depth was a constant, and he related this dimension to the length of the human gait. His formula was $2R + G = 24$ in., where R is the rise and G is the going (or run). Templer [15] adjusted Blondel's formula for the use of the old (pre French Revolution) inch and a modern gait more like 28 in. (710 mm) and arrived at the formula, $2R + G = 710$ mm. The 7 in. rise, 11 in. run stair geometry commonly required in US codes meets the relation $2R + G = 635$ mm.

Templer [15] summarizes a number of research studies of stair geometry and safety. Many such studies were conducted by observing people moving up or down stairs in buildings. Observations in subway or train stations at rush hours provided data for higher population densities. A few studies were conducted in laboratory settings on specially constructed stair sections where the geometries and stair angle could be varied systematically. Templer himself conducted several of these studies, including some at NBS.

Most of the studies reviewed concluded that the measure of Total Energy Cost per Meter Rise [15] is a useful metric for the evaluation of stair

What is an Alternative Solution?

LIMITATIONS AND CHALLENGES

- Higher level of engineering for design and enforcement teams
- Often greater engineering effort to prepare and review
- Change in occupancy may trigger reanalysis / modifications
- Limited by **available time and budgets**

- **City of Charlottetown Alternate Compliance wrt Wood**

Yesterday's Alternative (Performance) → Today's Prescriptive (Code)

Past Successes

THE STONE JUG – ALTERNATIVE SOLUTION
Carbonear, NL (2015)

- New A-2 (Assembly) occupancy
- Part 3; 3 storey w/ basement level
- 3 levels Interconnected – "mini atrium"
- Noncombustible construction required
- Wood construction w/ masonry loadbearing
- Analyses included:
  - Review of fire loss statistics
  - Timed egress calculations / fire models

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Past Successes

THE STONE JUG – ALTERNATIVE SOLUTION

Carbonear, NL (2015)

- Required upgrades:
  - Increased FRR for floor fire separation
  - New sprinkler system to NFPA 13
  - Occupant loading restrictions
  - Fire safety plan
  - FAS with enhanced smoke detection

- Demonstrated acceptable level of fire safety

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Past Successes

GAHAN HOUSE – ALTERNATIVE SOLUTION

Charlottetown, PE

- Two storey addition
- Four storeys total w/ 280 sq.m
- Heavy Timber w/ Masonry exterior
- NBC requires NC construction
- Alternative Solution
- Did not fit within COC A.C's
- CFD Simulation / TEA

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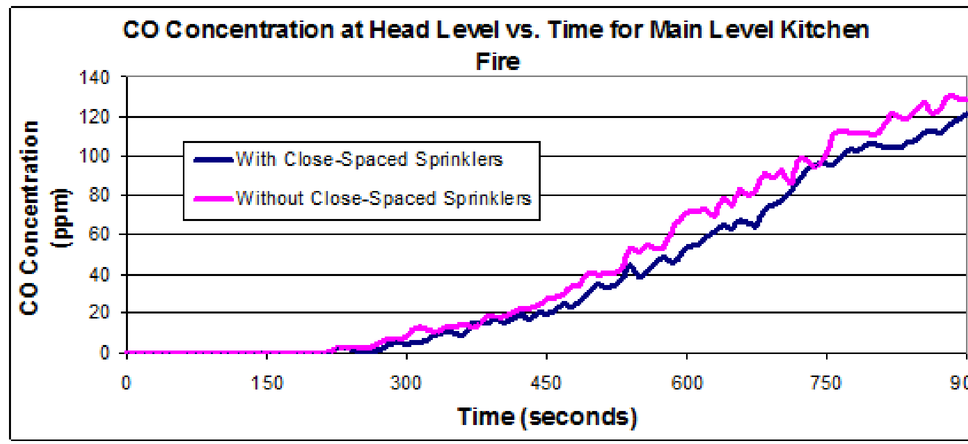
PAST SUCCESSES

GAHAN HOUSE – ALTERNATIVE SOLUTION

Charlottetown, PE

- TEA Considerations:
  - Temperature/Heat
  - CO Levels
  - Visibility Threshold



Total Evacuation Times (seconds) for Design Fire Scenario No. 1(Main Level Kitchen)				
	Activation Time	Delay Time	Time for Passage	Total
With Addition	108	180	114	402
Without Addition	108	180	95	383
Added Time with Addition				19

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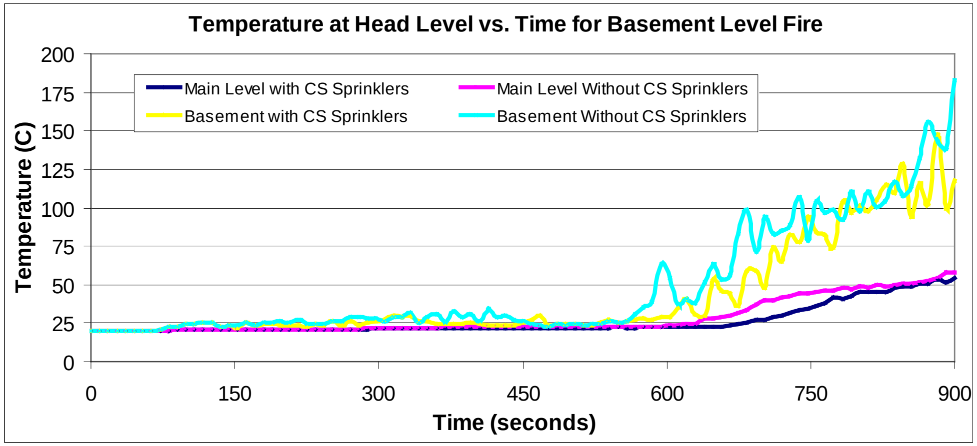
PAST SUCCESSES

GAHAN HOUSE – ALTERNATIVE SOLUTION

Charlottetown, PE

- Detection Calculations
  - Smoke detector and sprinkler activation calculations
  - Fire Dynamics Simulator (FDS)



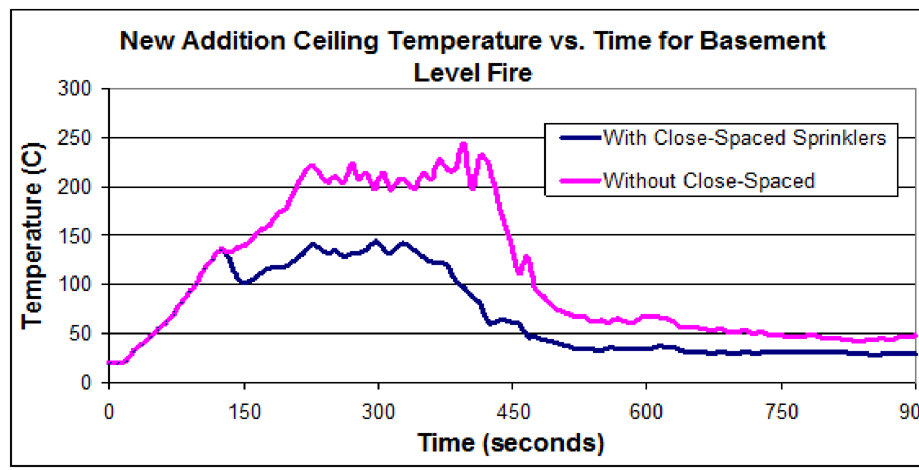
Past Successes

GAHAN HOUSE – ALTERNATIVE SOLUTION Charlottetown, PE

- Heat Transfer Analysis
  - 1-Dimensional Nodal Finite Difference Method

$$T_i^{p+1} = Fo\,(T_{i+1}^{p} + T_{i-1}^{p}) + (1-2\,Fo)\,T_i^{p}$$

$$Fo = \frac{\alpha\,\Delta t}{(\Delta x^2)}$$



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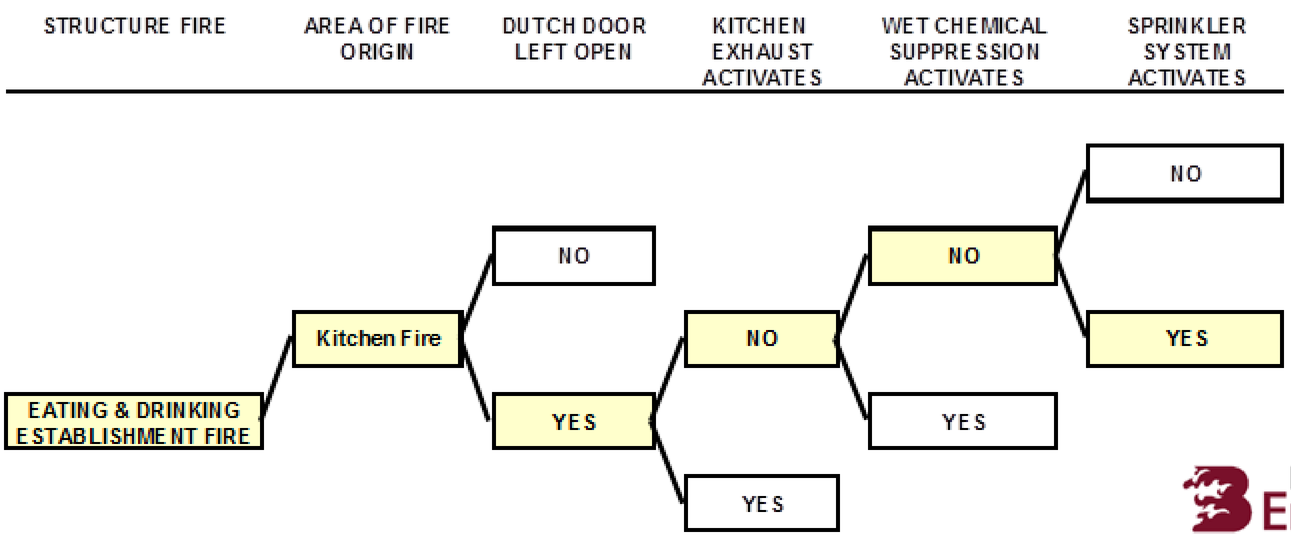
Past Successes

GAHAN HOUSE – ALTERNATIVE SOLUTION

Charlottetown, PE

- Design fire scenarios
  - Main level kitchen area
  - Basement level kitchen preparation area



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Past Successes

GAHAN HOUSE – ALTERNATIVE SOLUTION

Charlottetown, PE

Results

- Ignition temperature not reached
- Tenable conditions during evacuation time (ASET vs RSET)
- Sensitivity analysis

Required Measures

- Quick response sprinklers
- Water curtain approach at specific locations
- Cover wood assemblies with Type X thermal barrier
- Fire safety plan per NFC 2.8.

Past Successes

KAYS BUILDING – Charlottetown, PE

- Renovation of Historic 1872 Building
- New mixed Group E / D occupancies
- Wholesaler until 2009 (F-2)
- Four storeys w/ basement level
- 820 sq.m prior to Welsh Owen add’t
- Addition of A-2 Assembly on L1

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Past Successes

KAYS BUILDING – Charlottetown, PE

- BSI and NRC methods calc methods
- Estimate FRR for timber structures
- Beams / joists heated on 4 sides
- Fire penetration time @ timber deck

$$R = 2.54 f B \left[4 - 2\left(\frac{B}{D}\right)\right]$$

$$t = \zeta\left(\frac{d}{\beta}\right)$$

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Structure	Dimension (mm x mm) (w x d)	Heavy Timber[1] (Yes/No)
All Columns	200 x 250	Yes
Beam B1	250 x 280	Yes
Beam B2	150 x 150	No
Beam B3	225 x 225	Yes
Beam B4	250 x 290	Yes
Beam B5	250 x 350	Yes
Beam B6	300 x 290	Yes
Beam B7	240 x 290	Yes
Beam B8	280 x 330	Yes
Beam B9	300 x 355	Yes
Beam B10	300 x 330	Yes
Beam B11	290 x 355	Yes
2" x 8" Joist	38 x 235	No
3" x 8" Joist	64 x 184	No
3" x 12" Joist	64 x 285	No

1) As defined by the dimensional requirements of NBC Article 3.1.4.7.

Table A1: Summary of First Floor Timber Structures

Structure	Dimension (mm x mm) (w x d)	Heavy Timber[1] (Yes/No)
All Columns	175 x 175	No
Beam B1 (Built-up)	150 x 150 (top and bottom)	No
Beam B2 (Built-up)	175 x 175 (top and bottom)	No
Beam B3 (Built-up)	150 x 150 (top) 200 x 200 (bottom)	No
Beam B4 (Built-up)	175 x 175 (top) 200 x 200 (bottom)	No
Beam B5 (Built-up)	175 x 175 (top) 200 x 200 (bottom)	No
Beam B6 (Built-up)	190 x 175 (top) 175 x 200 (bottom)	No
Beam B7 (Built-up)	175 x 175 (top) 225 x 200 (bottom)	No
Beam B8 (Built-up)	175 x 200 (top) 150 x 175 (bottom)	No
Beam B9 (Built-up)	200 x 225 (top) 2 – 140 x 140 (bottom)	No
Beam B10 (Built-up)	2 – 25 x 150 (stacked - top) 150 x 200 (middle) 2 – 125 x 125 (bottom)	No
2" x 8" Joist	38 x 235	No
2" x 10" Joist	38 x 184	No

1) As defined by the dimensional requirements of NBC Article 3.1.4.7.

Table A4: Summary of Third Floor Timber Structures

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Past Successes

KAYS BUILDING – ALTERNATIVE SOLUTION
Charlottetown, PE

- Beams and columns estimated > 45 min FRR w/ LVL covering
- Acceptable level of fire and life safety
- Check against NFPA 101A FSES

Required Measures

- Enhanced early warning (smoke detection)
- Enhanced sprinkler system
- Fire safety plan
- Occupancy type restriction / re-evaluation with A-2

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Past Successes

YELLOWBELLY – ALTERNATIVE SOLUTION

St. John’s, NL

- Four storey with Basement
- New Group A-2 (Assembly)
- Originally built in 1725 … one of North Americas oldest
- 1846 Fire and survived Great Fire of 1892

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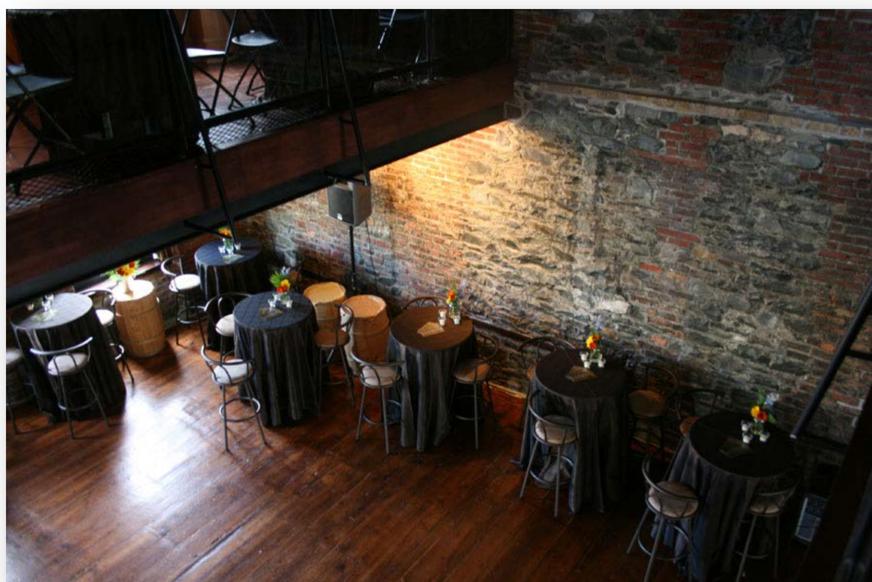
Past Successes

YELLOWBELLY – ALTERNATIVE SOLUTION

St. John's, NL

- Performance-based solution
- Computational Fluid Dynamics (CFD) simulations



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Past Successes

YELLOWBELLY – ALTERNATIVE SOLUTION
St. John's, NL

- Critical section of wooden beams (similar for columns)

$$kZ\frac{BD^2}{6} = \propto \frac{bd^2}{6}$$

- Fire endurance time

$$t_f = \begin{Bmatrix} 2.54ZB\left(4 - \frac{2B}{D}\right)\ 4 - sided\ exposure \\ 2.54ZB\left(4 - \frac{B}{D}\right)\ 3 - sided\ exposure \end{Bmatrix}$$

$$Z - \begin{Bmatrix} 1.3 \\ 0.7 + \frac{0.3}{R} \end{Bmatrix} R < 0.5$$

$$R \geq 0.5$$

Past Successes

YELLOWBELLY – ALTERNATIVE SOLUTION

St. John's, NL

- Timed Exit Analysis

Third Level	301	Lounge Area No 1	144.5	1.2	121
	302	Lounge Area No 2	40.4	1.2	34
	303	Bar	27.0	1.2	23
				Subtotal	178
				Available Exit Capacity	235

- Considerations:
  - Temperature/Heat Exposure
  - Visibility Threshold

- Worst-case Travel Distance = 16 m
- Travel Speed = 1.19 m/s
  50% to be conservative = 0.595 m/s
- Cueing Time = 112 s
- Travel + Cueing = 139 s
- Activate Smoke Detection = 12 s
- Total time = 151 s
- +++ Pre-movement times

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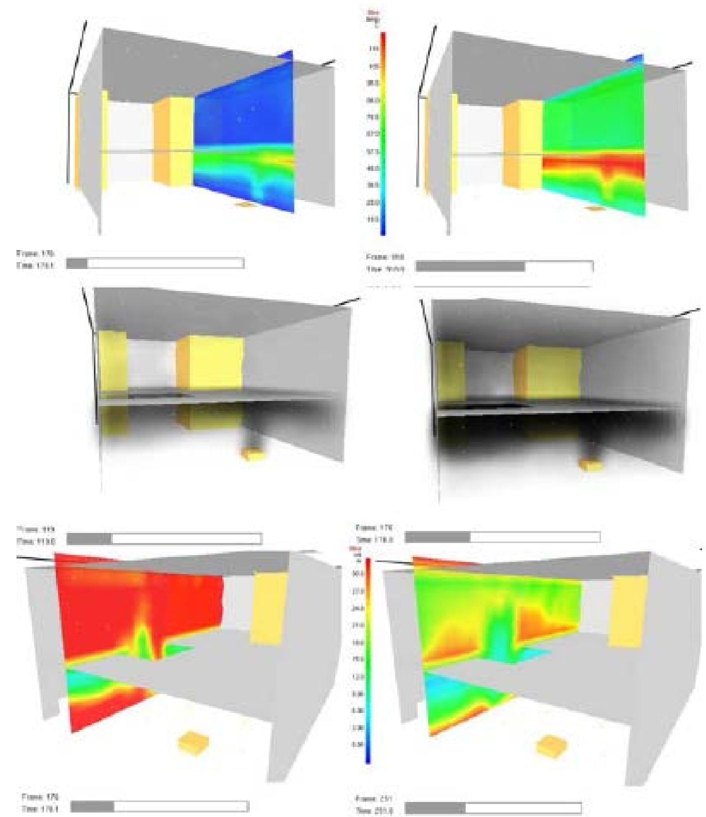
Past Successes

YELLOWBELLY – ALTERNATIVE SOLUTION

St. John’s, NL

- Worst case design fires
  - Third storey dining area
  - Second storey kitchen
- Fire growth scenarios by broad range of fuels
- Sensitivity Analysis



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Past Successes

YELLOWBELLY – ALTERNATIVE SOLUTION

St. John’s, NL

- Proposed conditions will not compromise safety
- Required measures:
  - Passive protection for columns
  - Limitations on occupant loading
  - Fire safety plan

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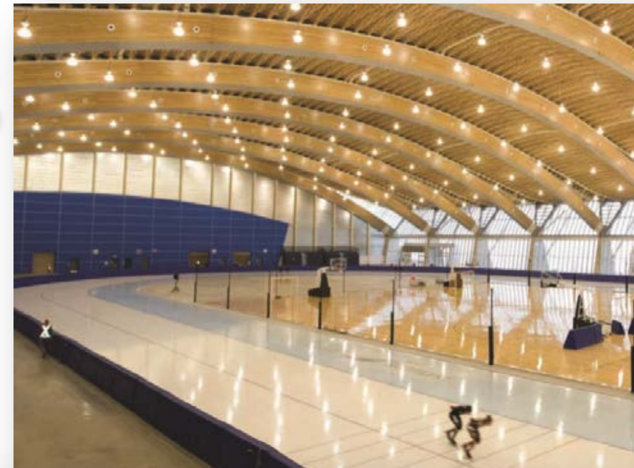
Past Successes (of Others)

2010 VANCOUVER OLYMPICS
The Richmond Olympic Oval



- Example of an alternative solution
- Conventional light frame lumber
- Sprinkler lines
- Mineral wool insulation
- FDS Software

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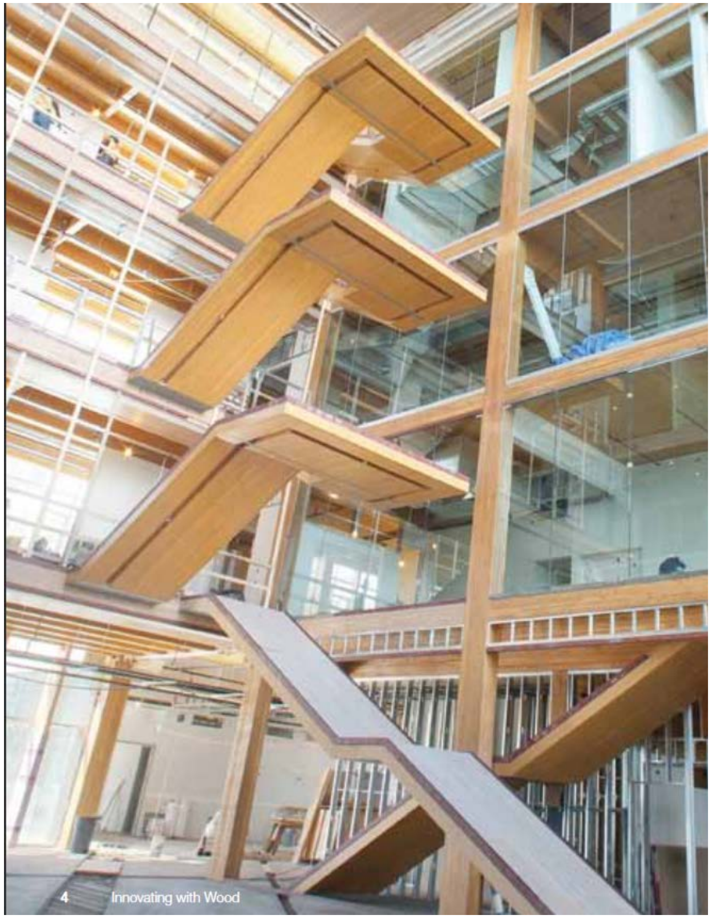
Past Successes (of Others)

UBC Campus

- Earth Sciences Building (GHL)
- BioEnergy Research (LMDG)



AGENDA

- Wood Construction and the NBC/NFC
- Past Successes (Alternative Solutions)
- Future Opportunities
- Available Tools and Calculations
- Questions

FUTURE OPPORTUNITIES

MULTI STOREY WOOD CONSTRUCTION

- Six storeys is new to the NBC - coming for many provinces
- Eight storeys for next step for NBC??? 13 being evaluated
- Fire safety of timber lining and cladding materials
- Fire resistance of pre-stressed timber frames and walls

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Future Opportunities

The Evolution of Building Codes

- Fire Statistics / Loss History effecting change
- Increased reliance and acceptance of alternative solutions
- Ever changing technologies
- Less Federal $$ for research and development
- Leveraging **industry partners** to drive innovation

Available Tools and Calculations


PERFORMANCE OF
CLT ASSEMBLIES IN FIRE

Noureddine Benichou, Ph.D., National Research Council Canada
Christian Dagenais, Eng., M.Sc., FPInnovations

May 28, 2015

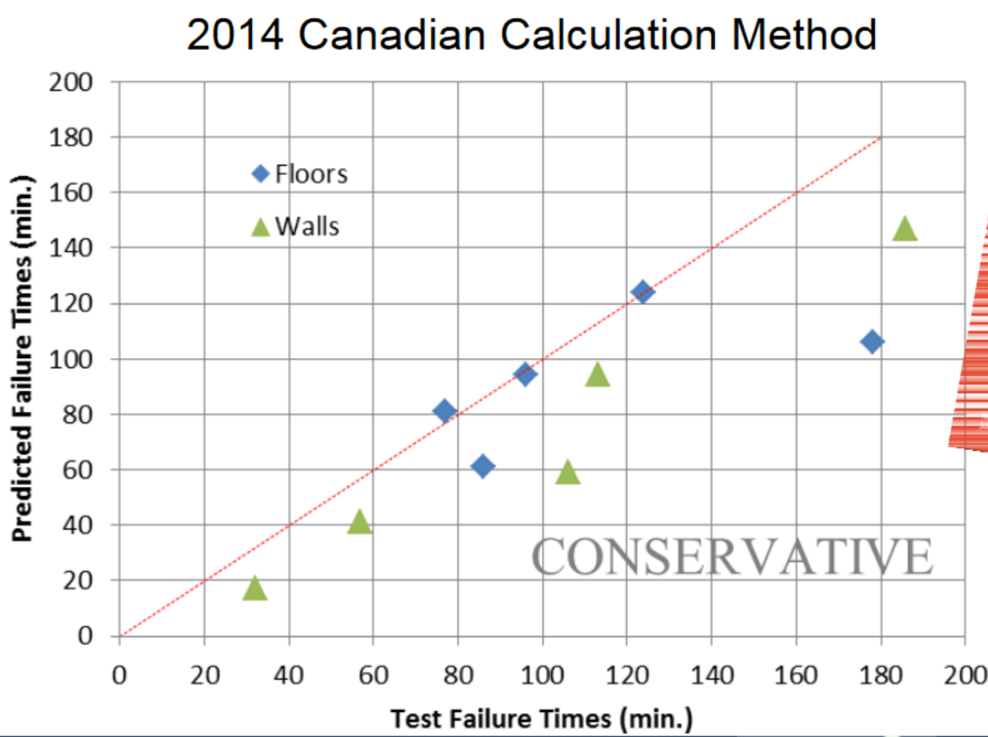
NRC·CNRC

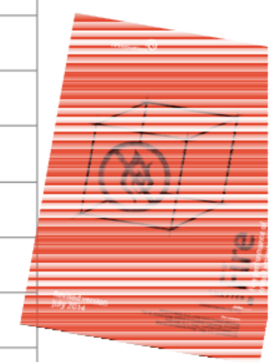
FPInnovations

Available Tools and Calculations

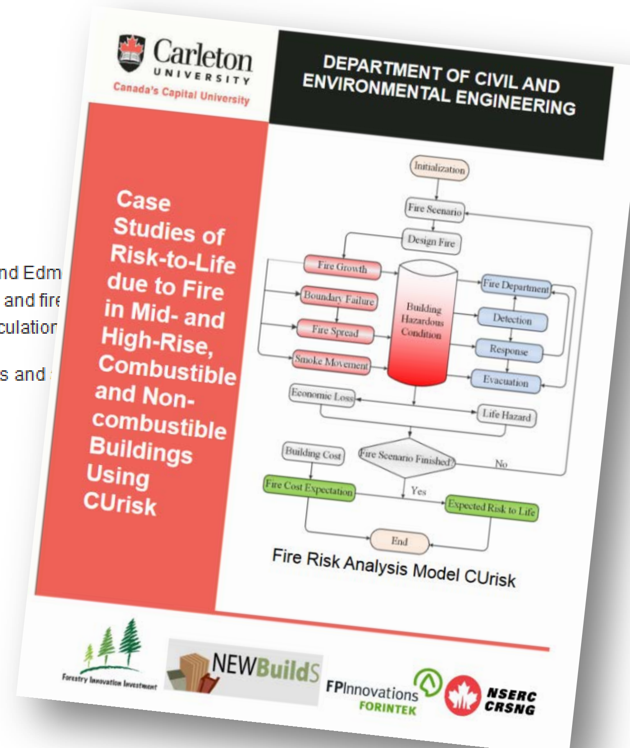
Available Tools and Calculations

CLT FR Calculation Methods





AVAILABLE TOOLS AND CALCULATIONS

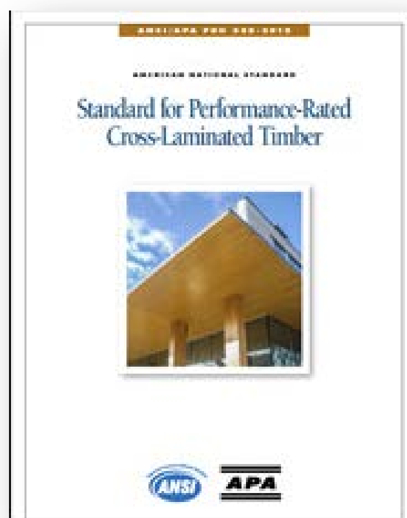


FUTURE OPPORTUNITIES

CONTEMPORARY RESEARCH

CLT – Cross Laminated Timber

ANSI/APA PRG 320-2011 Standard for Performance-Rated Cross-Laminated Timber



Available Tools and Calculations

FIRE RATING CALCULATIONS

Structural resistance of CLT floor assembly 90 minutes of exposure

- Factored Load

$$w_{f(fire)} = D_L + 0.5L_L = (5.1) + 0.5 \cdot (20.5) = 15.4\ \mathrm{kN/m^2}$$

$$m_{f(fire)} = \frac{w_{f(fire)}\, l^2}{8} = \frac{(15.4)\cdot(4730)^2}{8} = 43.1\ \mathrm{kNm/m}$$

- Char depth
  - Charring rate = 0.65 mm/min

$$d_{char} = \beta t = (0.65\ \mathrm{mm/min}) \cdot (90\ \mathrm{min}) = 58.5\ \mathrm{mm}$$

  - Remaining cross-section

$$D_{char} = D - d_{char} = (38\ \mathrm{mm} \times 5) - 58.5 = 131.5\ \mathrm{mm}$$

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Available Tools and Calculations

FIRE RATING CALCULATIONS

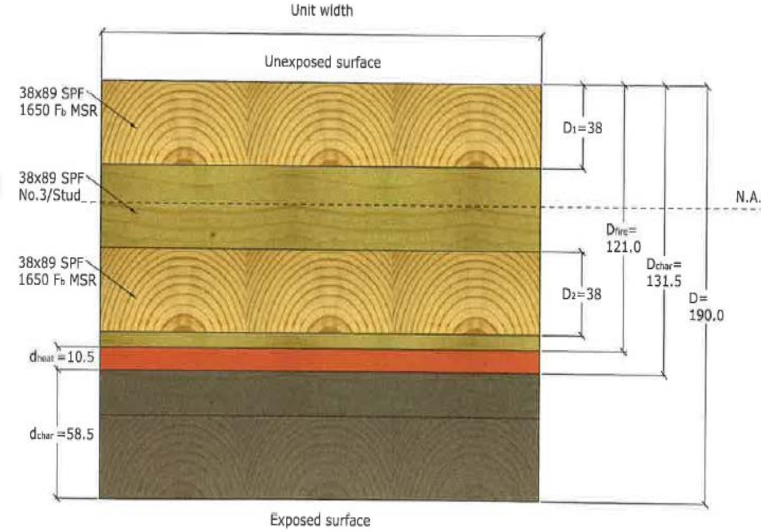
Structural resistance of CLT floor assembly after 90 minutes of exposure

- Effective residual cross-section
  - Heated zone for floors = 10.5 mm
  - Remaining cross-section

$$D_{fire} = D_{char} - d_{heat} = 131.5\text{ mm} - 10\text{ mm} = 121.5\text{ mm}$$

- Location of neutral axis

$$\bar{y} = \frac{\sum_i \tilde{y}_i D_i}{\sum_i D_i} = \frac{\left[\left(\frac{38}{2}\right)\cdot(38) + \left(\left(\frac{38}{2}\right) + (2\times 38)\right)\cdot(38)\right]}{(38+38)} = 57.0\text{ mm}$$



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AVAILABLE TOOLS AND CALCULATIONS

FIRE RATING CALCULATIONS

Structural resistance of CLT floor assembly after 90 minutes of exposure

- Moment of inertia

$$I=\sum_i \frac{B\,D_i^{\,3}}{12}+\sum_i B\,D_i\,d_i^{\,2}=\left[\frac{(1000)\cdot(38)^3}{12}+\frac{(1000)\cdot(38)^3}{12}\right]+$$

$$\left[(1000)\cdot(38)\cdot\left(57.0-{}^{38}\!/_{2}\right)^2+(1000)\cdot(38)\cdot\left(38+38+{}^{38}\!/_{2}-57.0\right)^2\right]=119\times10^6\ \mathrm{mm}^4$$

- Moment resistance

$$M_r=\varphi\,F_b\,S\,K_{Zb}\,K_L=(1.0)\cdot(27.5)\cdot\left(2.09\times10^6\right)\cdot(1.0)\cdot(1.0)=57.5\ \mathrm{kNm/m}$$

AVAILABLE TOOLS AND CALCULATIONS

ONLINE RESOURCES

Canadian Wood Council technical manuals

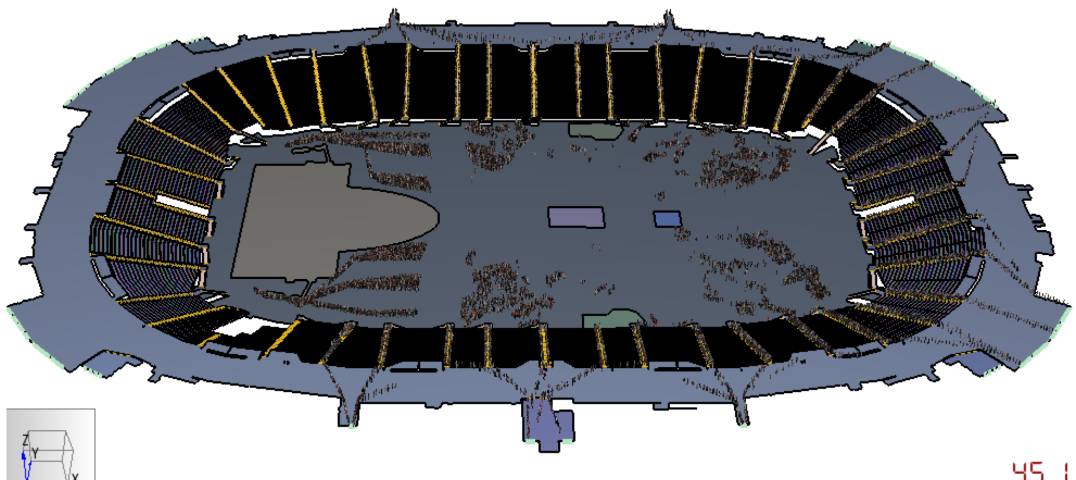
Available Tools and Calculations

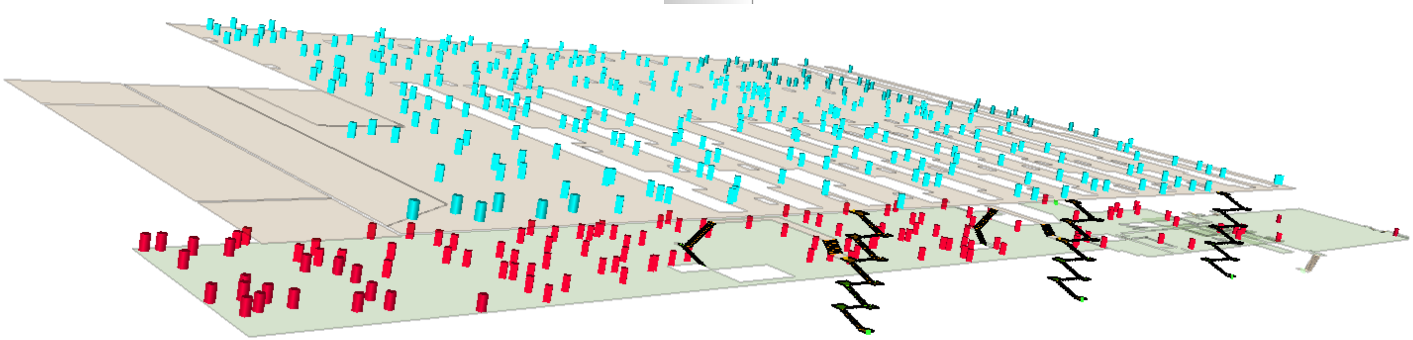
PATHFINDER

Pathfinder

Movement Simulation

- Evacuation
- Animated results





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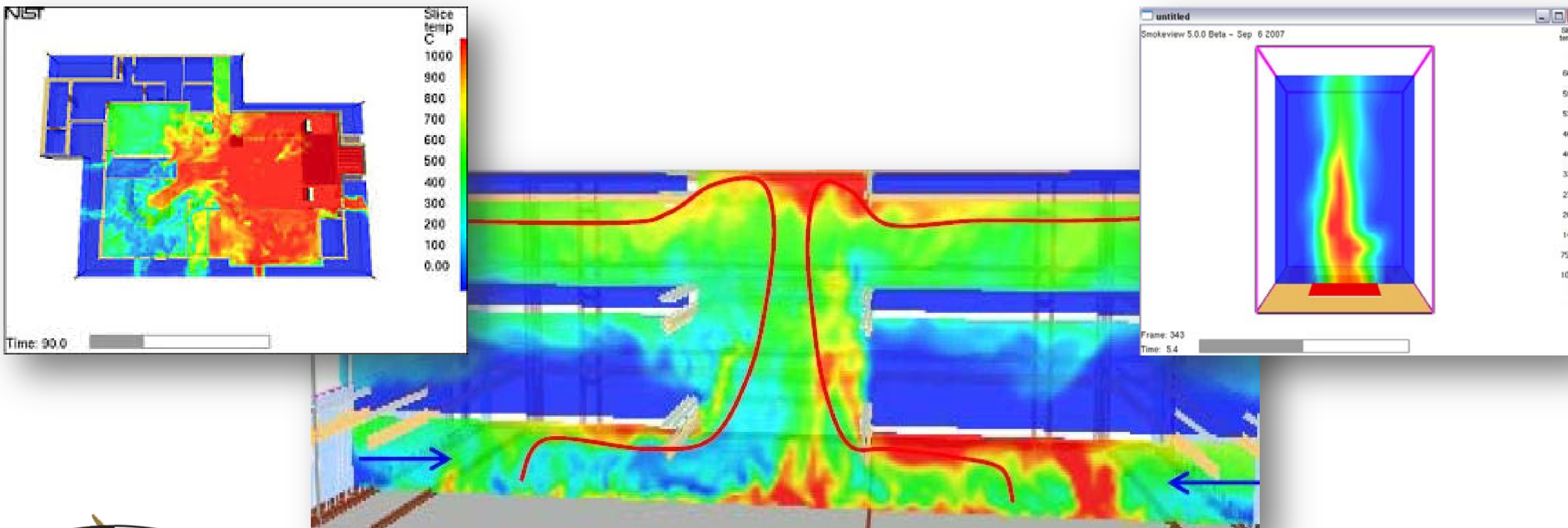
Available Tools and Calculations

FIRE DYNAMICS SIMULATOR (FDS)

- Computational fluid dynamics of wood construction
- Fire cause and origin investigations



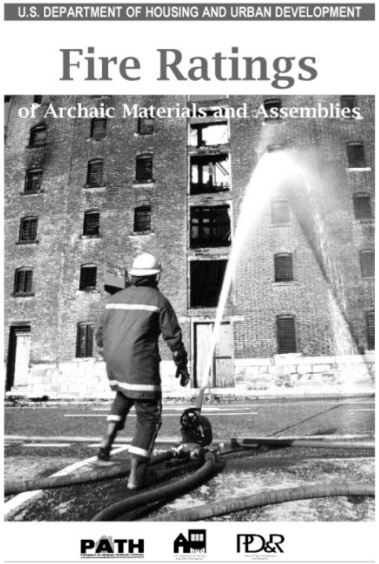
AVAILABLE TOOLS AND CALCULATIONS

ARCHAIC HANDBOOK

Test FRR in existing construction

Table 1.3.2
Wood Frame Walls, 4" (100 mm) to less than 6" (150 mm) thick

Item Code	*Thick-ness*	*Construction Details*	*Performance*		*Reference Number*			*Notes*	*Rec Hours*
			Load	*Time*	*Pre BMS 92*	*BMS*	*Post-BMS 92*		
W-4-W-1	4"	2" x 4" stud wall; 3/16" CAB; no insulation; design A	35 min	10 min	-	-	4	1–10	1/6
W-4-W-2	4 1/8"	2" x 4" stud wall; 3/16" CAB; no insulation; design A	38 min	9 min	-	-	4	1–10	1/6
W-4-W-3	4 3/4"	2" x 4" stud wall; 3/16" CAB and 3/8" gypsum board face (both sides); design B	62 min	64 min	-	-	4	1–10	1
W-5-W-4	5"	2" x 4" stud wall; 3/16" CAB and 1/2" gypsum board face (both sides); design B	79 min	>90 min	-	-	4	1–10	1



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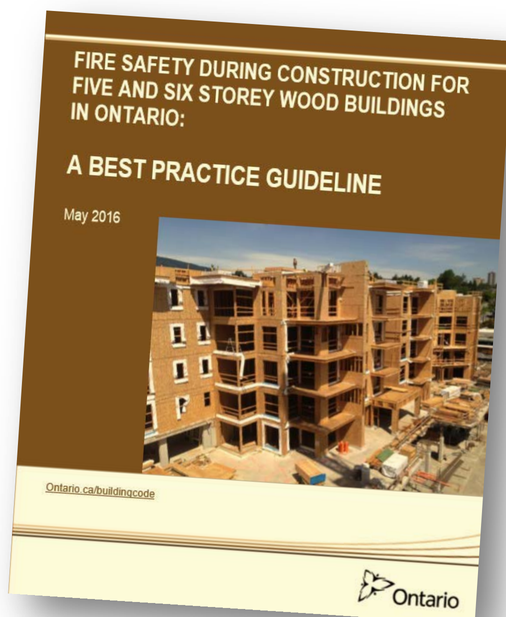
Available Tools and Calculations

ONTARIO BEST PRACTICE GUIDELINE

Canadian Wood Council Collaboration with Ontario Ministries and Stakeholders

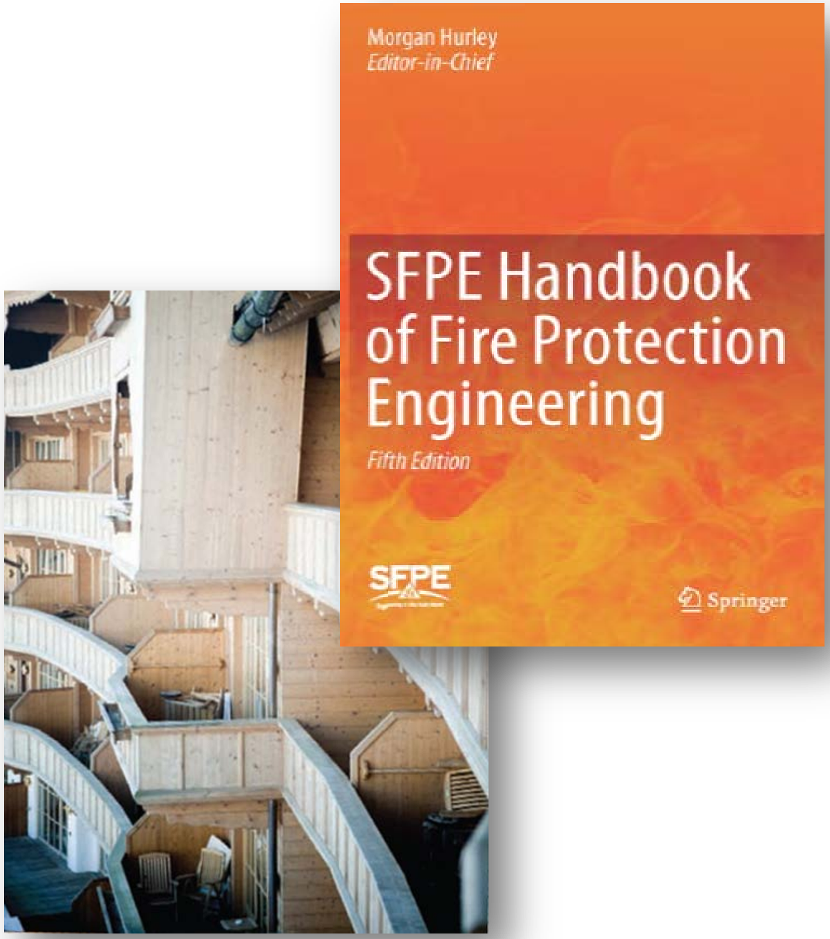


Available Tools and Calculations

GUIDANCE FROM OTHER COUNTRIES

SFPE Handbook

- Guidelines in Europe
- Fire resistance of heavy timber



AVAILABLE TOOLS AND CALCULATIONS

Guidance from other countries

NFPA 557

Sprinklers / FAS present = construction type / FRR less significant

Table D.5(a) Rate of Fires (per year) Relative to Numbers of Buildings and Square Feet of Floor Space for Educational Complexes

Statistic	Rate
Fires per year	7,700
Thousands of buildings with at least 1000 ft²	[illegible]
Millions of square feet in buildings with at least 1000 ft²	8,388
Fires per thousand buildings per year	25.0
Fires per million square feet per year	0.91

Table D.5(b) Percentage of Fires with Flame Spread Beyond Room of Origin and Estimated Number of Fires Used as Basis for Percentages

	No Sprinklers		Sprinklers Present	
Type of Construction	No Detectors	Detectors Present	No Detectors	Detectors Present
Fire resistive	7% 12,140	3% 9,878	4% 1,017	2% 4,293
Protected, noncombustible	7% 5,544	4% 4,753	2% 689	3% 2,826
Unprotected, noncombustible	9% 4,040	4% 3,071	1% 251	2% 652
Protected, ordinary	8% 8,215	4% 6,025	5% 737	3% 2,786
Unprotected, ordinary	16% 6,169	8% 3,962	4% 308	5% 858
Protected, wood frame	18% 2,794	7% 1,595	5% 263	2% 647
Unprotected, wood frame	30% 5,108	13% 1,692	11% 179	3% 313

Sources: NFPA analysis of NFIRS; NFPA survey; Energy Information Administration Commercial Buildings Energy Consumption Surveys, building characteristics tables.

Note: These are 1989–1998 fires reported to U.S. municipal fire departments and so exclude fires reported only to federal or state agencies or industrial fire brigades. These years are used because they are the latest for the type of construction that is included in the coded elements. All estimates are based on at least 200 reported fires (raw, not projected estimates) in the 10 years with the indicated data known. Buildings and floor space are estimated from 1992, 1995, and 1999 surveys, using linear interpolation and extrapolation for years before or between the three years when surveys were taken, resulting in a final formula of {(7 × 1992 estimate) + [1.5 × (1995 estimate + 1999 estimate)]}/10.

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QUESTIONS

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