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<https://doi.org/10.4224/20374231>

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# **Structural Fire Performance of Unprotected Floor Assemblies Used in Single Family Houses**

**Ottawa Fire 2010 Symposium  
20 May 2010**

**Noureddine Bénichou, Joseph Su, Alex Bwalya, Gary Lougheed,  
Bruce Taber, Patrice Leroux**

# Outline

- Background
- Objectives
- Experimental Program and Results
- Key Findings

# Background

- Advent of new materials and innovative products and systems used in construction of houses
- Need to better understand performance and impact on occupants life safety under fire conditions
- Canadian codes and materials commissions requested NRC to undertake this research
- Title of the project “Fire Performance of Houses”



# Objectives

To better understand

- the factors that affect life safety of occupants
- the impact of residential construction products and systems on life safety of occupants

in single-family houses in the event of a fire

# Research on Fire Performance of Houses

- Research studies include a number of phases
- Phase I – basement fires with unprotected floor assemblies
  - To study impact on the ability of occupants on upper storeys to escape in the event of a basement fire
    - fire development
    - smoke movement & tenability conditions
    - **structural integrity of unprotected floor assemblies**
  - To determine the sequence of fire events
    - fire initiation
    - smoke alarm activation
    - onset of untenable conditions
    - failure of floor assembly above the basement

# Experimental Program - Test Facility

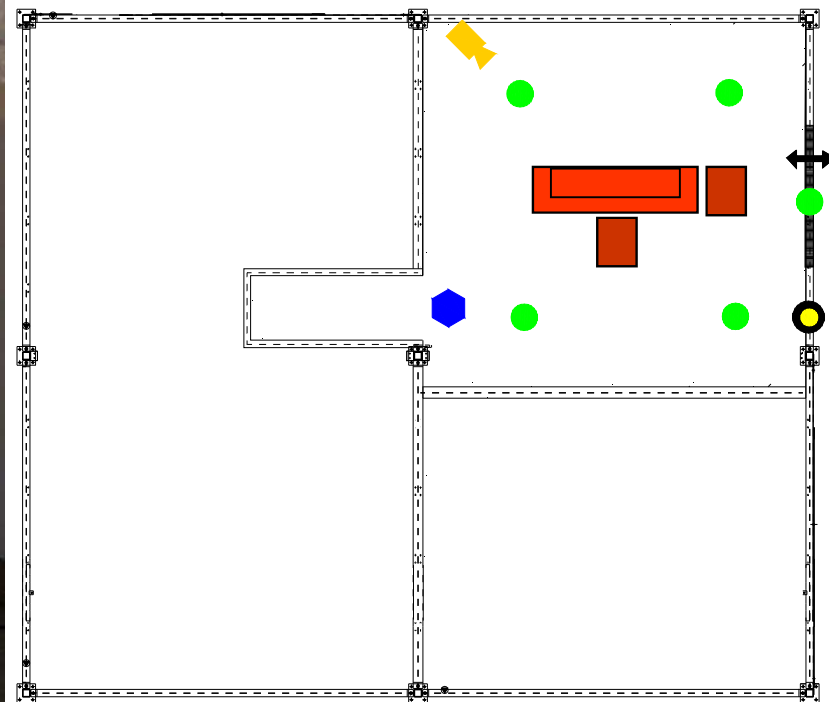
- A full-scale test house simulating a two-storey detached single-family house with a basement





# Experimental Program - Basement

- Relatively severe, fast-growing fire to challenge the floor





# Experimental Program – Unprotected Assemblies used as Ceiling

Solid wood joists



Wood I-joists (LVL flanges)



Wood I-joists (FJL flanges)



Steel C-joists



Metal-plate wood trusses



Metal-web wood trusses



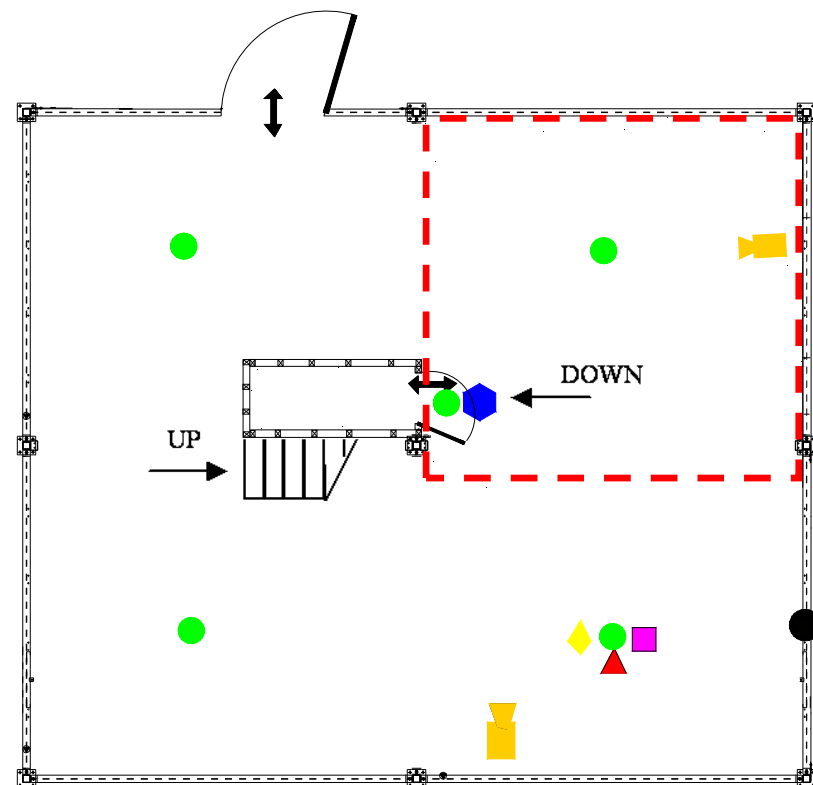
# Experimental Program - First Storey

- State of doorway to basement:

- Open



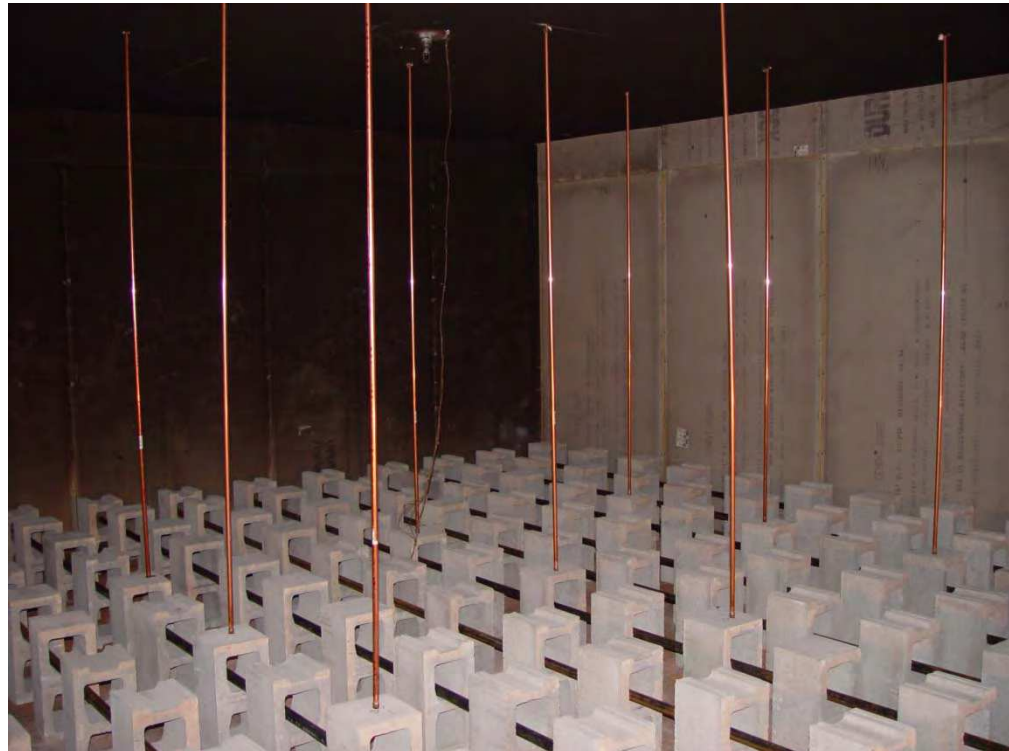
- Closed



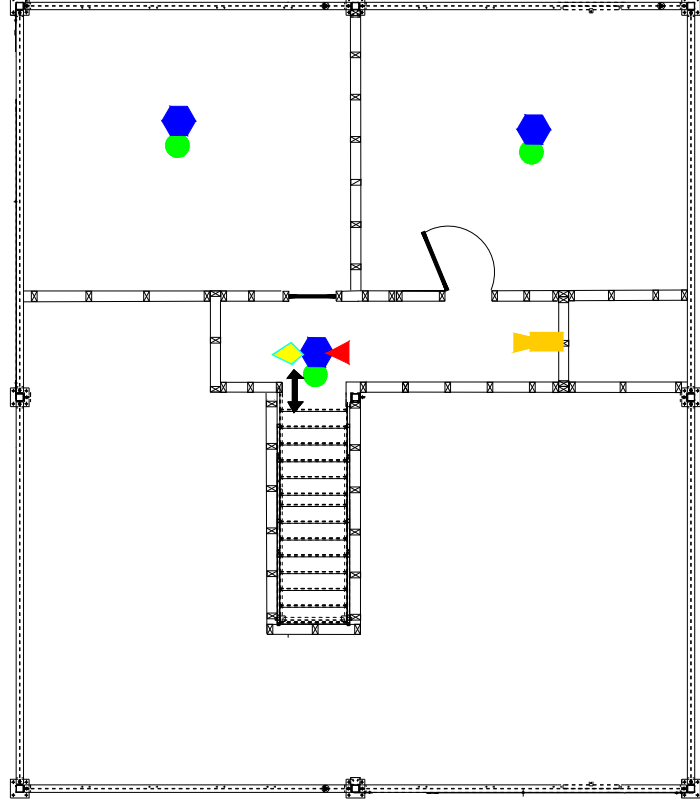


# Experimental Program Loading on Floor Assembly

- OSB Subfloor
- 0.95 kPa imposed load (20 psf, i.e.  $\frac{1}{2}$  NBC design load)
- Self-weight of floor assembly



# Experimental Program - Second Storey





# Openings and their States

- One window in basement (initially closed)
- Basement staircase door open or closed
- First storey exterior door (initially closed)

# Sequence of Events (Fire Scenario)

- Ignition of the sofa
- Development of fire in basement
- Open basement window when:
  - Temp. at window reaches 300°C
- Open first storey exterior door after 3 min from ignition
- Test termination
  - Excessive flame penetration through the floor
  - Structure failure of the floor
  - Safety issues

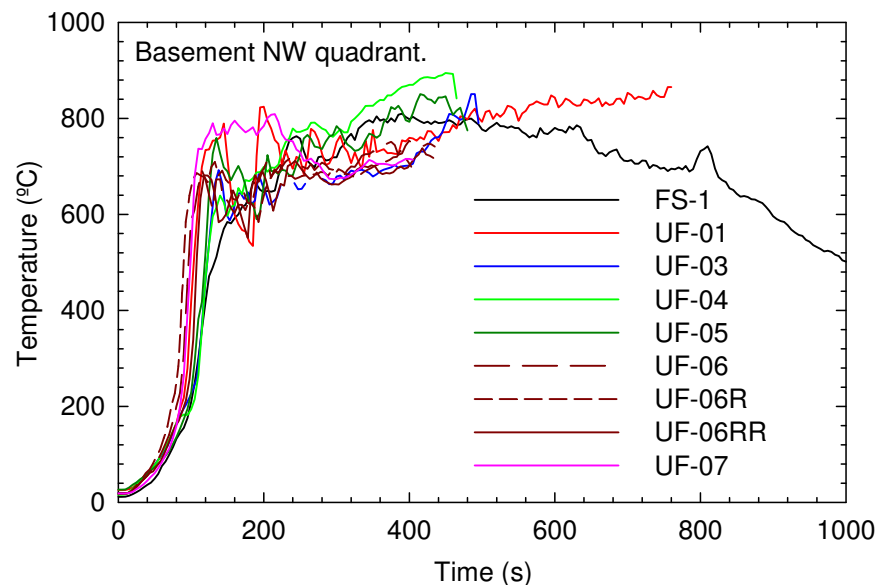
# Experimental Results

## Flames at the window

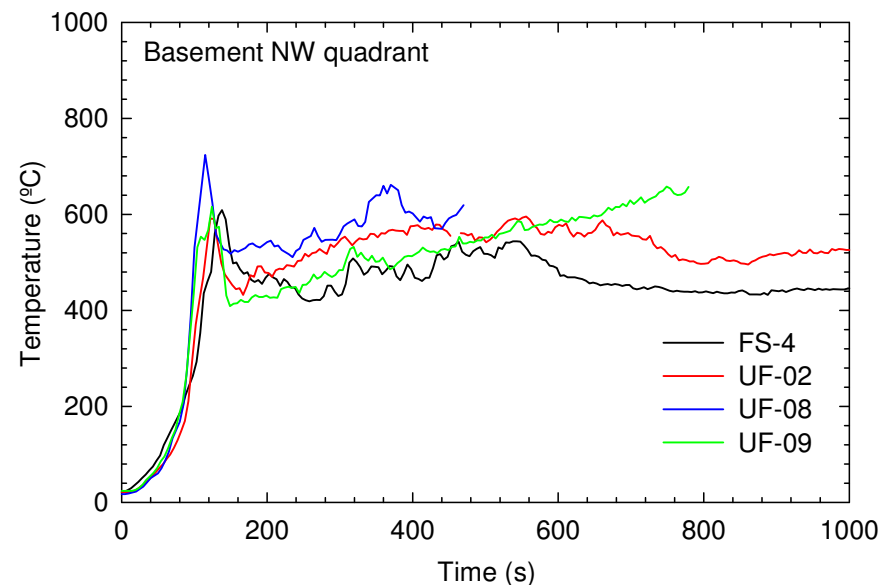


# Experimental Results - Fire Scenarios

*open basement doorway*



*closed basement doorway*



*Temperatures in basement fire room at 2.4 m height*

- Relatively severe, fast-growing fire in the basement
- Very reproducible fire exposure
- Challenge to the structural integrity of unprotected floor systems

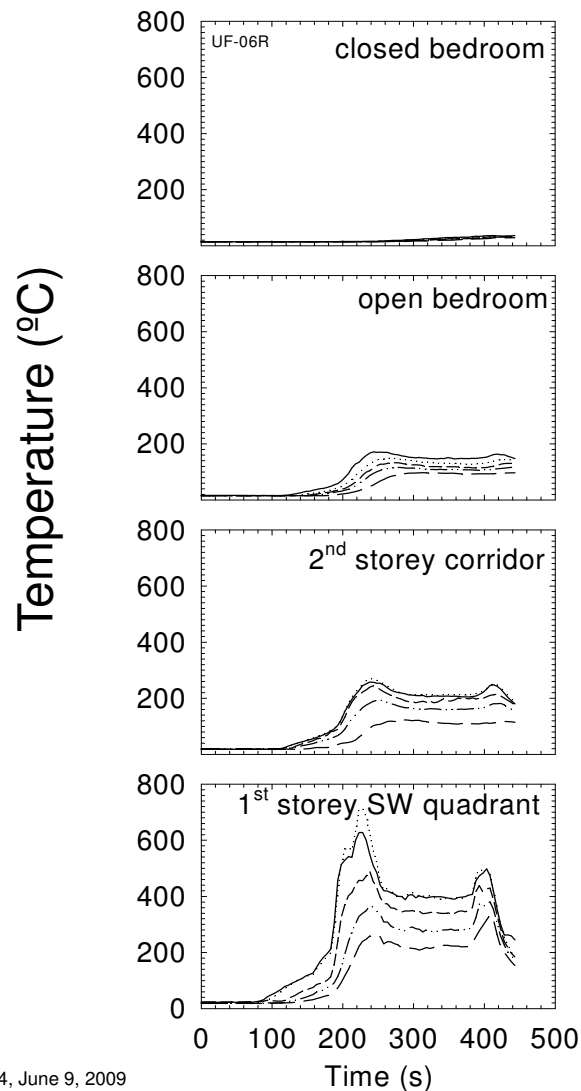


# Experimental Results - Smoke Alarm Responses

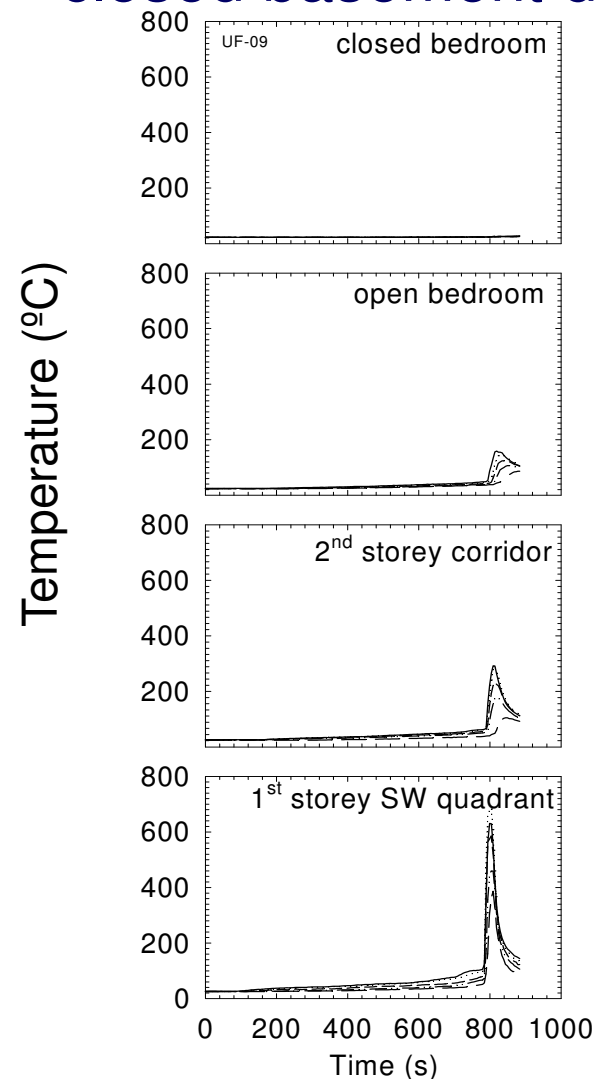
Smoke alarm location	Basement fire room		1 <sup>st</sup> storey		2 <sup>nd</sup> storey corridor		2 <sup>nd</sup> storey bedroom (open)		2 <sup>nd</sup> storey bedroom (closed)	
type	I	P 2	I 3	P 4	I 5	P 6	I 9	P 10	I 7	P 8
<i>Tests with open basement doorway</i>										
Test UF-01	-	40	75	85	125	135	140	150	200	205
Test UF-03	-	48	58	73	123	133	143	143	218	228
Test UF-04	-	30	65	85	115	130	160	225	230	250
Test UF-05	-	45	40	55	130	145	155	165	245	275
Test UF-06	-	45	75	85	115	125	130	200	230	255
Test UF-06R	-	38	58	78	113	123	138	163	198	223
Test UF-06RR	-	43	73	78	128	138	143	153	223	248
Test UF-07	-	50	40	55	110	130	130	145	190	210
<i>Tests with closed basement doorway</i>										
Test UF-02	-	42	72	97	172	182	212	n.a.	427	541
Test UF-08	-	50	85	95	205	205	220	210	515	515
Test UF-09	-	44	79	89	179	179	209	204	479	459

# Tenability Analysis – temperature measurements

## open basement doorway

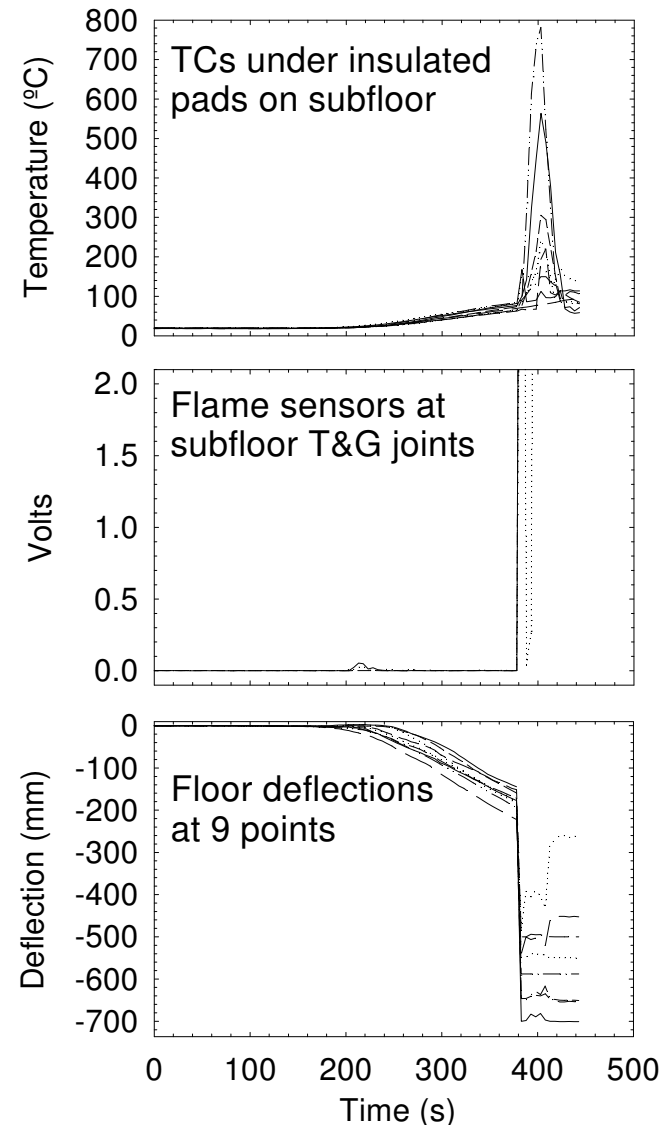


## closed basement doorway



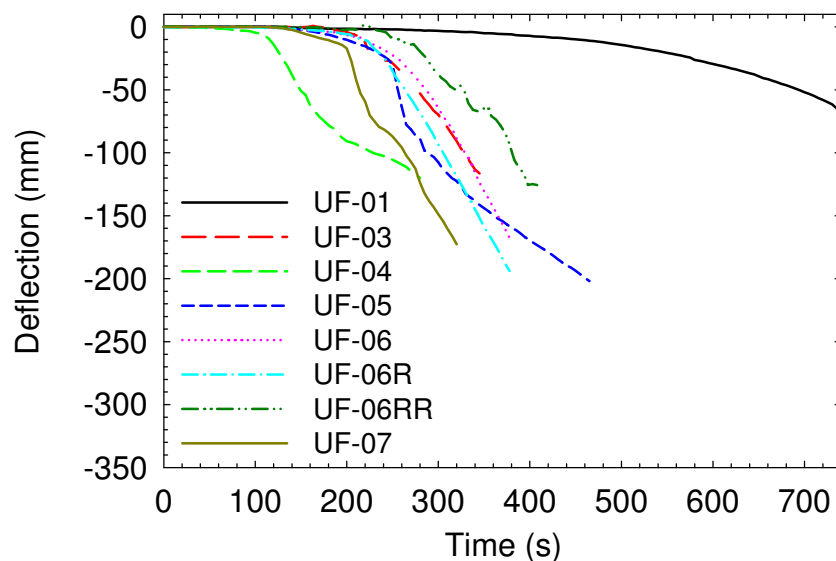
# Experimental Results - Structural Response of Floor Assemblies

- Measurements on floor assembly to determine time to floor failure
  - Temperatures
  - Flame penetration
  - Deflections
  - Visual observations

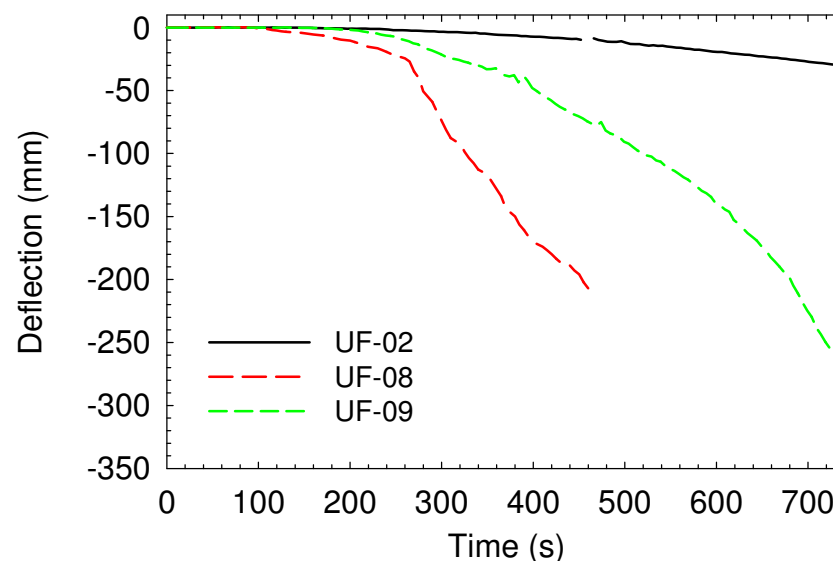


# Experimental Results - Structural Response of Floor Assemblies

## ■ Deflection prior to floor failure



a) Tests with open basement doorway



b) Tests with closed basement doorway



# Experimental Results - Primary Mode of Failure of Floor Assemblies

- Solid wood joist assemblies
  - subfloor failure (burn through)
  - most of the joists charred but still in place
- Engineered floor assemblies
  - joist or truss failure
  - collapse into the basement

# Experimental Results - Primary Mode of Failure of Floor Assemblies

Solid wood joist assemblies: subfloor failure (burn through)

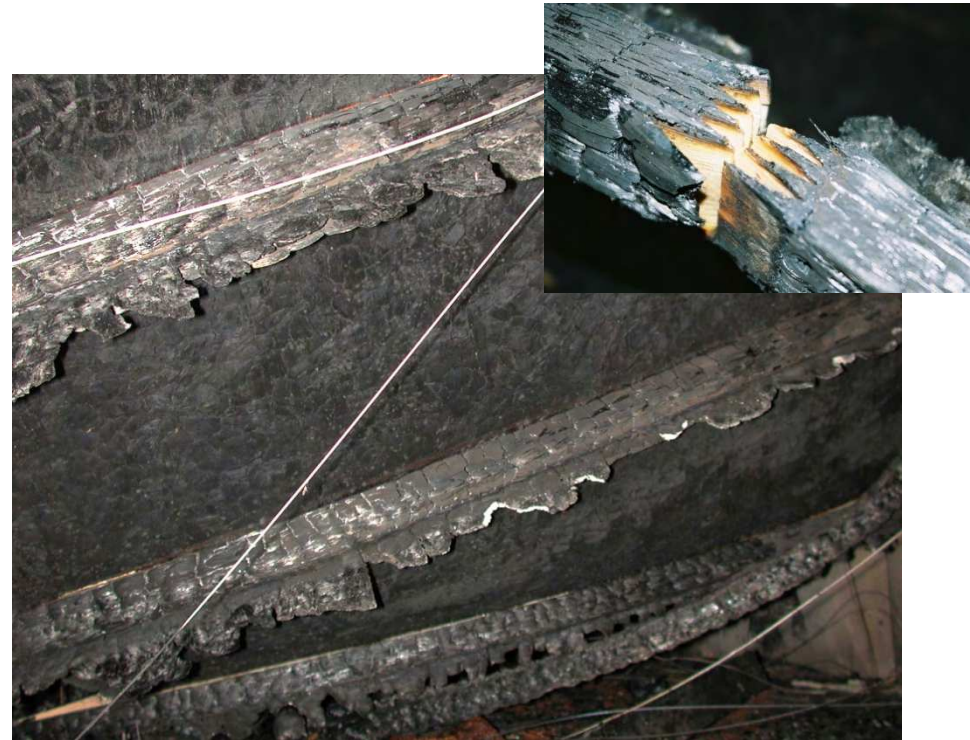




# Experimental Results - Primary Mode of Failure of Floor Assemblies

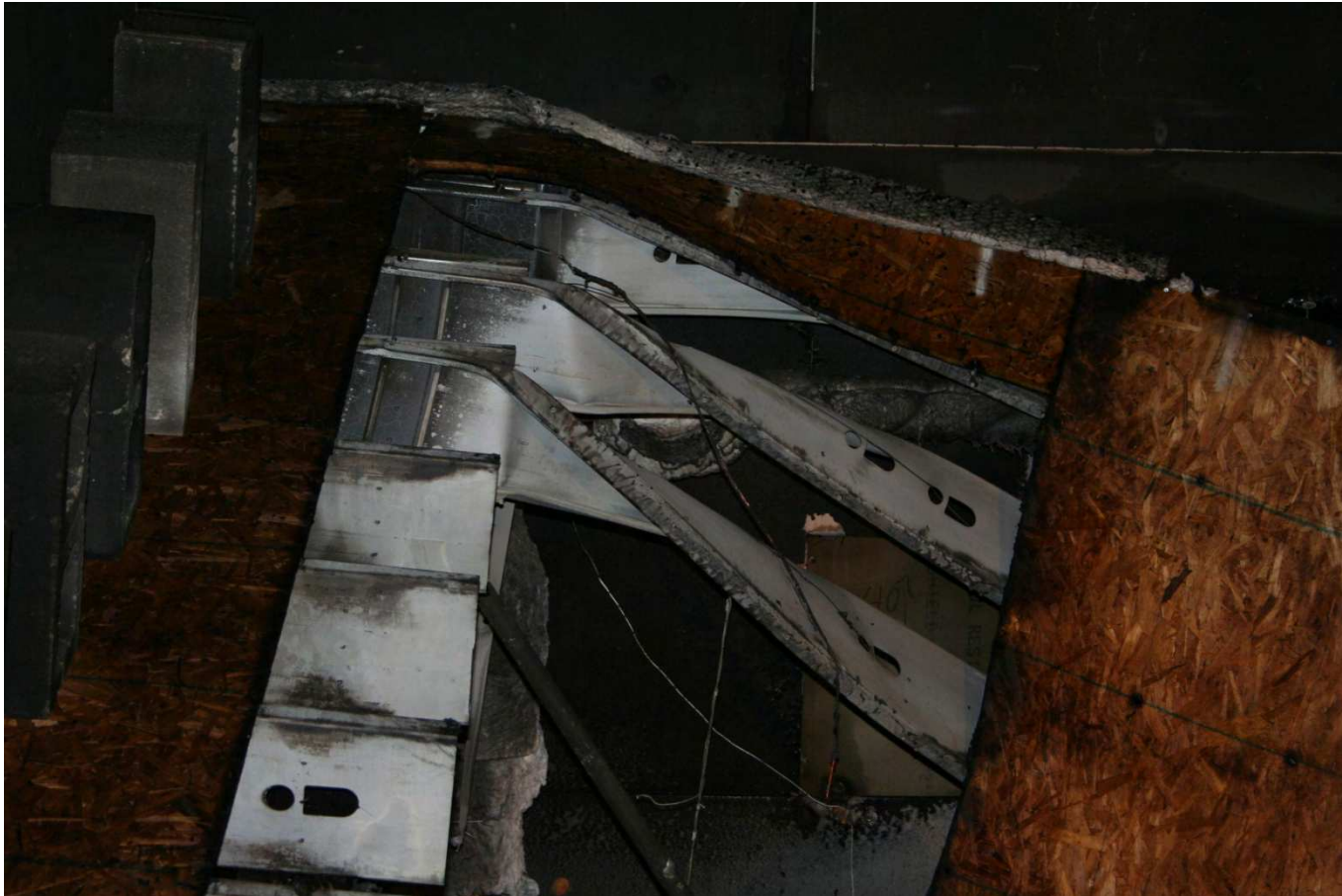
Wood I joists A and B: web materials burned through

Wood I-joist B: breakdown at finger joints of lumber flanges



# Experimental Results - Primary Mode of Failure of Floor Assemblies

Steel C-joists: lost strength and deformed





# Experimental Results - Primary Mode of Failure of Floor Assemblies

Metal-web & metal-plate wood trusses: metal-wood connections

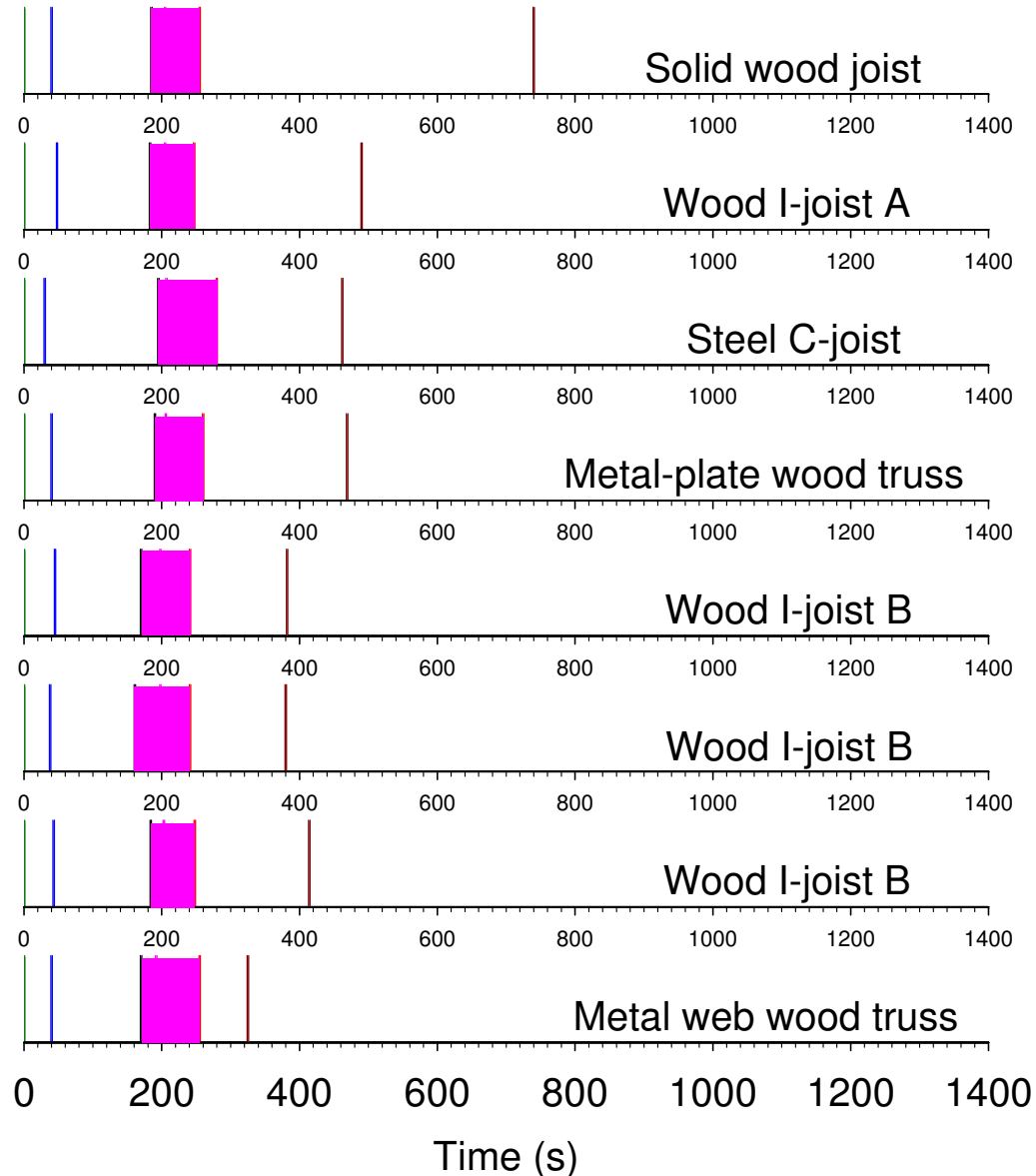




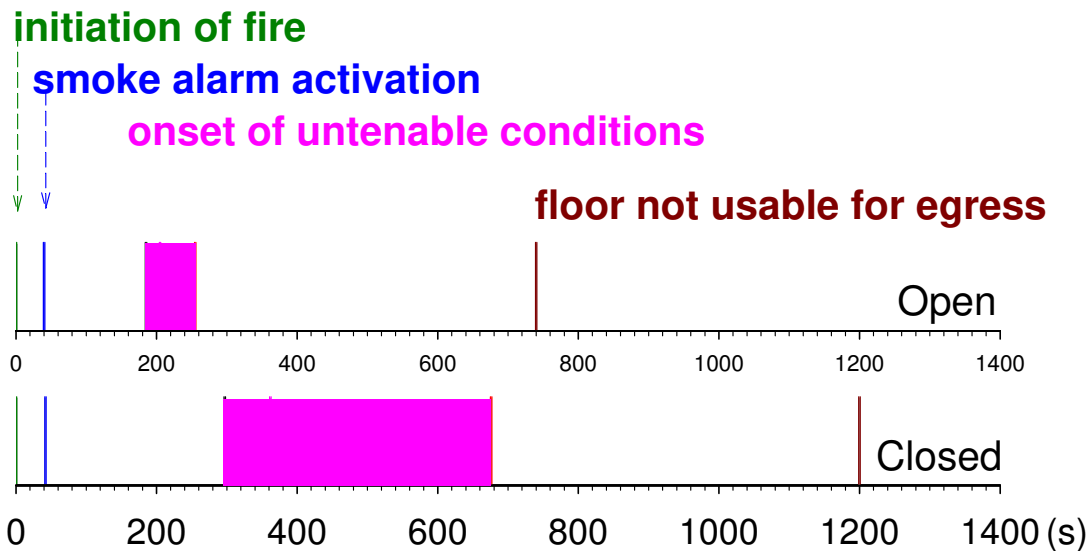
open  
basement  
doorway

initiation of fire  
smoke alarm activation  
onset of untenable conditions

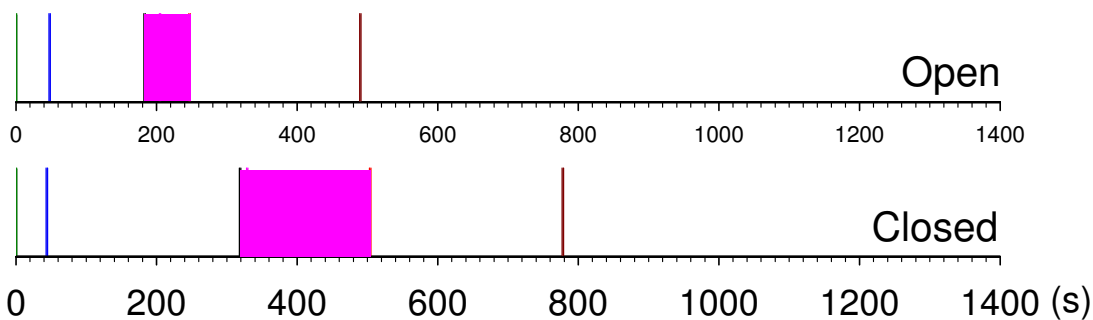
floor not usable for egress



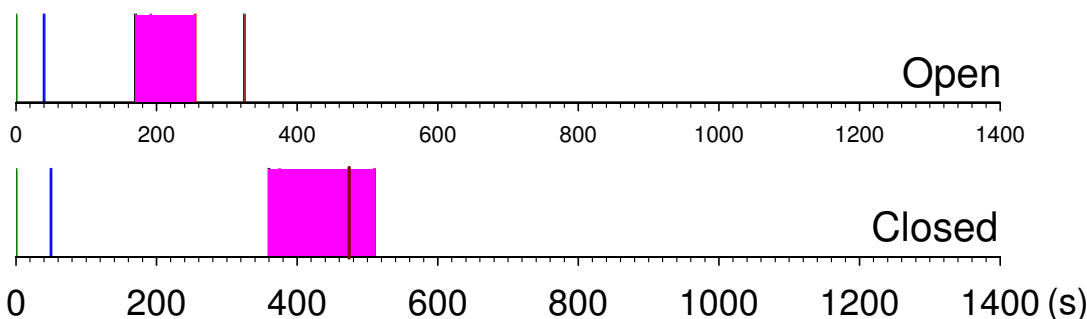
Comparison:  
open vs. closed  
basement  
doorway



**a) Solid wood joist**



**b) Wood I-joist A**



**c) Metal web wood truss**

# Key Findings

- **Tests with an open stairwell to the basement**
  - Fire events followed a chronological sequence:
    - initiation of the fire
    - activation of smoke alarms
    - loss of tenable conditions in open areas on upper storeys
    - finally structural failure of the test floor assembly
  - Untenable conditions for occupants in open areas on upper storeys were reached:
    - at approximately the same time regardless of the type of the test floor assemblies
    - before failure of the test floor assemblies occurred



## Key Findings (continued)

### ■ **Limited tests with a closed door to the basement**

3 assemblies: solid wood joist, wood I-joist, metal-web wood truss

- Reduced the rate of fire growth in the basement
- Slowed the transport of combustion products from the basement to the upper storeys
- Delayed the time to reach tenability limits for occupants on upper storeys
- Delayed the times for the test floor assemblies to reach structural failure
- Metal-web wood truss assembly failed before tenability limits were reached in open areas on upper storeys

# Key Findings (continued)

## ■ All tests

- The time to reach failure for the engineered assemblies was shorter than for the solid wood joist assemblies
- Untenable conditions were not reached, for the duration of the tests, in the second-storey bedroom where the door to the bedroom was kept closed
- Results support code requirements for interconnected smoke alarms on each level of a house to alert occupants
- Results reinforce the importance of continued public education on home fire safety

# Acknowledgments

- Partners in Phase 1 of the project:
  - *Canada Mortgage and Housing Corporation*
  - *Canadian Automatic Sprinkler Association*
  - *Canadian Wood Council*
  - *Cement Association of Canada*
  - *City of Calgary*
  - *FPInnovations - Forintek Division*
  - *North American Insulation Manufacturers Association*
  - *Ontario Ministry of Community Safety and Correctional Services/Office of the Fire Marshal*
  - *Ontario Ministry of Municipal Affairs and Housing*
  - *Wood I-Joist Manufacturers Association*



# Acknowledgments

- NRC-IRC project team:

- *J.Z. Su*
- *N. Bénichou*
- *A.C. Bwalya*
- *G.D. Lougheed*
- *B.C. Taber*
- *P. Leroux*
- *G. Proulx*
- *A. Kashef*
- *C. McCartney*
- *J.R. Thomas*

Thank you!  
Questions?

**Summary** <http://irc.nrc-cnrc.gc.ca/pubs/fulltext/rr/rr252/rr252.pdf>

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