Structural fire performance of unprotected floor assemblies used in single family houses

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

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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

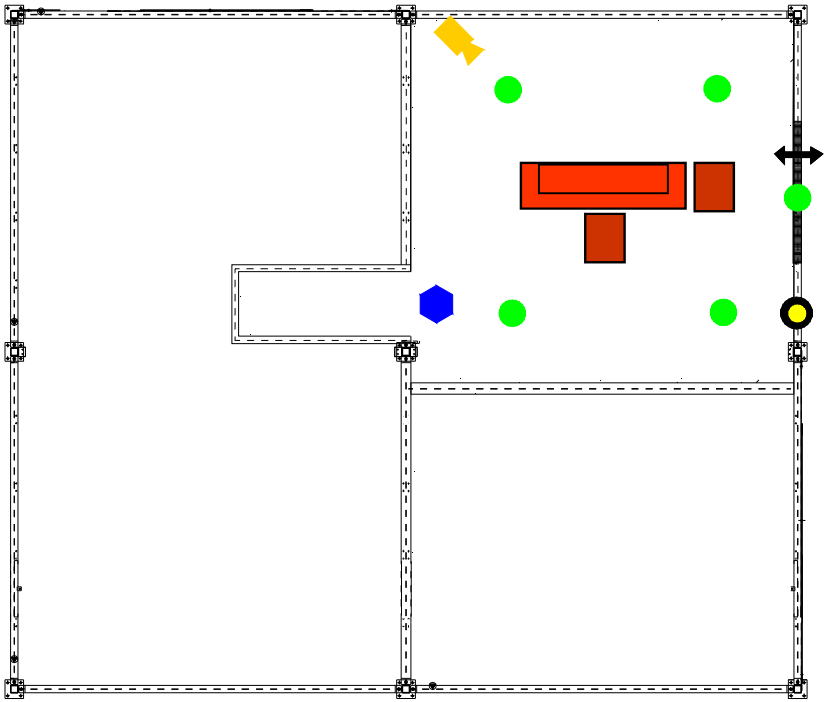
- Research studies include a number of phases
- Phase I – basement fires with unprotected floor assemblies
  - To study impact on the ability of occupants on upper storeys to escape in the event of a basement fire
    - fire development
    - smoke movement & tenability conditions
    - structural integrity 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)

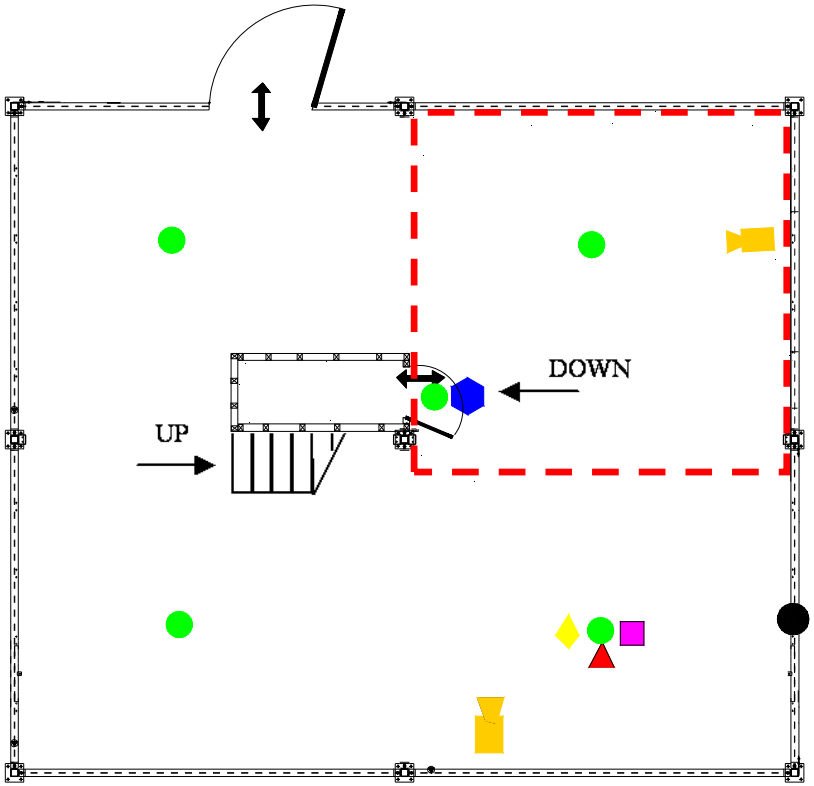
Steel C-joists

Metal-plate wood trusses

Metal-web wood trusses

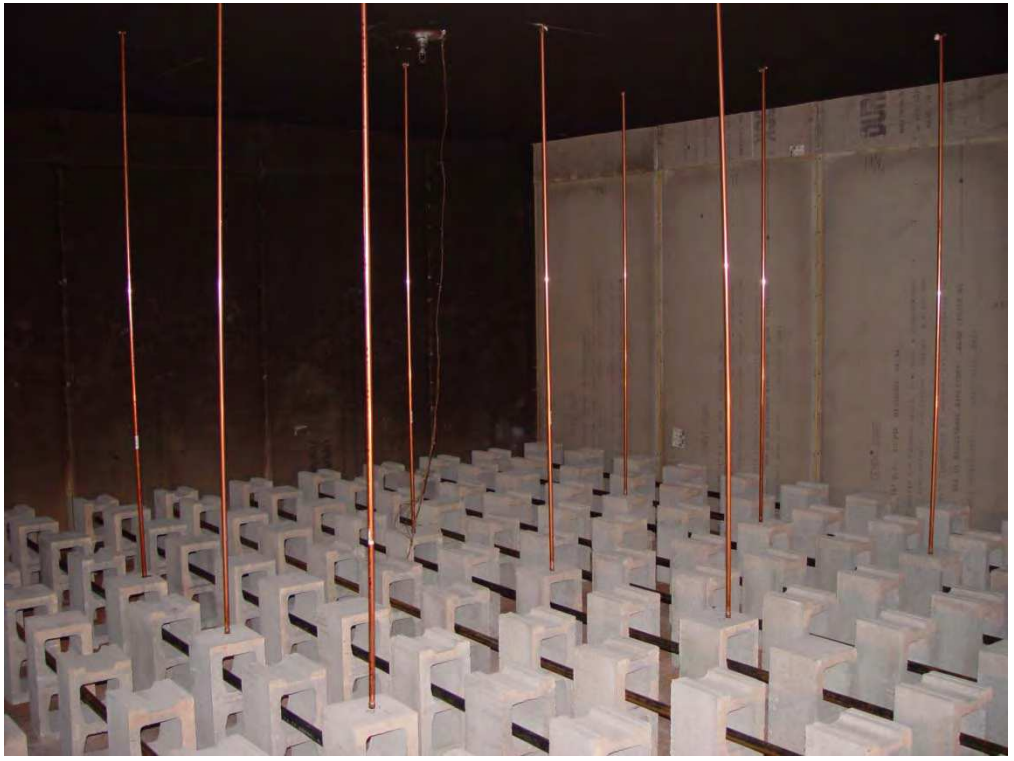
Experimental Program - First Storey

- State of doorway to basement:
  - Open
  - Closed

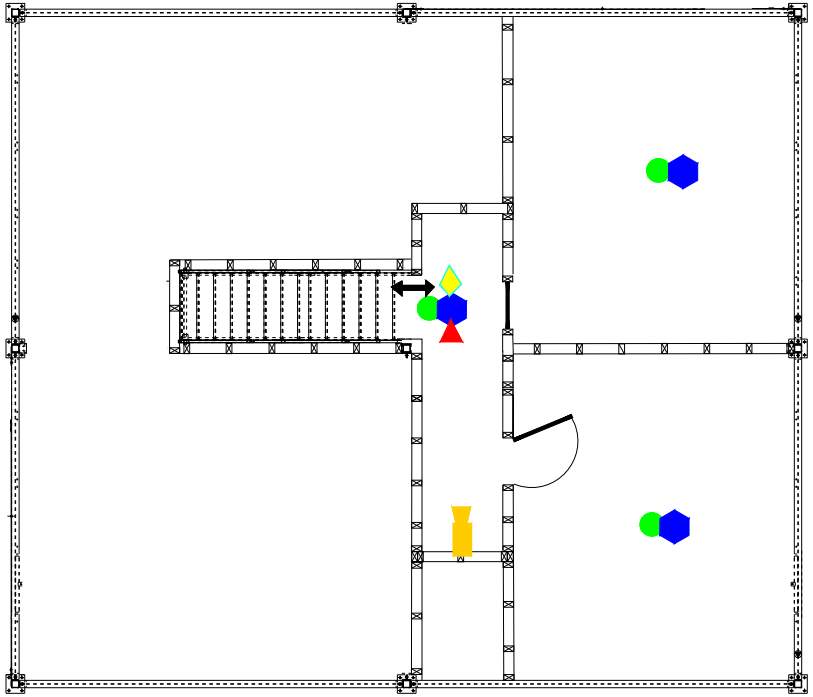


Experimental Program
Loading on Floor Assembly

- OSB Subfloor
- 0.95 kPa imposed load (20 psf, i.e. ½ 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)

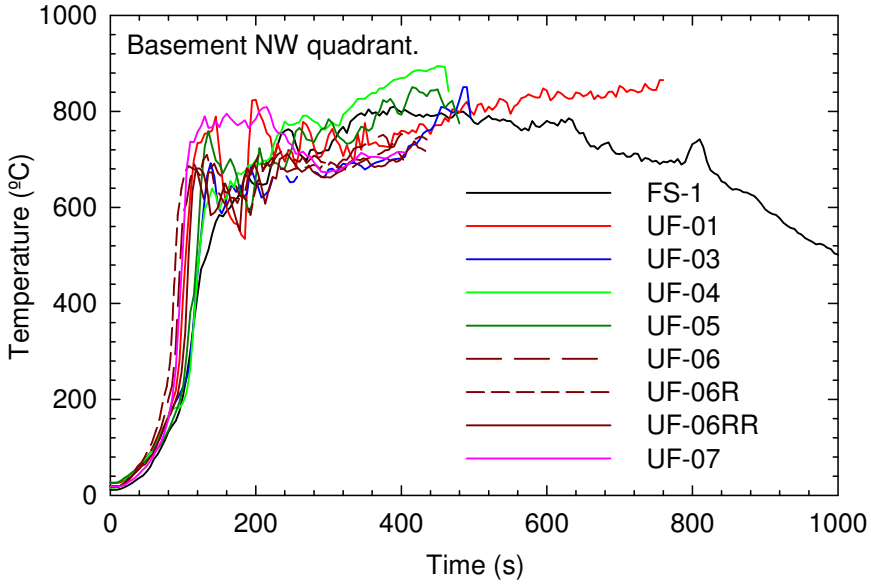
- Ignition of the sofa
- Development of fire in basement
- Open basement window when:
  - Temp. at window reaches 300°C
- Open first storey exterior door after 3 min from ignition
- Test termination
  - Excessive flame penetration through the floor
  - Structure failure of the floor
  - Safety issues

Experimental Results

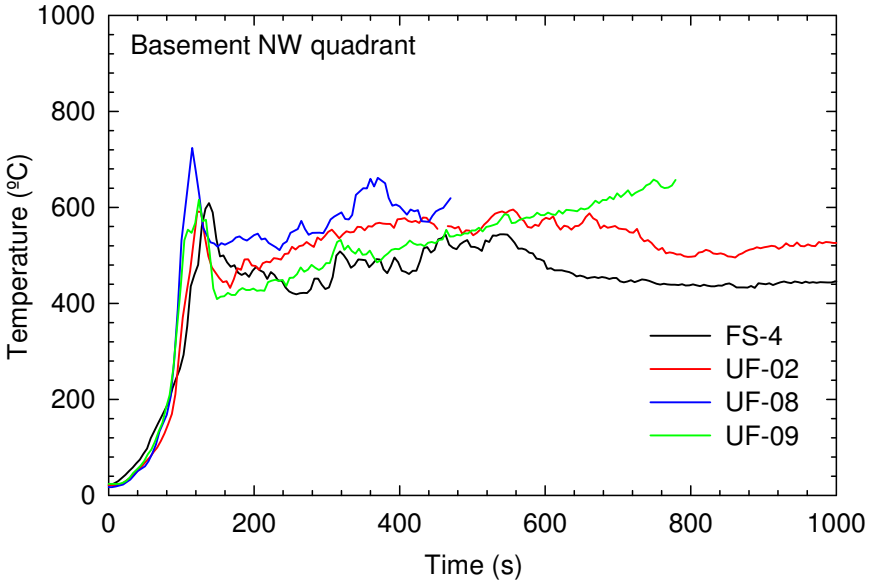
Flames at the window

Experimental Results - Fire Scenarios

open basement doorway



closed basement doorway



Temperatures in basement fire room at 2.4 m height

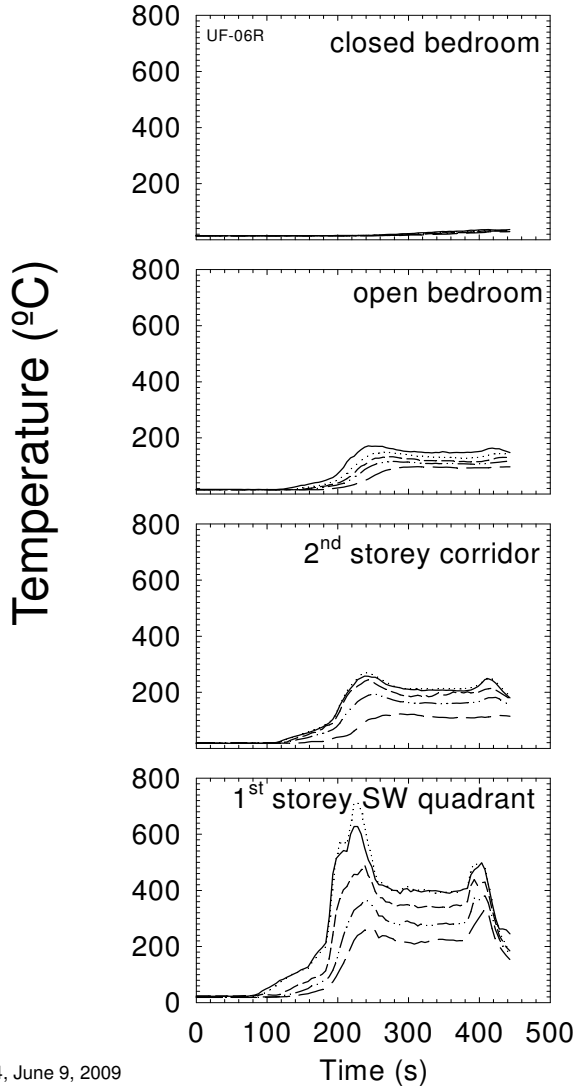
- Relatively severe, fast-growing fire in the basement
- Very reproducible fire exposure
- Challenge to the structural integrity of unprotected floor systems

Experimental Results - Smoke Alarm Responses

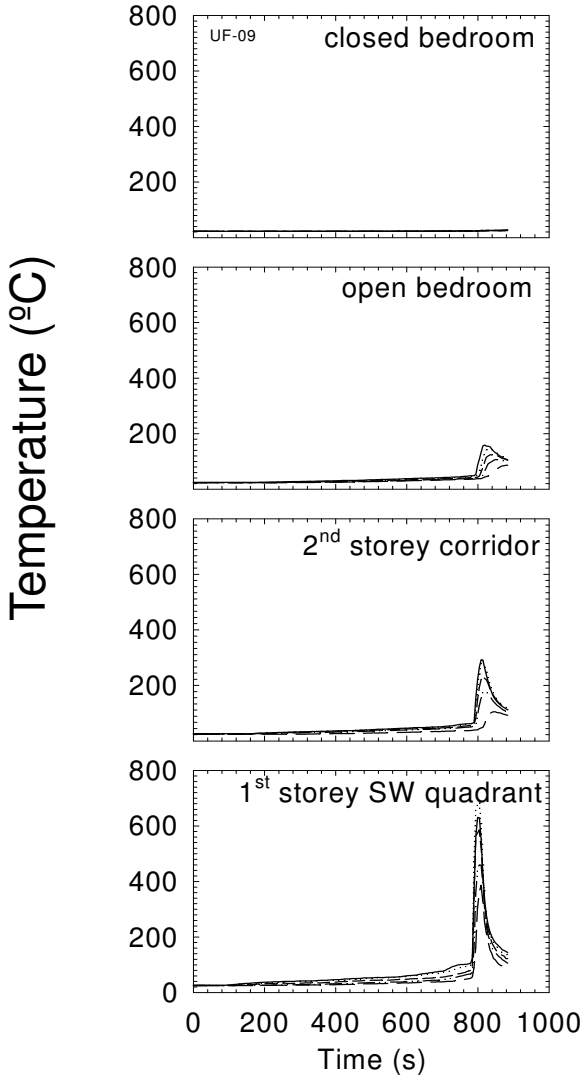
Smoke alarm location	Basement fire room		1st storey		2nd storey corridor		2nd storey bedroom (open)		2nd storey bedroom (closed)	
type	I	P 2	I 3	P 4	I 5	P 6	I 9	P 10	I 7	P 8
Tests with open basement doorway										
Test UF-01	-	40	75	85	125	135	140	150	200	205
Test UF-03	-	48	58	73	123	133	143	143	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
Tests with closed basement doorway										
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

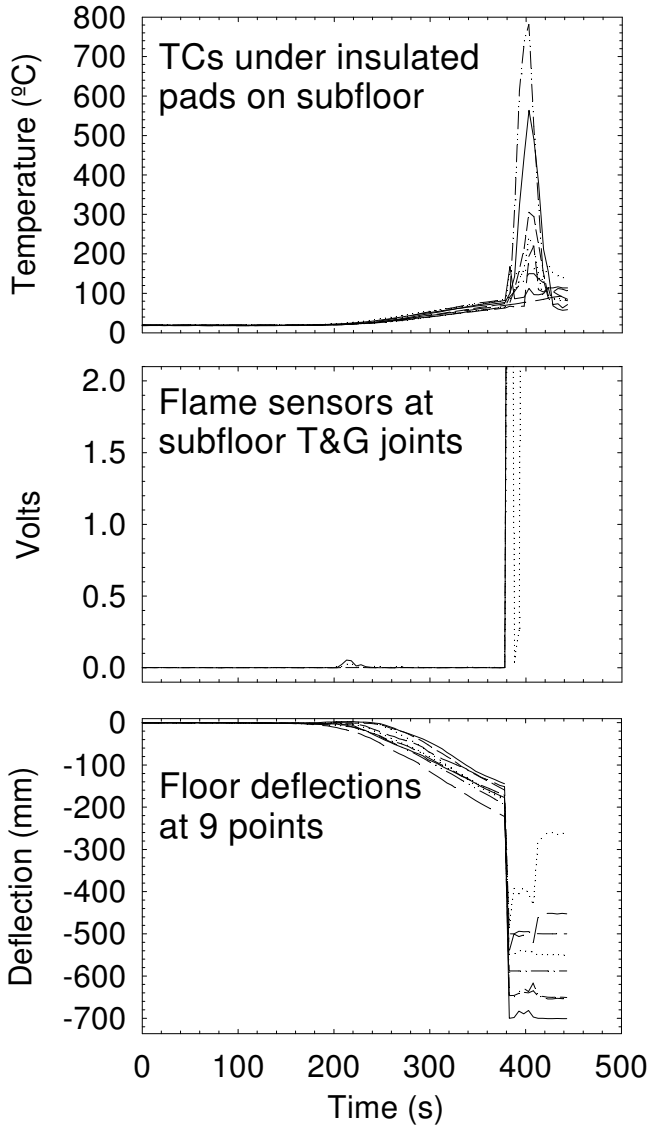


closed basement doorway



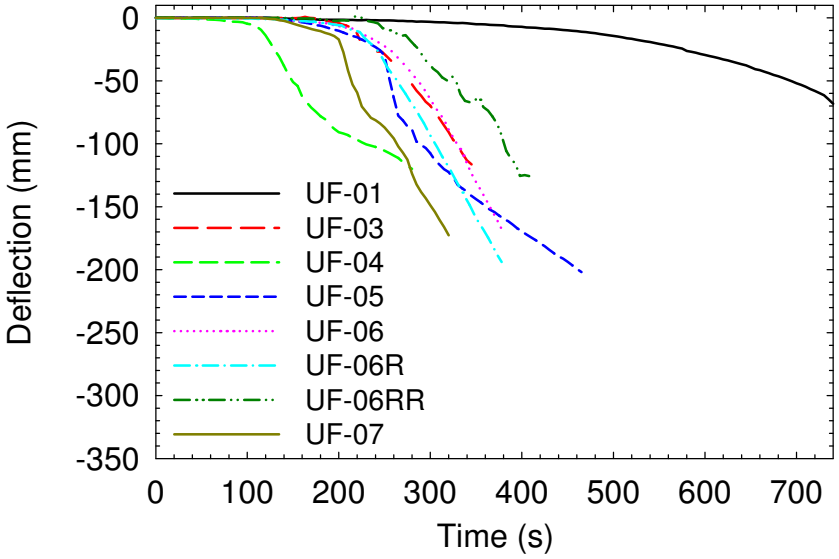
Experimental Results - Structural Response of Floor Assemblies

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

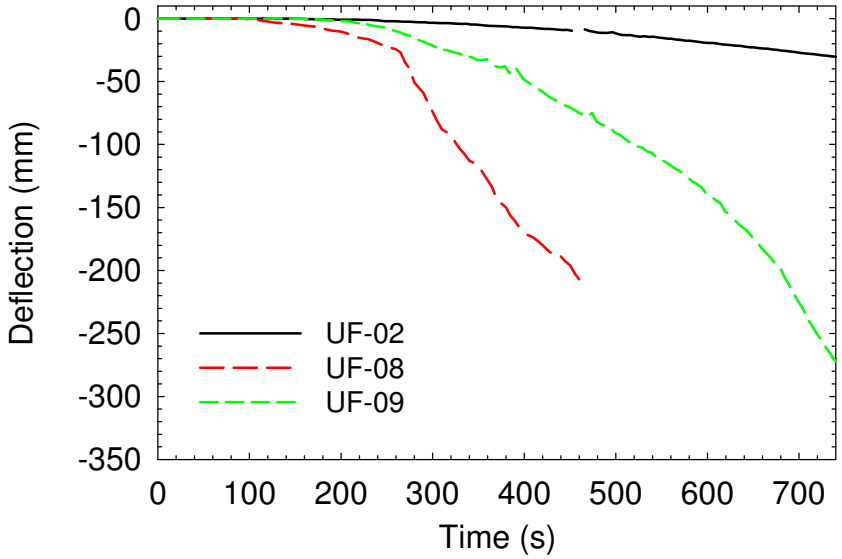


Experimental Results - Structural Response of Floor Assemblies

- 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

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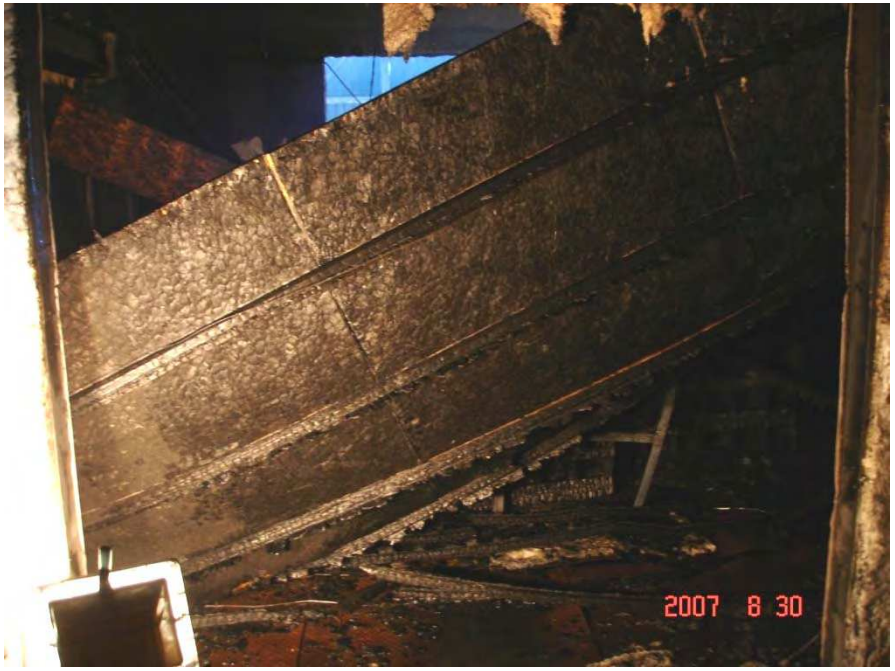
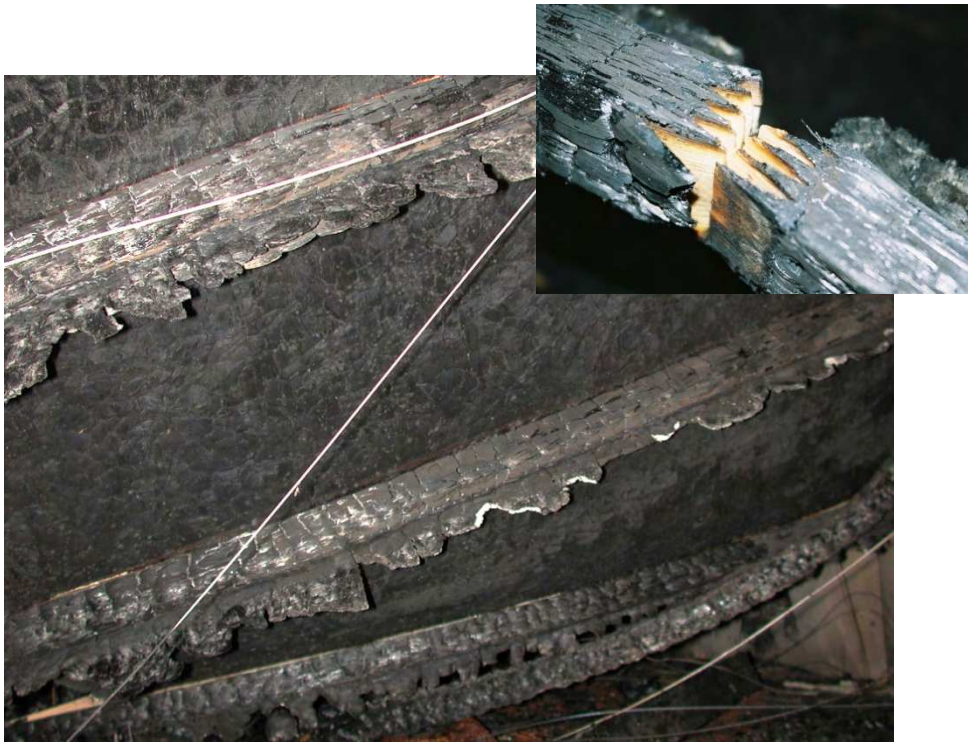
Solid wood joist assemblies: subfloor failure (burn through)

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

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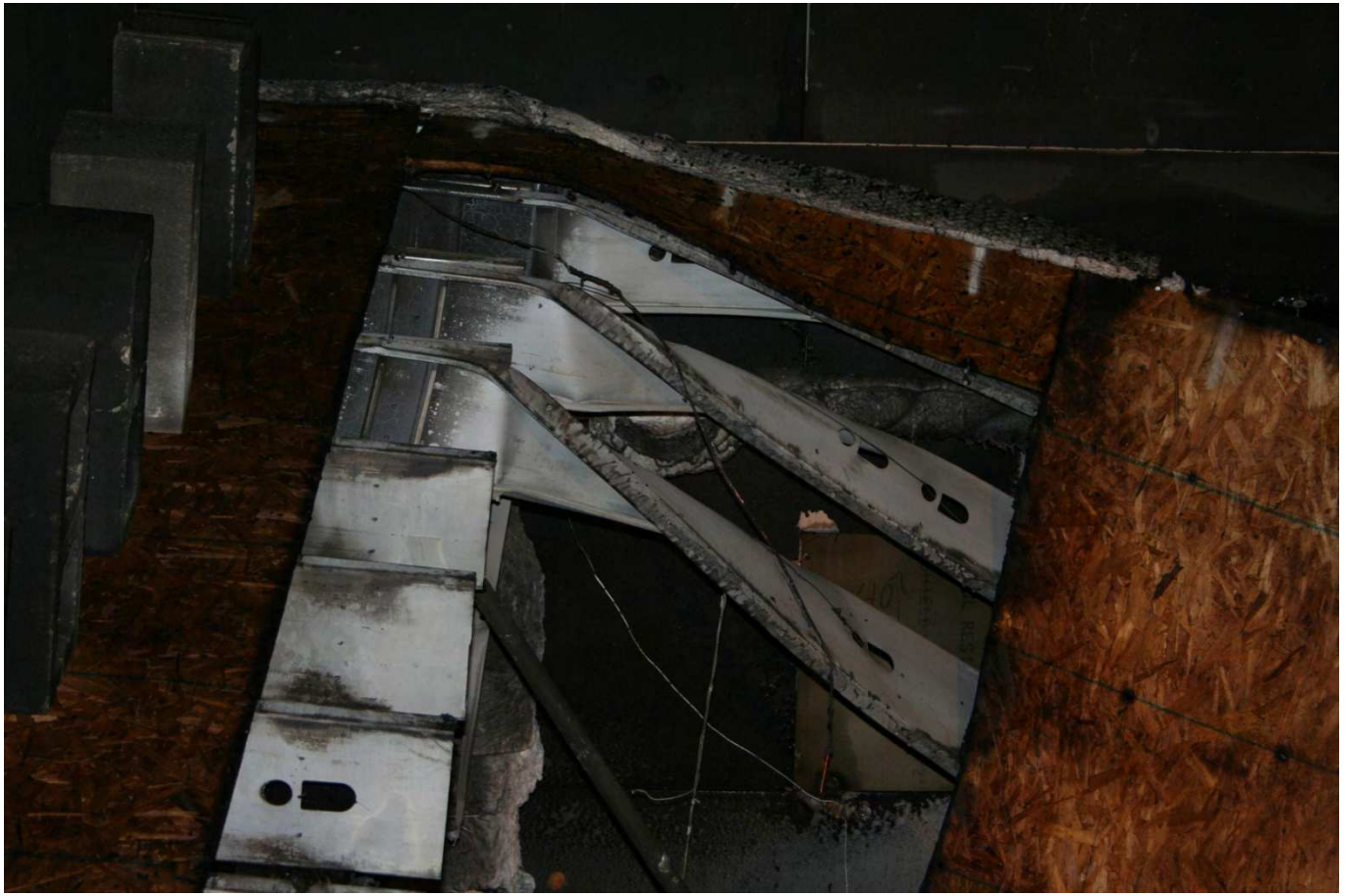
Steel C-joists: lost strength and deformed



Experimental Results - Primary Mode of Failure of Floor Assemblies

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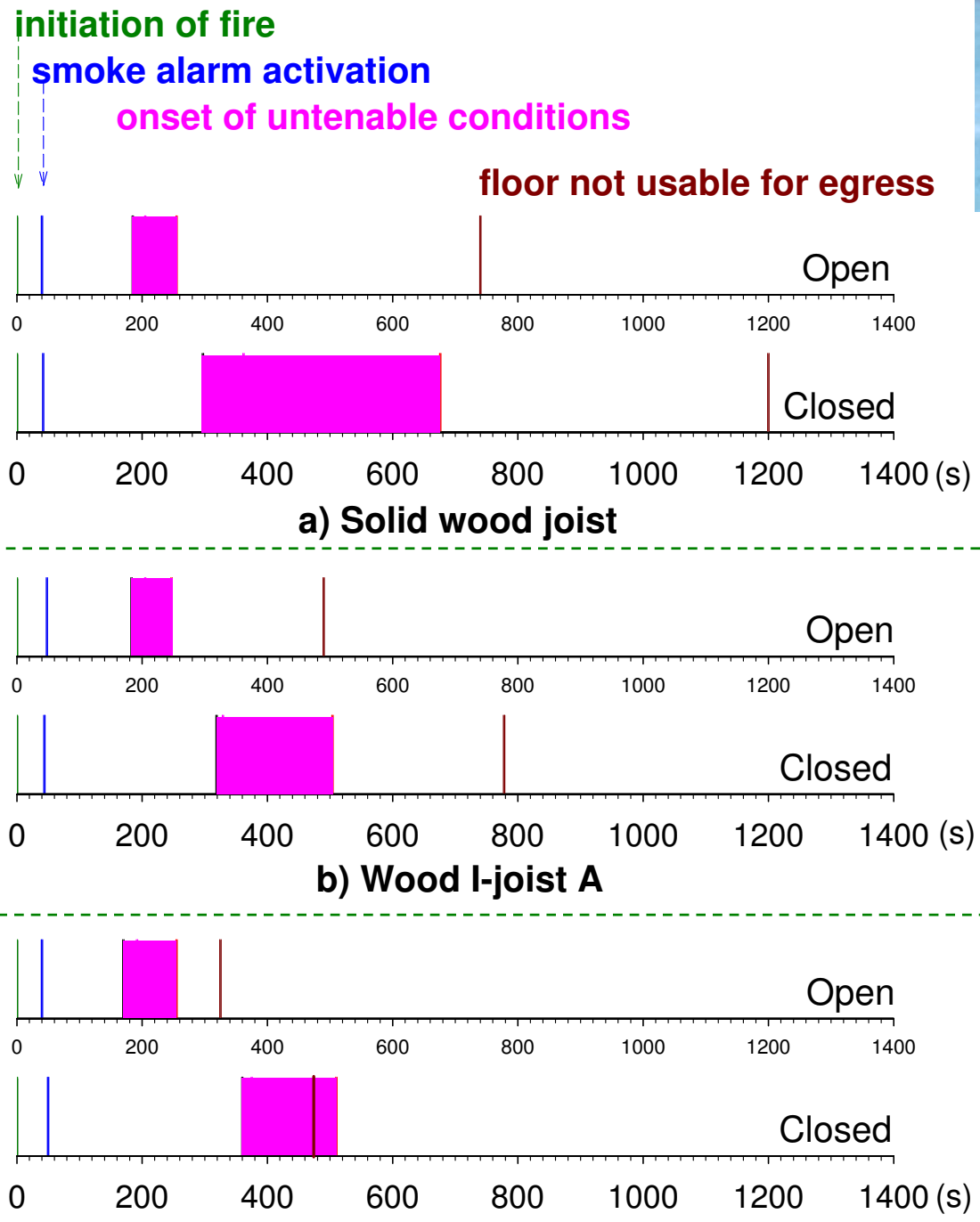
Metal-web & metal-plate wood trusses: metal-wood connections

open basement doorway

Comparison: open vs. closed basement doorway



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*
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  - *Ontario Ministry of Municipal Affairs and Housing*
  - *Wood I-Joist Manufacturers Association*

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Thank you!

Questions?

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

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