# Reliability of Sprinkler Systems During and After a Seismic Event and Application to Tall Wood Buildings

## World Conference on Timber Engineering
### Quebec City, Canada

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August 10-14, 2014

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# Outline

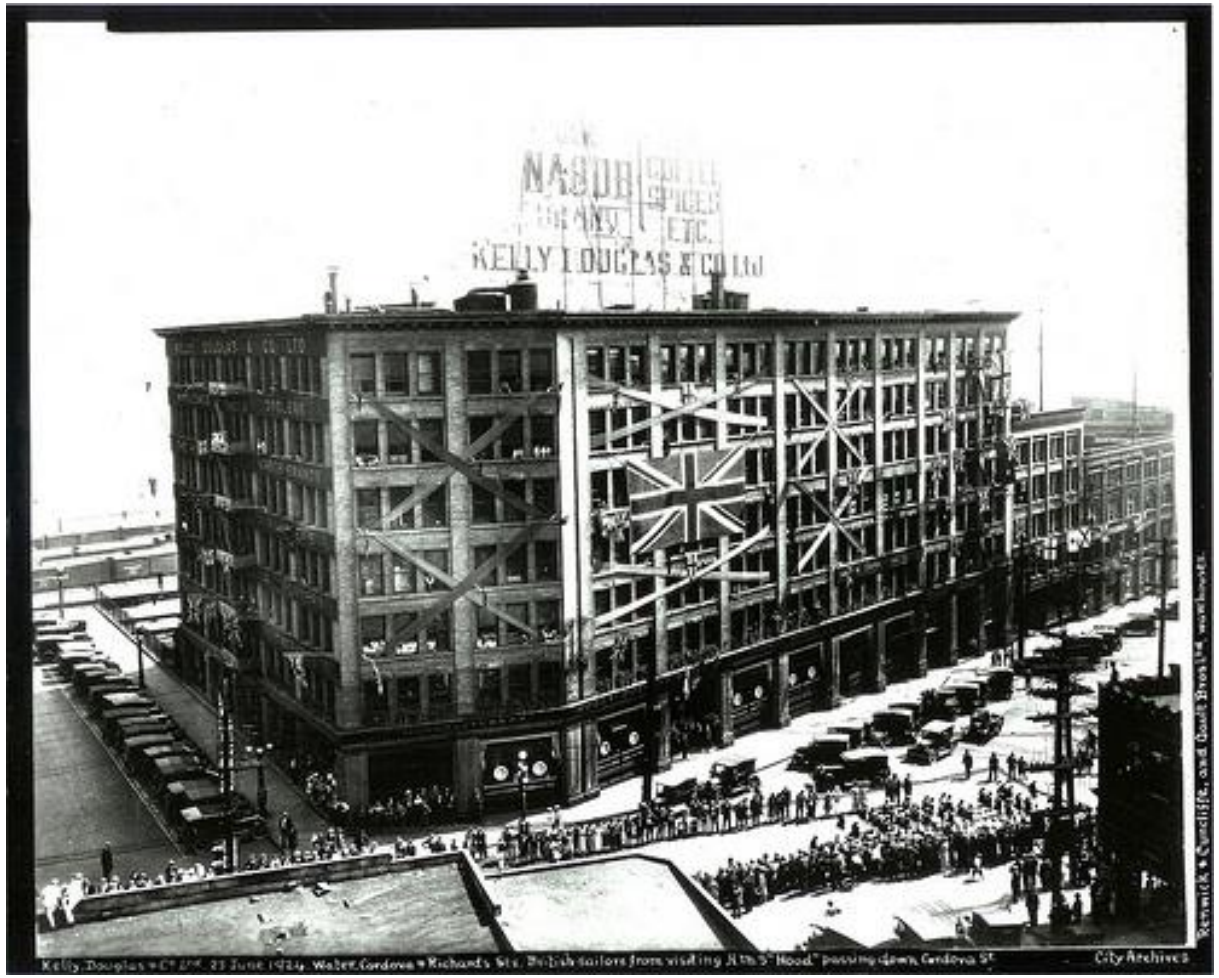
- Introduction
- History of fire and earthquakes
- Fire resistance of Tall Wood buildings
- Fire protection systems
- Emergency Response to fire
- Approach to mitigating risk of Tall Wood Buildings
- Numerical analysis of reliability of fire protection systems in combustible and noncombustible buildings

# 1 Introduction

# Tall Wood Alternative

- Fast growing building alternative supported by:
  - New engineered wood materials
  - Solutions to fire, structural, durability and acoustic issues
- In designing tall wood building, risk assessment is important
  - Fires during earthquakes
  - Reliability of fire protection systems
- Fire protection in tall wood building include reliance on sprinkler system

# 9 Storey Heavy Timber - 1905




Kelly Douglas Building, Vancouver

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# Current and Future Concepts

Green-Karsh 30-storey ~ 80m

36 storey ~ (95 m)
Switzerland

312 ft. (95 m) Sitka Spruce
Canada

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# 2
# History of Fires and Earthquakes





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# Historic Fires and Earthquakes

- Great city fires of late 1800's and early 1900's in North America
  - Chicago fire, 1871
  - Vancouver Fire 1886
  - San Francisco Fire, 1906
- Loma Prieta Earthquake, 1989 – 4 buildings damaged by fire
- Northridge Earthquake, 1994 -110 earthquake related fires
- Lead to major changes in North American Construction

CHICAGO IN FLAMES—BURNING OF THE CROSBY OPERA-HOUSE.—[See Page 1010.]

# Historic Fires and Earthquakes

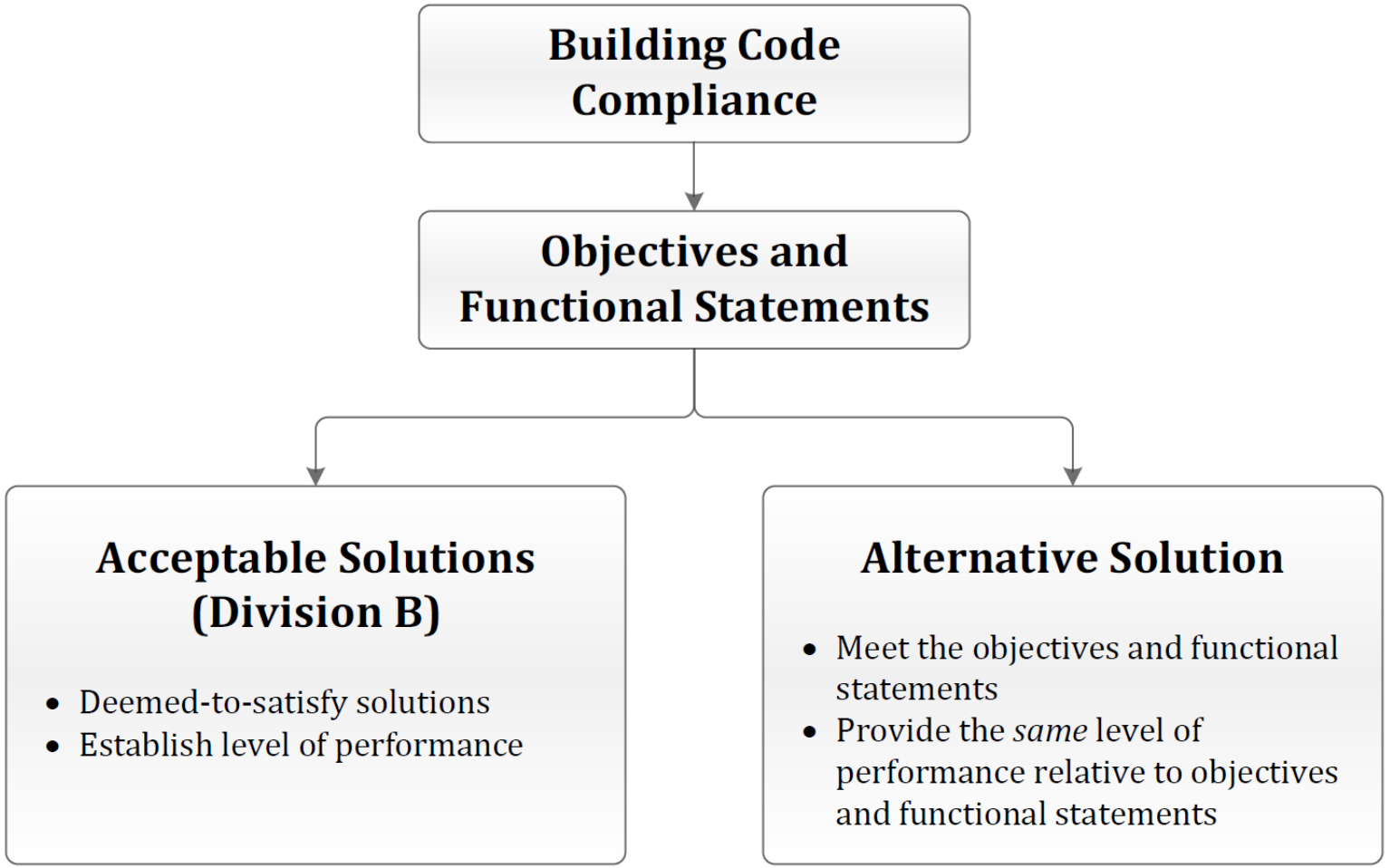
- Led to major changes in North American Construction
  - Development of building and fire codes
    - Requirements for noncombustible construction
    - Masonry exterior walls
    - Minimum building separations distances
    - Provisions for firefighting
- In recent times, there is a reduced number of earthquake fires
- Risk of earthquake fires should be addressed in tall wood design
- The probability and consequence of fires during earthquake is higher than fire during normal conditions

# 3
# Fire Resistance of Tall Wood Buildings

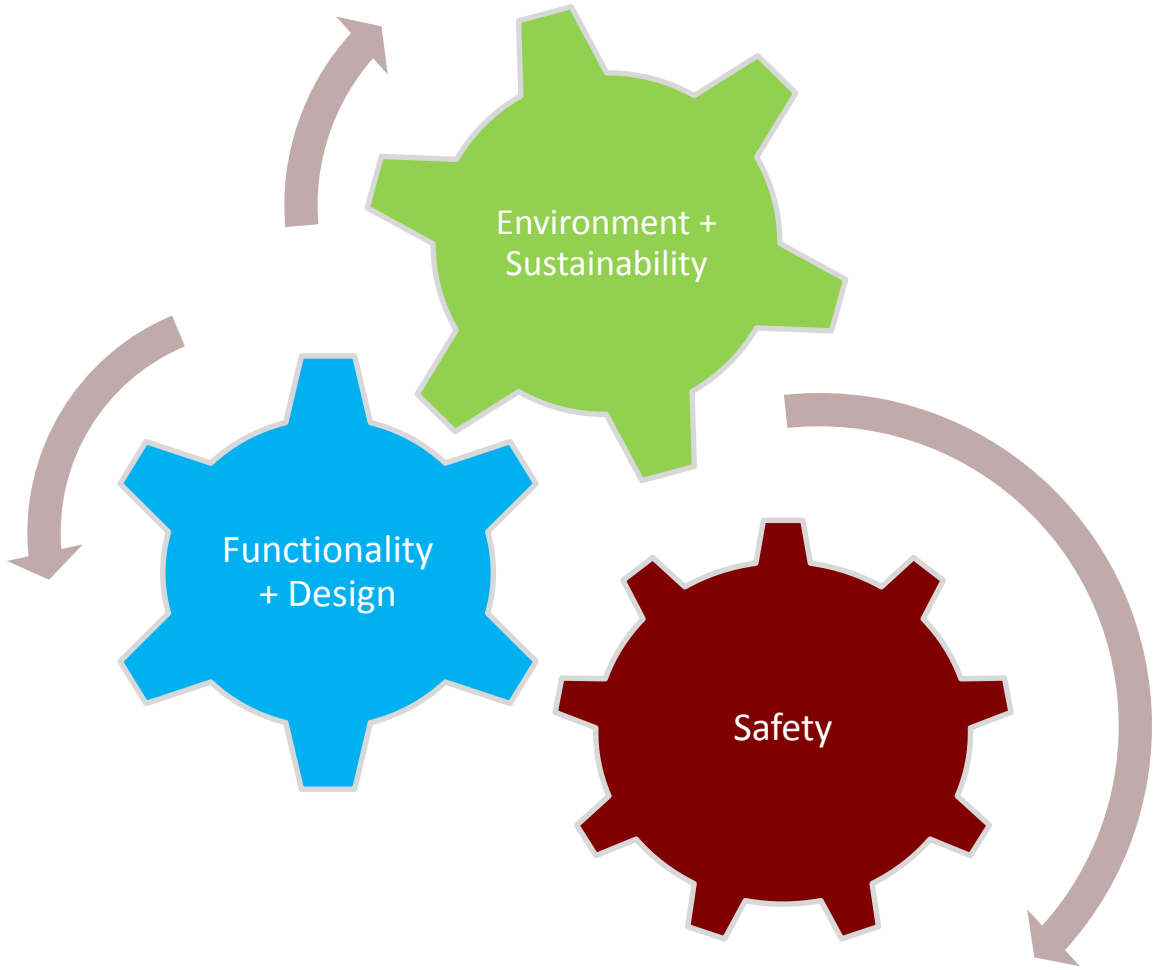
# Fire Resistance of Tall Wood Buildings

- National Building Code is objective based code with prescribed solutions, and options for alternative solution development
- “Acceptable solutions” prescribe noncombustible construction and 2h fire-resistance rated elements for high buildings
- To use alternative solution option, designer must show that tall wood building provided equivalent or better level of safety

# Canadian Objective-based Code Framework



# Safety Needs to Balance Other Goals





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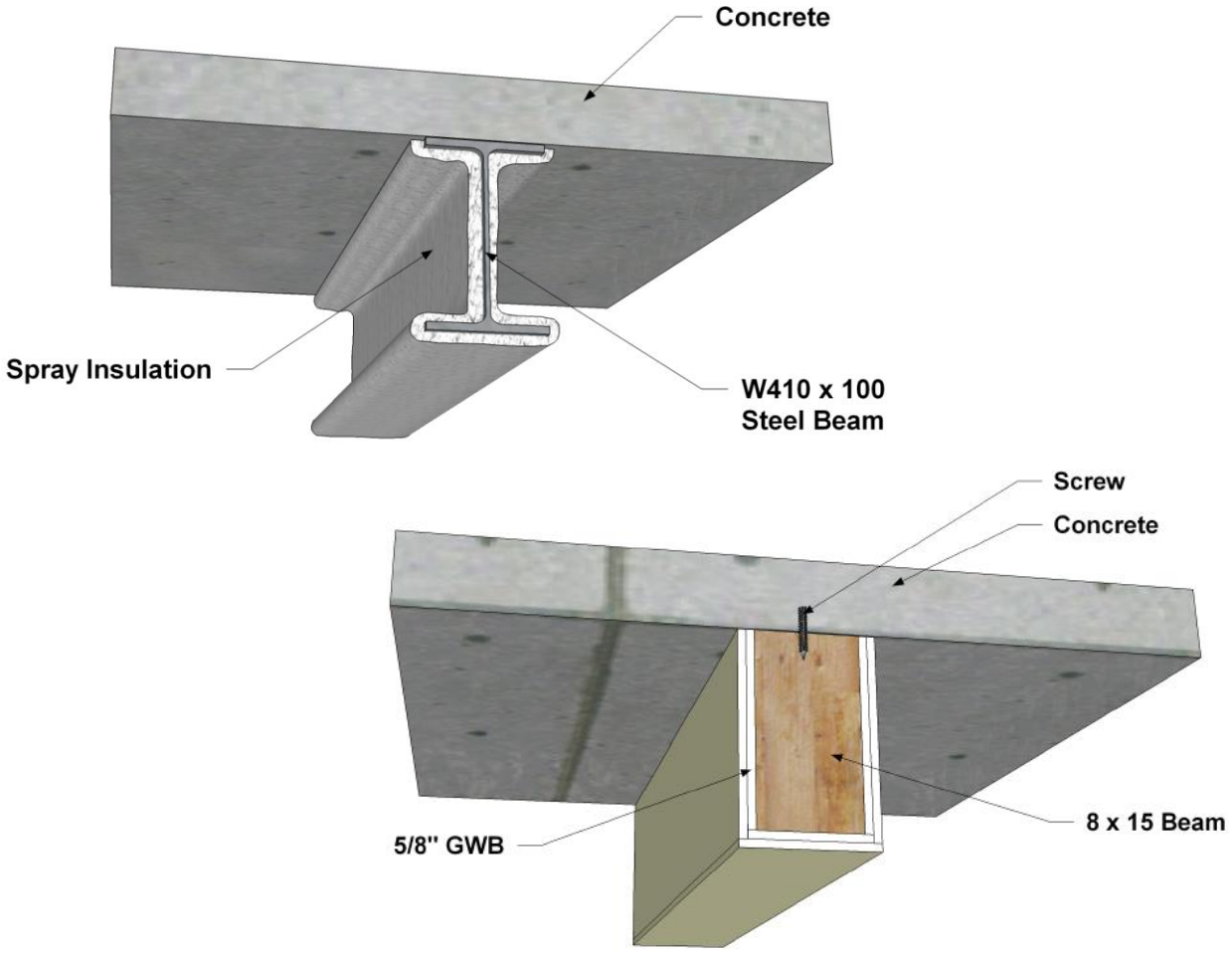
# Fear & Uncertainty of Using Wood

- Yes, wood burns, but wood can be protected, just like how steel needs to be protected!

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# Fire Resistance of Tall Wood Buildings

- With operating sprinkler system, and appropriate fire protection design performance of mass timber building is no different from noncombustible building for first 30 to 45min of fire

- In the absence of sprinklers, mass timber building may continue to building after contents are consumed

# 4
# Fire Protection Systems

# Fire Protection Systems

- Passive Protection
  - Floor and wall assemblies
  - Fire resistance rated enclosures
- Active Protection
  - Fire alarm system
  - Sprinkler system
  - Fire and smoke detectors and alarms

# Reliability of Passive Protection

- Passive Protection based on
  - Controlling fire load
    - Limiting combustible materials
    - Occupancy classification
    - Fire inspections
  - Protecting structural systems
    - Structural elements with inherent FRR
    - Applying fire protection materials
    - Protection of structural elements by fire rated floors and walls
  - Compartmentation
    - Fire rated barriers
    - Fire rated closures at openings

# Reliability of Passive Protection

- Fixed structural elements and assemblies are design to  have a high degree of reliability during and after earthquakes
- Weak links exist and include
  - Fire stopping
  - Closures
  - Doors in regular use are often maintained in good condition
  - Fire shutters and dampers have a high potential for failure

# Increased Reliance on Sprinkler Systems

- Building codes rely of sprinklers systems for almost all buildings exceeding 4 storeys
- In City of Vancouver, BC, all buildings are required to have sprinkler systems
- Population growth and densification of cities
  - Increases proximity of buildings
  - Not accompanied by increase in firefighting forces
  - Reinforces need for sprinkler protection

# Reliability of Sprinkler Systems

- Reliability 89% - 99%
- Modern supervised and monitored system --> 98%
- Sprinkler system with back-up water supply >99% (more on this later)

(Statistics from Australia, Canada and the US)

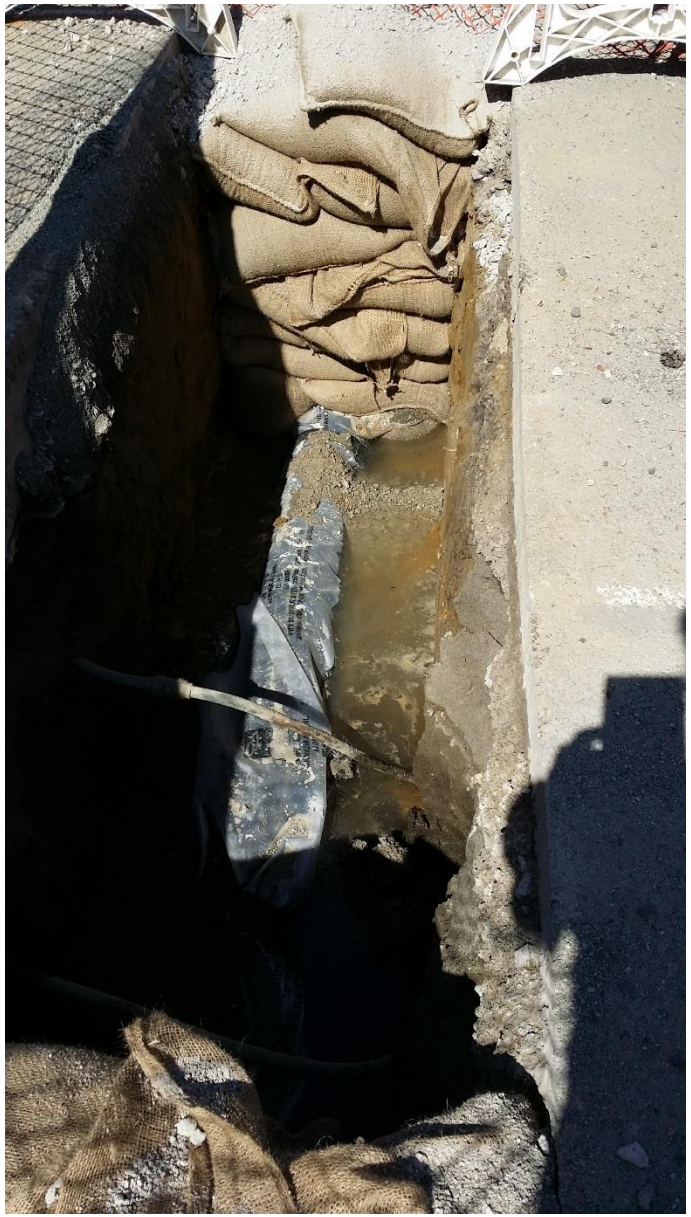
# Sprinkler Systems in Earthquakes

- NFPA 13 includes provisions for minimizing damage to sprinkler systems during earthquakes
- Provisions are regularly revised based on experience and knowledge
  - Extensive modifications occurred after San Francisco earthquake of 1971, the Loma Prieta Earthquake of 1989 and the Northridge earthquake in 1994.
- Reliability of sprinkler systems dependent on availability of water

# City Water Supply

- City water considered highly reliable under normal conditions
- Historical data shows that during and after seismic event
  - Many supply mains break
  - Reduced pressure and volume
  - Complete loss of water in some locations
- Example: Almost complete failure of water, sewer and power in Christchurch in 2010 and 2011 for up to one week after earthquake.
- Water supply systems in many locations remain old and frangible, and new mains not seismically restrained

# City Water Supply







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# 5
# Emergency Response

# Firefighter Response

- Fire departments equipped to deal with a few fires at a time
- During and after earthquakes
  - Primary activity for firefighters is search and rescue
  - High probability of multiple fires
  - Inadequate water pressure, electrical hazards, and roads blocked with debris further degrade firefighter response
- Fire Department reliability estimated at 80% under normal conditions and 10% after an earthquake are proposed

# Emergent Volunteer Response

- Tremendous volunteer response reported during most disasters
- Volunteers play significant firefighting role during earthquakes
- Sprinkler systems help to maintain tenable conditions during fires and limit fire growth such that fire sizes are manageable by volunteers.

# 5

# Approach to Mitigating Risk of Tall Wood Buildings

# Alternative Solutions For Tall Wood

- Canadian Codes permit alternative solution development
- Need to show equal or lower level of risk to life and property
- Building are not required to be connected to a seismically robust water supply systems – “acceptable solution” is noncombustible construction with full sprinkler protection
- Addition of  seismically robust water supply system for tall timber building will reduce the overall level of risk

# On Site Water Supply

- Provided in a number of buildings in Vancouver to mitigate
  - Spatial separation
  - Interconnected floor spaces
  - Glazed Exits

# On-Site Water Supply

# Numerical Analysis of Fire Protection Systems

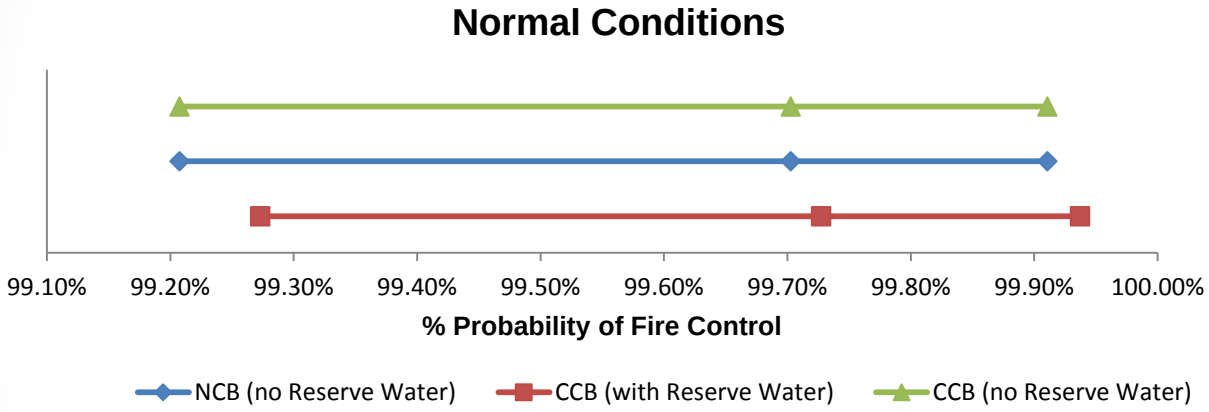
- Numerical analysis performed to show that combustible building with reserve water tank provided a higher level of safety than noncombustible building with no reserve water.

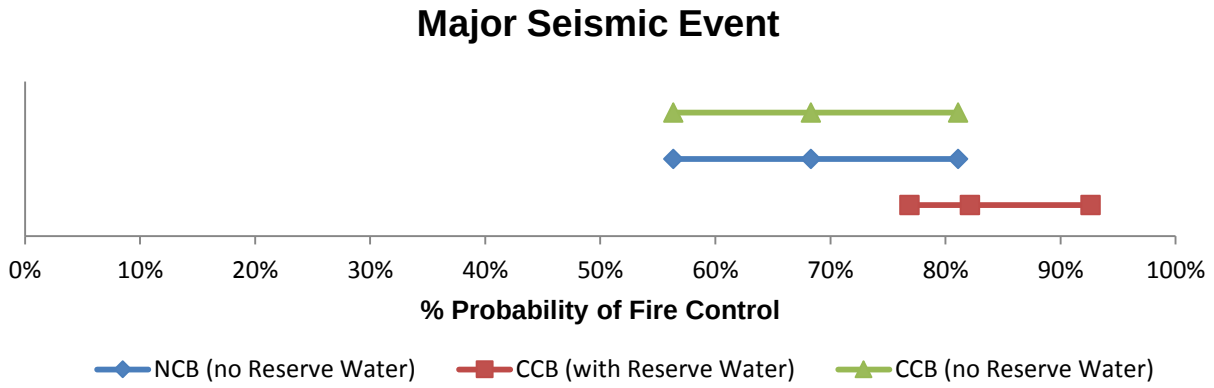
# Numerical Analysis of Fire Protection Systems

- Most fires start within a compartment and involve contents.
- Probability of ignition in a well designed combustible building is the same as in noncombustible building

# Numerical Analysis of Fire Protection Systems

Probability of Fire in combustible and noncombustible building =1

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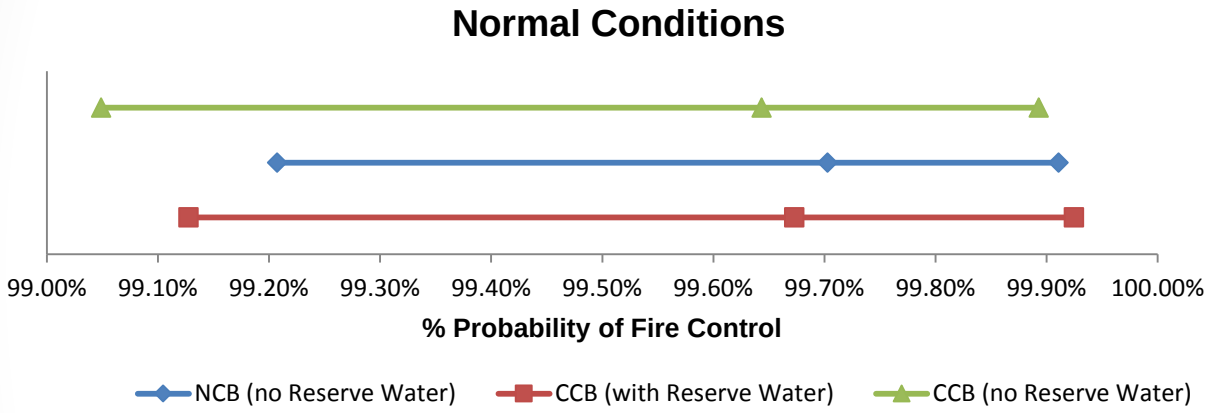
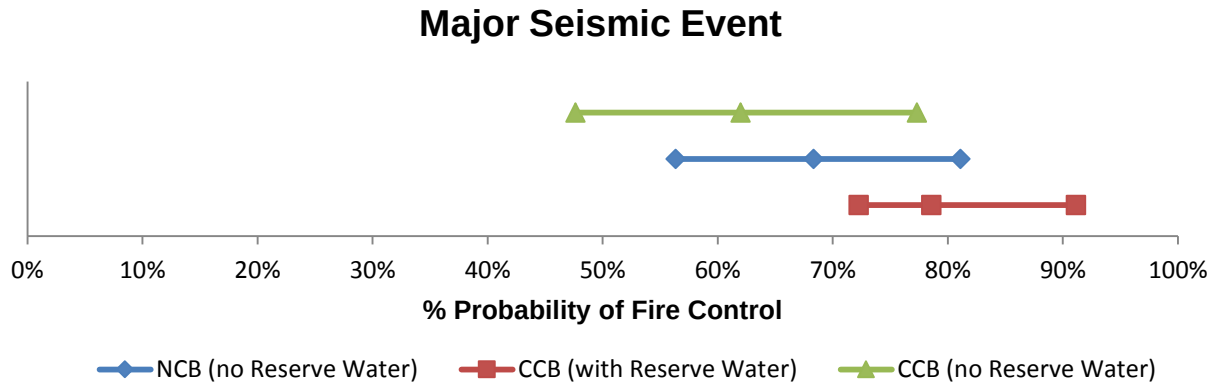
# Numerical Analysis of Fire Protection Systems

Probability of Fire combustible =1.2  Probability of Fire noncombustible building =1

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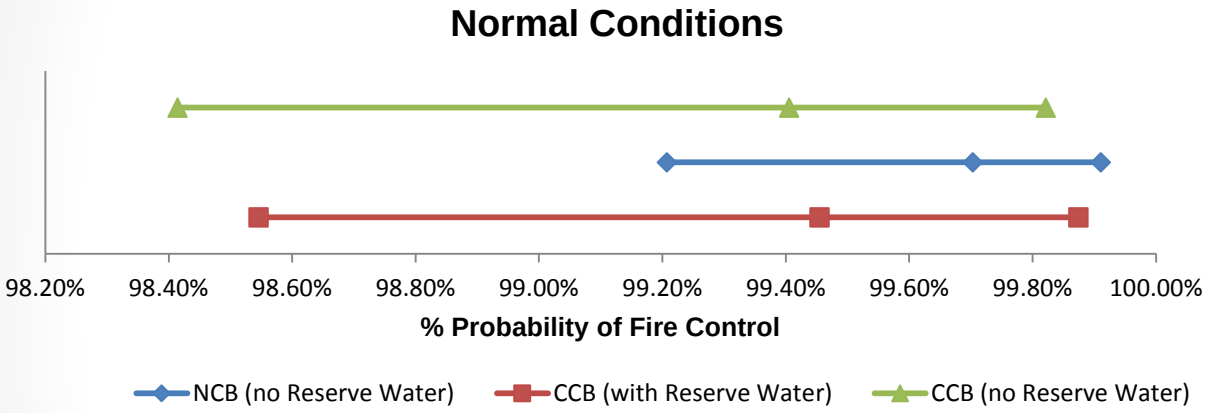
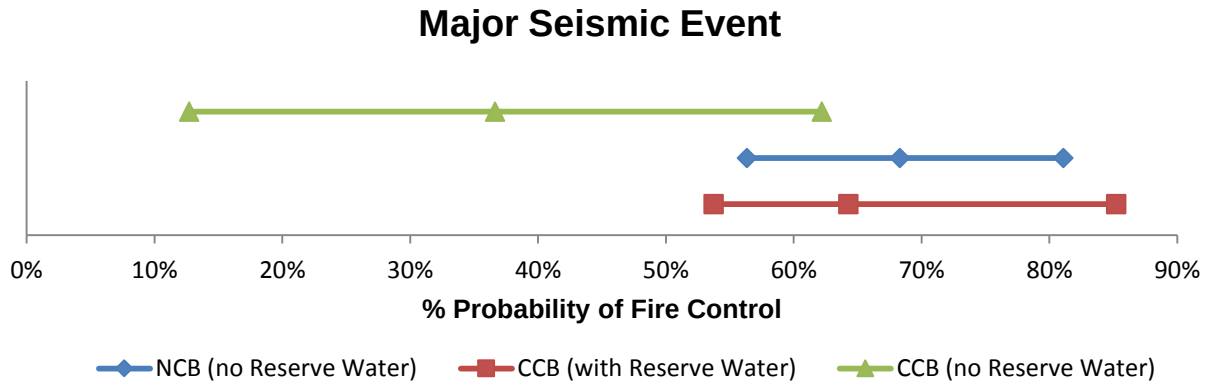
# Numerical Analysis of Fire Protection Systems

Probability of Fire combustible =2.0  Probability of Fire noncombustible building =1

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# 6 Conclusion

# Conclusion

- High reliability of sprinkler systems can be relied upon to reduce risk of tall timber buildings
- Addition of an on-site reserve water supply for combustible building presents a lower level of risk than “acceptable solution”

# Acknowledgements


- FPInnovations
- Forestry Innovation Investment
- Dr. Jim Mehaffey

# Thank you

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