Fire Safety of Tall Wood Buildings: A Research Review

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Course Description

Recent architectural trends in sustainable urban densification have spurred a movement toward increasingly tall buildings made from mass timber products or a combination of wood and other materials. Many tall timber building concepts are motivated by their suggested advantages in sustainability resulting from the use of wood as a renewable resource and low-carbon construction material. However, to ensure occupant safety and the protection of property, the next step is to fully assess the fire performance of these buildings. This presentation will discuss results of an initial study performed in coordination with the Fire Protection Research Foundation, as well as recommendations for research and testing.
Learning Objectives

1. Explain the current state of fire and life safety codes and standards as they relate to allowing timber as a structural material.
2. Describe the current understanding of fire performance of tall timber buildings, including results of fire testing and examples of high-rise timber buildings.
3. Identify areas for future testing and research needed to demonstrate safety in tall timber buildings.
4. Understand the importance of effective risk communication with timber building stakeholders.

Agenda

- Introduction to fire safety
- Introduction to timber buildings
- Timber building regulations
- Timber fire performance
- Gaps in knowledge
- Risk communication: performance based design and building codes

Fire Safety

- Safety from fire
  - Occupant evacuation
  - Emergency operations
- Safety from structural failure
  - Structural stability
- Safety during building use
  - Occupation

Timber Buildings

- Non-structural applications
  - Flooring, linings, facades, finishes
Timber Buildings

- Structural applications
  - Building materials

Timber Buildings

- Light timber frame products
  - 2” x 4” studs
  - “I” joists

Timber Buildings

- Light timber frame construction
  - Stick framing

Timber Buildings

- Heavy timber frame products
  - Engineered wood products

- Glue laminated wood (Glulam)
- Laminated Veneer Lumber (LVL)
Timber Buildings

- Heavy timber frame products
  - Engineered wood products

Cross Laminated Timber (CLT)

Timber Buildings

- Heavy timber frame products
  - Composite wood products

Post-tensioned timber

Timber Buildings

- Heavy timber frame products
  - Composite wood products

Timber-concrete composite

Timber Buildings

- Heavy timber frame construction
  - Panelized construction
Timber Buildings

- Heavy timber frame construction
  - Post and beam construction

Timber Buildings

- Heavy timber frame construction
  - Post-tensioned timber construction

Timber Buildings

- Historical examples
  - Yangxian Pagoda, China, 1056
  - Urnes Stakirke, Norway, 1132
  - Leckie Building, Vancouver, Canada, 1908

Timber Buildings

- Contemporary examples
  - Post and beam construction
  - Life Cycle Tower One, Austria, 2012
  - Bullitt Center, Seattle, Washington, 2013
Timber Buildings
- Contemporary examples
  - Post and beam construction

Wood Innovation Design Centre, Prince George, Canada, 2014

Stadthaus, London, UK 2009
Via Cenni, Milan, Italy, 2013

Timber Buildings
- Contemporary examples
  - Panelized construction

Forte Building, Melbourne, Australia, 2013

40-story office building, CEI Architecture, 2013
Timber Tower, SOM, 2013

Timber Buildings
- Feasibility studies
Timber Buildings
• Feasibility examples
  - Case for Tall Wood
  - 30-story high-rise, Michael Green Architecture, 2012

Building Regulations in Timber
• International regulations

<table>
<thead>
<tr>
<th>Country</th>
<th>Applicable Building Code</th>
<th>Maximum # of Stories</th>
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<tr>
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<td>Sprinklered</td>
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<tr>
<td>Australia</td>
<td>2013 Building Code of Australia (BCA)</td>
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<td>Sweden</td>
<td>2013 Planning and Building Act</td>
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<tr>
<td>United Kingdom</td>
<td>2010 Building Regulations</td>
<td>5**</td>
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</table>

* Indicates a height limit in addition to a maximum story limit

Building Regulations in Timber
• US regulations

<table>
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<th>Applicable Building Code</th>
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<td>2013 International Building Code (IBC)</td>
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<td>2012 National Fire Protection Association (NFPA) 5000</td>
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</tbody>
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* Number of heavy timber stories permitted
Timber Fire Performance

- Charring
  - Well-understood
  - Predictable
    - ~0.03 in/min [0.7mm/min]

- Fire Resistance
  - Sacrificial char layer
  - Post-fire stability

Timber Fire Performance

- Fire performance
  - Light timber

- Fire performance
  - Heavy timber
Timber Fire Performance

- Fire performance
  - Composite members

- Fire performance
  - Connections

Timber Fire Performance

- Fire protection
  - Light timber

- Fire protection
  - Heavy timber
Timber Fire Performance

- Fire protection
  - Connections

Timber Fire Performance

- Timber Frame 2000 (TF 2000)
  - Cardington, UK, 1999
  - Fire resistance mid-rise timber building

Timber Fire Performance

- Natural fire testing, Frangi and Fontana, 2005
  - CLT structure
  - Sprinklered vs. non-sprinklered
  - Exposed wood vs. gypsum lining

Timber Fire Performance

- Light timber assemblies
  - Improved fire resistance with gypsum board layers and thickness
  - Design equations (Just, Schmid and König, 2010)
Timber Fire Performance

- CLT assemblies (Osborne, Dagenais, Benichou, 2012)
  - Charring rate consistent with wood (~0.03 in/min [0.7mm/min])
  - Predictable behavior
  - Improved performance with gypsum board protection

Timber Fire Performance

- Timber composite assemblies (O’Neill, 2012)
  - Fire performance based on testing
  - Up to 2-hour ratings for assemblies

Gaps in Knowledge

- System-level testing
  - Exposed steel testing

Gaps in Knowledge

- Composite assemblies
Gaps in Knowledge

- Connections

Gaps in Knowledge

- Delamination

Gaps in Knowledge

- Penetrations
  - Fire-stopping

Gaps in Knowledge

- Economics
  - Fire protection
  - Life cycle costs
Risk Communication

• Technical understanding
  - Foundation for demonstrating safe design

Risk Communication

• Performance based design
  - Alternative solution to prescriptive codes

Risk Communication

• Initiating change
  - Model building codes

Risk Communication

• We cling to the myth that timber construction presents risks, while concrete and steel do not. Nonsense. Every material presents risks, but we manage them in different ways…
  - Russell Fortmeyer, Arup Structures
Acknowledgements

- Fire Protection Research Association
- National Fire Protection Association
- WoodWorks

Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

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