Fire Protection for Tall Wood Buildings

NFPA Symposium on Fire Protection for a Changing World
Munich 18 April 2016

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Outline

• State of the art
  • Present knowledge and design tools - Passive fire protection, Active fire protection
• Challenges
  • Proper design and control critical for fire safety
  • Fires at building sites
  • Reluctance and scepticism for very high timber buildings
  • Contribution to fire load
• Two aspects
  • Life safety – National building codes
  • Property loss prevention – Insurance concerns
• Way forward
  • Performance Based Design
  • Prioritised research
Background info

- Nordic and European projects, e.g. FireInTimber
- White paper *Fire resistance of timber structures* for NIST (Buchanan, Östman and Frangi)
- Ongoing project *Fire challenges of Tall Wood Buildings* for FPRF (NRC in Canada and SP)
New timber materials

Engineered Wood

- Glulam
- LVL
- CLT-Cross Laminated Timber
- PSL
- Pres-Lam
- etc
Background to recent development - Performance based requirements

Multi-storey timber buildings
Performance requirements for structures

Load bearing R

Integrity E

Insulation I
Non-combustibility

Performance requirements (R, E, I)

e.g. REI 60, EI 30 etc
Possibilities for multi-storey timber buildings in Europe 1990-2020

14 storeys
Bergen, Norway
Fire safety in timber buildings –
The very first European guideline

- Main result of the FireInTimber project
- Short version in nine languages
## Fire safety in timber buildings

### Chapters:

1. Timber buildings
2. Fire safety in buildings
3. European system for construction products
4. Wood products as linings, floorings, claddings and facades
5. Separating timber structures
6. Load-bearing timber structures
7. Timber connections
8. Fire stops, service installations and detailing in timber structures
9. Novel products and their implementation or application
10. Active fire protection
11. Performance based design
12. Quality of construction workmanship and inspection
Ch 4. Wood products as linings, floorings, claddings and facades (Reaction to fire)

Criteria for:

- Reaction to fire classification in end uses, CWFT, Euroclass D
- Improved reaction to fire performance, Euroclass B or C
- Wood coverings with fire protection ability, class $K_{10} - K_{60}$
- Wooden facades

News:
European K classes may be reached by wood products
Calculation of the time $t_{\text{ins}}$ by adding the contribution to the fire resistance of the different layers. The time of each layer depends on:

- Material and thickness of the layer
- Position of the layer within the assembly

The position has to be considered, because layers influence each other:

$$t_{\text{ins}} = \sum_{i=1}^{i=n-1} t_{\text{prot},i} + t_{\text{ins},n}$$
Ch 6. Load-bearing timber structures R, REI

Design acc to Eurocode 5

News: New models for

• Cross-laminated timber (CLT)
• Light timber frame floors with I-joists

• Failure time of claddings
  • Data base for gypsum plasterboards with generic conservative values
  • The producer may declare better values obtained from testing
Ch 8. Fire stops, service installations and detailing
Ch 10. Active fire protection

- Fire detection and alarm
- Smoke control
- Suppression systems
- Sprinklers save lives!
- Fire safety design with sprinklers
  - Relaxations of prescriptive requirements, e.g. more visible wood
Challenges:

1. Proper design, detailing and control
2. Fires at building sites
3. Reluctance and scepticism for very high timber buildings – Insurance concerns
4. Contribution to fire load – Strategies to avoid collapse
Challenge 1: Proper design, detailing and control

Recent accident

Small kitchen fire

Total damage (after fire)
Fire spread to attic

Inbetween

Spread downwards

Summary
- Small fire
- Spread to attic and through voids, also downwards
- Large consequences

Main reasons
- Voids within structure
- Lacking detailing
- Inferior installations
Challenge 2: Fires at building sites

Happened in the UK and North America. Mainly related to timber frame structures.

None in rest of Europe so far. Massive (CLT) structures more robust for higher buildings.
Challenge 3: Reluctance to very high timber buildings

Vision
100 m - 34 stories
Stockholm 2023
100 years anniversary
HSB (Building association)
Some insurance companies have recently started to react heavily against high timber buildings

May not insure timber buildings

Mainly afraid of water damage (not fire)
Two aspects:

1. Life safety - National building regulations
2. Property loss prevention - Insurance concerns

- Many insurance companies have limited experience of high timber buildings and limited technical expertise (in Europe)
- Limited statistical data available

International cooperation needed
Recent study on statistics
Multi storey timber buildings since 1994 in Sweden

First step:
Identify timber buildings
# Fire incidents in timber buildings 1994-2015 acc to Swedish statistics from MSB

<table>
<thead>
<tr>
<th></th>
<th>Total incidents</th>
<th>In item first ignited</th>
<th>In room of origin</th>
<th>In fire cell of origin</th>
<th>In building of origin</th>
<th>To other buildings</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>All buildings</td>
<td>49 949</td>
<td>32 386</td>
<td>11 160</td>
<td>3 865</td>
<td>1 347</td>
<td>84</td>
<td>107</td>
</tr>
<tr>
<td>Expected in timber buildings</td>
<td>73</td>
<td>47</td>
<td>17</td>
<td>6</td>
<td>2</td>
<td>0,1</td>
<td>0,2</td>
</tr>
<tr>
<td>Incidents in timber buildings</td>
<td>22</td>
<td>12</td>
<td>7</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

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Conclusions on statistics study

- Less fire incidents in modern multi storey timber buildings than average
- Probably due to more modern and safe fire design than average
- The timber structure had influence in only 1 case
- No fire victims
- Too few buildings and incidents for quantitative conclusions
Challenge 4: Contribution to fire load?

Can we design for burnout?

Depends on:

- Fire severity
- Duration of burning period
- Depth of charring
- Ventilation allowing temperatures to drop
- Intervention after the fire is out
- Etc
Can we design for burnout?

**YES**, with full encapsulation
Challenges - Summary

- Quality of construction workmanship and inspection - proper detailing is the main challenge to reach fire safety
- Fire safety during construction – separation and control
- Define and control the main strategies to reach property loss prevention
- Control the main strategies to avoid collapse of the building, if a fire is not extinguished (by an automatic active system or by the fire services)
Performance Based Design

- Quantitative risk assessment
- Consider all factors
- Define fire exposure
- Assess performance of all components

A possible performance statement:
“Very tall buildings shall be designed with a very low probability of fire spread and structural collapse, regardless of fire-fighting services.”
Possible hierarchy by building height: Performance Based Design

<table>
<thead>
<tr>
<th>Level of specified performance:</th>
<th>Design strategy:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low-rise buildings</strong></td>
<td></td>
</tr>
<tr>
<td>Escape of occupants with no assistance</td>
<td>No encapsulation.</td>
</tr>
<tr>
<td>No property protection</td>
<td>No sprinklers.</td>
</tr>
<tr>
<td><strong>Mid-rise buildings</strong></td>
<td></td>
</tr>
<tr>
<td>Escape of occupants with no assistance</td>
<td>No encapsulation.</td>
</tr>
<tr>
<td>Some property protection</td>
<td>Sprinklers.</td>
</tr>
<tr>
<td><strong>Taller buildings</strong></td>
<td></td>
</tr>
<tr>
<td>Escape with firefighter assistance</td>
<td>Limited encapsulation.</td>
</tr>
<tr>
<td>Burnout with some firefighting intervention</td>
<td>Sprinklers, with extra water nearby.</td>
</tr>
<tr>
<td><strong>Very tall buildings</strong></td>
<td></td>
</tr>
<tr>
<td>Protect occupants in place</td>
<td>Complete encapsulation.</td>
</tr>
<tr>
<td>Complete burnout with no intervention</td>
<td>Sprinklers, with water stored on roof.</td>
</tr>
</tbody>
</table>

Development of this will require a lot of work - 10 years?
Prioritised research needs

1. Design fires (for all structural materials)
2. Contribution of timber to the fire load
3. Charring rates as a function of fire exposure
4. Self-extinguishment of charred wood
5. Performance of encapsulated timber
6. Fire resistance of connections
7. Prevention of fire spread via voids and cavities
8. Wooden façade claddings and linings
9. Influence of passive and active fire protection
Conclusions

- Timber is starting to compete with concrete and steel
- We need Performance Based Design
- Timber buildings can have the same level of fire safety as other structural materials, if:
  - All factors are considered in design
  - Risk assessment tools are used properly
  - Computer models are verified by fire tests
  - Good design guides and codes are prepared
  - Peer reviews and site inspections are carried out

Discussion needed
Thanks!

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