Performance Based Design of Fire Safety in High Rise Timber Buildings

Carl Pettersson
MSc (Risk), BSc (Fire), MIEAust, MSFS, CEng, NER (Fire Safety)

Senior Fire Engineer
RED Fire Engineers
Offices in Adelaide, Brisbane, Melbourne, Perth, Sydney
Projects throughout Australia
Engineered Timber

Common products
- Cross Laminated Timber (CLT)
- Glued Laminated Timber (Glulam)
- Laminated Veneer Lumber (LVL)
- Oriented Strand Board (OSB)
- Medium Density Fibreboard (MDF)
- Plywood

Other
- Engineered Bamboo (grass)
- Bamboo Scrimber and Laminated Bamboo Sheets
Why Engineered Timber?

- Benefit 1 – Sustainability
- Benefit 2 – Structural Capability
- Benefit 3 – Construction Method
- Benefit 4 – Cost Savings
- Benefit 5 – Time Savings
Potential of Tall Timber?

Extensions to existing buildings
Session Outline

• The principles of fire safety
• Timber is different – fire dynamics
• Large scale testing
• Practical challenges
• Fire safety design
The Principles of Fire Safety

What do we have to protect against fire?
The Principles of Fire Safety

Protected egress/access core (fire stairs)

- Scissor stairs in separate shafts
- 9 m min.
- 45 m max. in Class 2 & 3
- 45 m max. in patient care area of Class 9a
- 60 m max. for other cases
The Principles of Fire Safety

Fire compartmentation

De Pass Gardens, Barking, London, 9 June 2019 courtesy of @SAKUKRISH

The Principles of Fire Safety

2004, Parque Central office building, a 54-story structure in Caracas, Venezuela

Withstand full burnout of a fire
The Principles of Fire Safety

No catastrophic collapse

Plasco building, Tehran 2017
The Principles of Fire Safety

- Safety for people, fire brigade and protection of property
- Protected egress/access core of the building
- Fire compartmentation
- Complete burnout of a fire
- No catastrophic collapse
Timber is Different

Timber is Different
Timber is Different

CLT
Large sections

Glulam
Columns and beams
Joseph Su and Pierre Simon Lafrance, Matthew Hoehler and Matthew Bundy, Fire Safety Challenges of Tall Wood Buildings – Phase 2: Task 2 & 3 – Cross Laminated Timber Compartment Fire Tests, National Institute of Standards and Technology (NIST) Gaithersburg, MD, USA, 2018

Figure G1 in Wood Solutions Technical Guide 38 – 10 – 2016

Figure 89. CLT contribution to heat release rate in Test 1-5 (baseline time shifted).
Large Scale Testing - CLT

Six fire tests by NIST – NRC Canada
Test 1-5 – Exposed side wall – 60 min

HRR = 4000 kW
Time = 60 min

Figure 89. CLT contribution to heat release rate in Test 1-5 (baseline time shifted).
Test 1-5 – Exposed side wall – 120 min

HRR = 950 kW
Time = 2 hours

https://www.nist.gov/el/fire-research-division-73300/national-fire-research-laboratory-73306/fire-safety-challenges-0
Test 1-6 – Exposed side wall and ceiling
Figure 103. Heat release rates in CLT compartment tests.
Large Scale Testing - CLT

• Some more testing presented in the following publications
  • Rory M. H, et.al “Effects of exposed cross laminated timber on compartment fire dynamics”, The University of Edinburgh 2017
  • Samuel L. Zelinka et.al “Compartment fire testing of a two-storey mass timber apartment building” 2017, U.S department of Agriculture, Forest Service, Forest Products Laboratory 2018
Large Scale Testing - CLT

- The fuel load in walls and ceilings contribute to:
  - Long fire scenarios
  - High temperatures
  - Combustion outside the compartment

Design Challenges

• Additional fuel load
• Ventilation, layout and fire dynamics
• Delamination of lamellas
• Second flashover scenarios
• Adhesive glue type used (PUR or MUF), thermal properties?
The Adhesive is Important

Delamination of Cross-laminated timber and its impact on fire development Focusing on different types of adhesives, Eric Johansson, Anton Svenningsson - 2018
Design Benefits

• It takes a long time before the structure lose its loadbearing capacity

• Sprinkler protection is efficient - unlikely to involve timber in a fire
Practical Challenges

• Connections and fixings to timber, concrete or lightweight construction
• Screw fixings and other fixings
• Ventilation and service fixings
• Penetrations
• Cavities and gaps
Design Challenges

Charring calculations are not appropriate
Design Challenges

- Furnace testing to the standard fire curve
- Compare with DtS Requirements
- Charring calculation to expected structural failure (reduced cross section method)
How do we make these designs possible?

Acceptable risk for:
- Occupants
- Fire fighters
- Property

Risk = consequence x probability
Fire Safety Design

Consequence <
Fire Safety Design

> Consequence

25 King St, Brisbane Photo credit: Bates Smart / batessmart.com
Fire Safety Design

• Maybe acceptable to lose in a fire, if occupant can escape and there is a demonstrated period for fire brigade intervention.

• Accepted that a low rise building may be lost in a fire.

• Occupants may be required to remain in the building.
• Occupants may be above fire floor.
• Takes fire brigade longer to intervene.
• **Structure must survive burn-out.**
“Very tall buildings shall be designed in such a way that there is a very low probability of fire spread to upper floors and a very low probability of structural collapse, at any time during a fire regardless of whether or not the fire can be controlled by fire-fighting services and/or suppression systems.”

INSTA/TS 950 Fire Safety Engineering – Comparative method to verify fire safety design in buildings, InterNordic Standard, 2014.


BBRAD, general recommendations on the analytical design of a building’s fire protection

PAS 79:2012 Fire Risk Assessment. Guidance and a recommended methodology


Fire Safety Design

Determine risk acceptance criteria:
• Understand different types of fire scenarios
• Consider the use and type of building

Reduce the risk:
• Automatic sprinkler protection (effective ~90-98 % fires)
• Reduce the fuel load (protect the timber)
• Reduce ignition sources
• Fire compartmentation to contain a fire
• Distance to other buildings
Fire Safety Design

Most important in tall buildings:

• Protect exits
• No structural collapse
Fire Safety Design

Most important in tall buildings:

- Internal fire spread
- External fire spread
- No structural collapse
Fire Safety Design

Most important in tall buildings:
- Water supply
- Protected access paths
- No structural collapse
Fire Safety Design

• The whole design team must be aware of the design challenges
• Identify the risks early (approval, fire safety, delivery, compliance)
• A holistic understanding
Fire Safety Design

• Involve experts early in the design
• Identify the practical challenges early
• What products and materials are proposed?
• Allow for redundancy with conservatism to get flexibility
• Document the construction extremely well
• Rigorous inspections of everything, all the time
Summary

• Safety of occupants, fire brigade and property protection
• Timber is different
• There are many ‘unique’ challenges with timber construction
• We need more research
• Adopt a holistic risk based approach
• United responsibility
Summary

Is tall timber a good idea?

• There are many benefits
• We have the tools
• We have the knowledge
• But are we prepared to put in the effort?
• Can we afford mistakes?
Thank you

Carl Pettersson
M: +61 451 032 967
E: carl@redfireengineers.com.au
W: www.redfireengineers.com.au