Performance Based Design of Fire Safety in High Rise Timber Buildings

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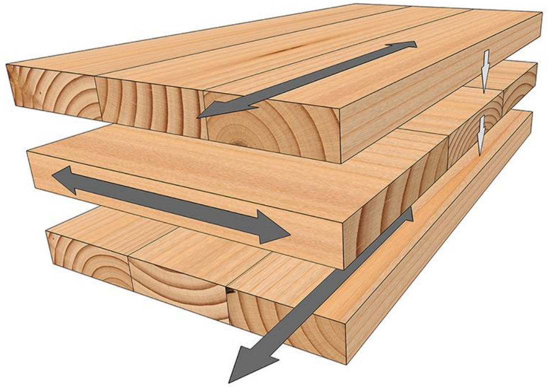
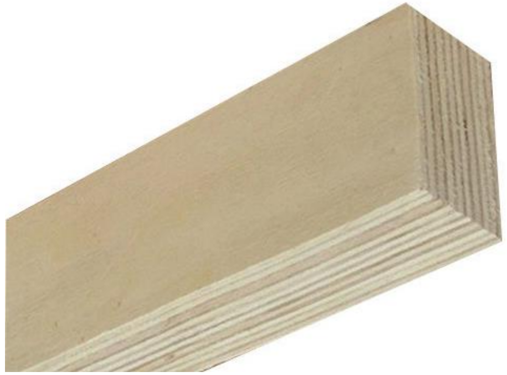
Engineered Timber





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?

Bergen, Norway

Dalston Lane, London

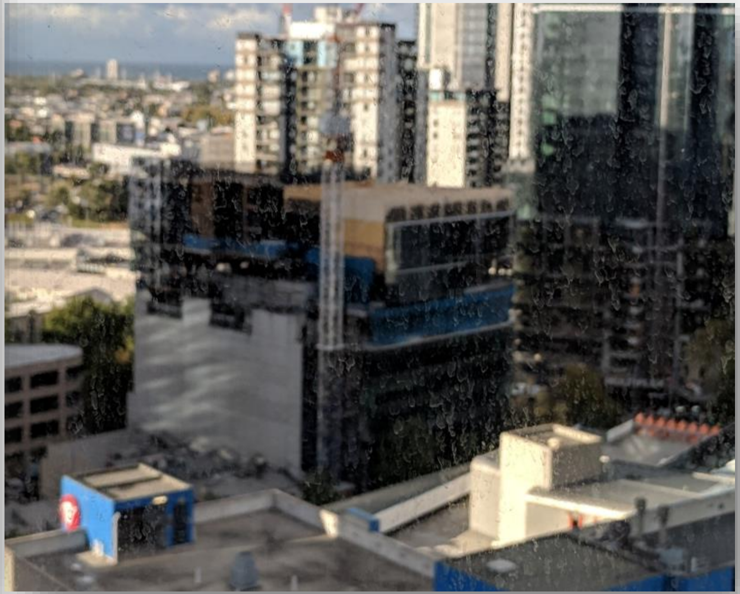
International House Sydney, Barangaroo

- Benefit 1 – Sustainability
- Benefit 2 – Structural Capability
- Benefit 3 – Construction Method
- Benefit 4 – Cost Savings
- Benefit 5 – Time Savings

Potential of Tall Timber?

55 Southbank Boulevard, Southbank VIC 3006
Courtesy of Council on Tall Buildings and Urban Habitat

Extensions to existing buildings



Session Outline

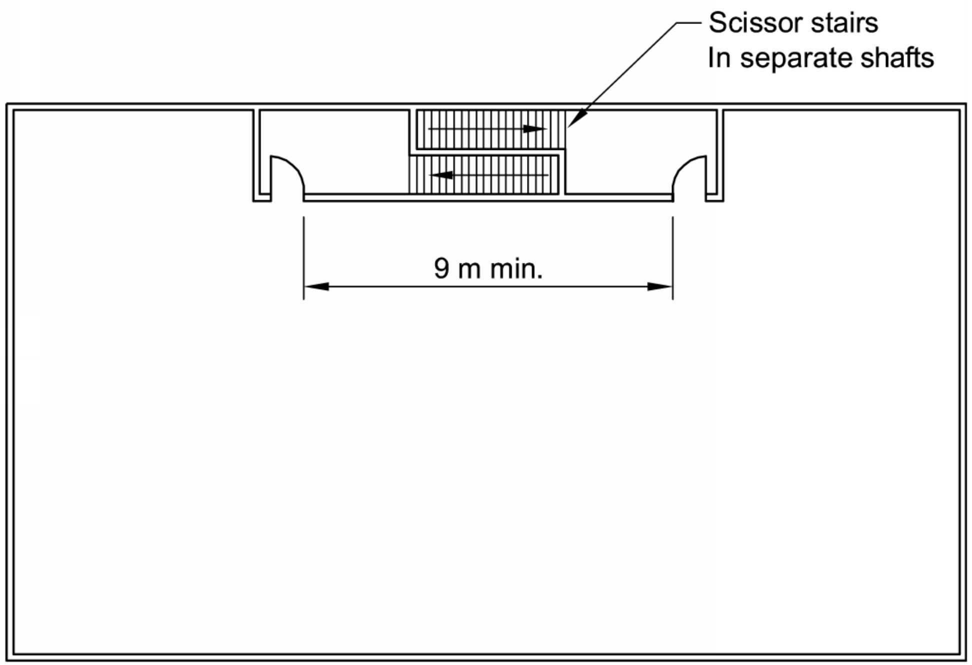
- The principles of fire safety
- Timber is different – fire dynamics
- Large scale testing
- Practical challenges
- Fire safety design

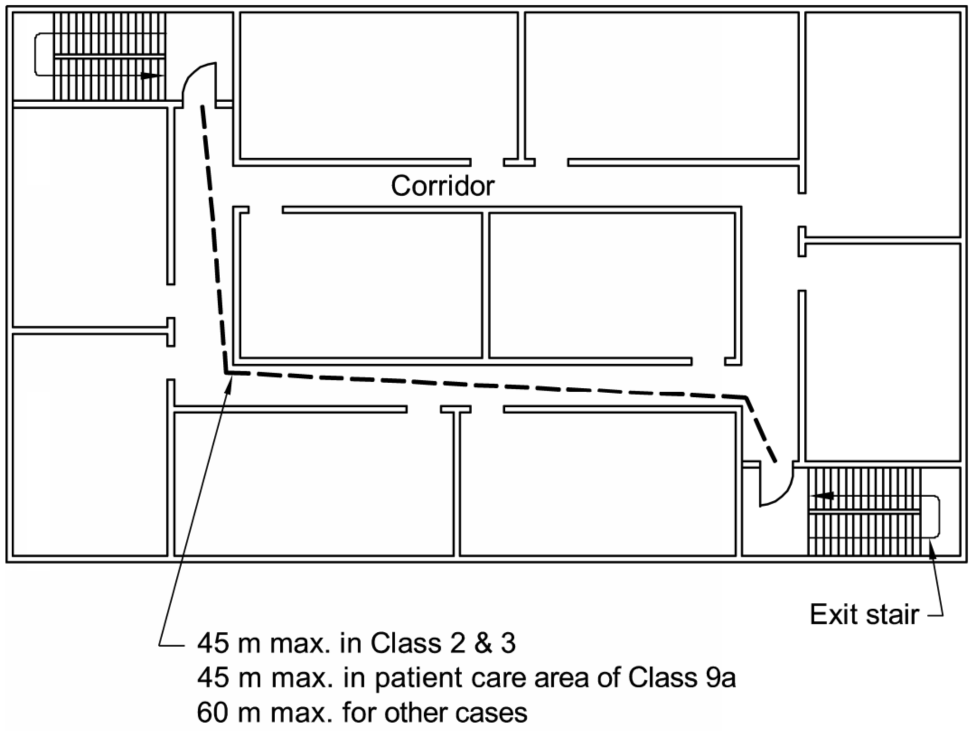
The Principles of Fire Safety

What do we have to protect against fire?

The Principles of Fire Safety

Protected egress/access core (fire stairs)





The Principles of Fire Safety

Fire compartmentation

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

Lakanal House, Sceaux Estate, Camberwell, London (GB) on 3rd July 2009.

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

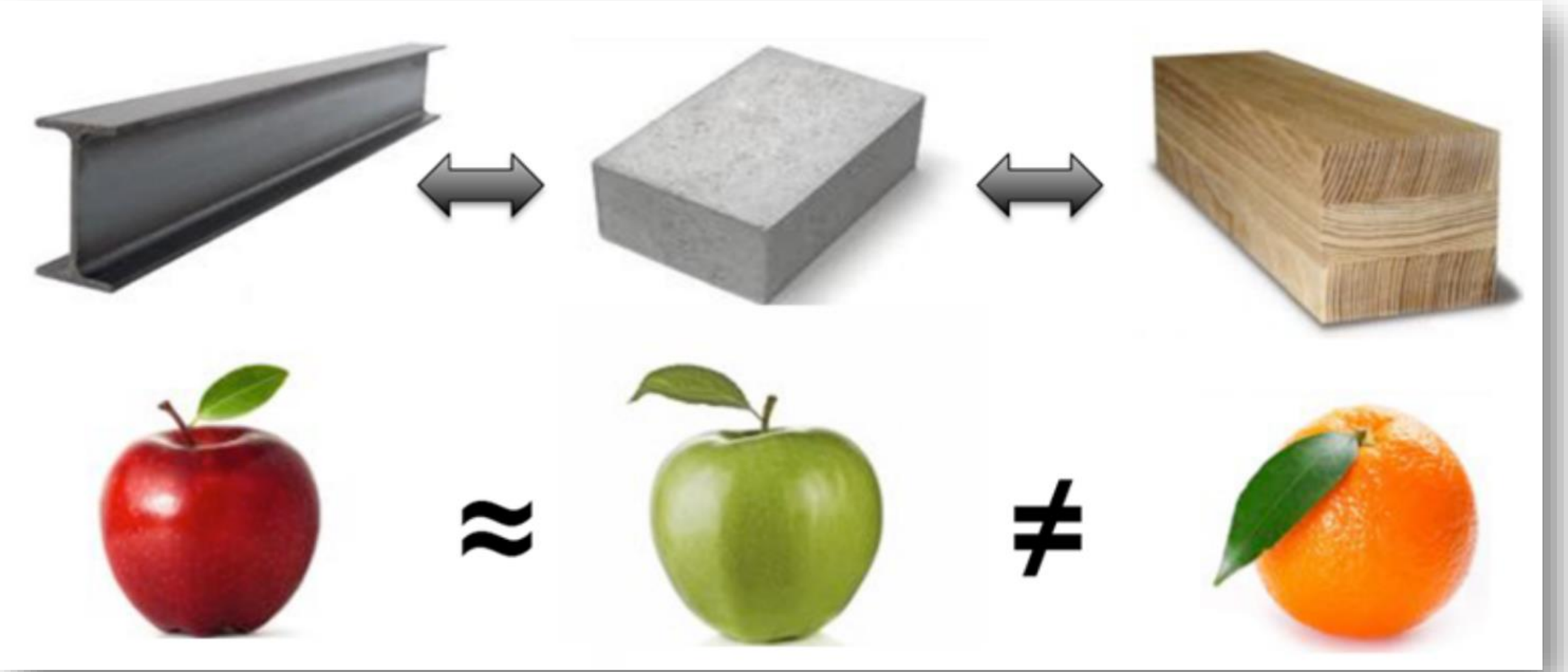
Plasco building , Tehran 2017

No catastrophic collapse

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



Luke Bisby, Presentation at IAFSS 12th International Conference, Lund, 2017

Timber is Different

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Timber is Different

CLT

Large sections

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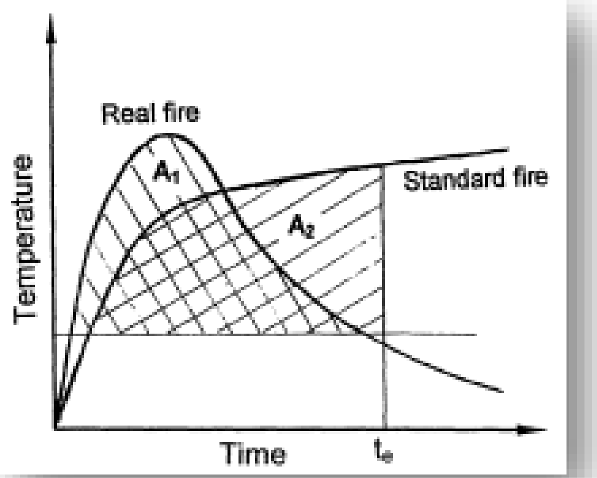
Glulam

Columns and beams



http://blog.strongbuild.com.au/clt-fire-testing/

Figure G1 in Wood Solutions Technical Guide 38 - 17-10-2016

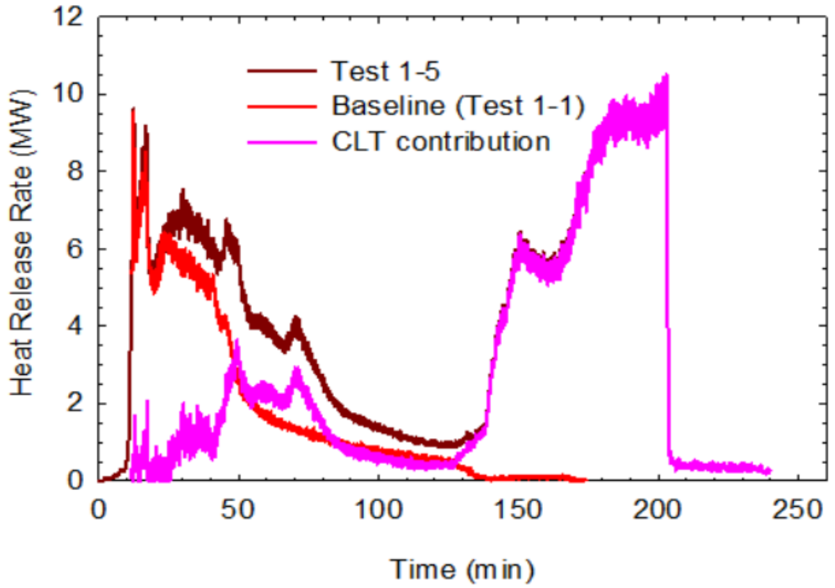
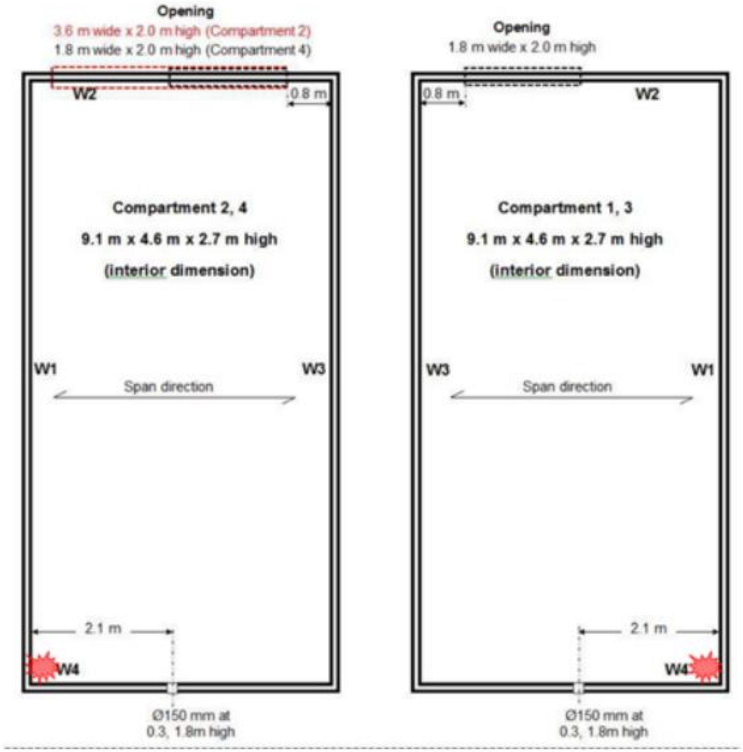


Figure 89. CLT contribution to heat release rate in Test 1-5 (baseline time shifted).

Joseph Su and Pier-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

Large Scale Testing - CLT

Six fire tests by NIST – NRC Canada



a)

b)

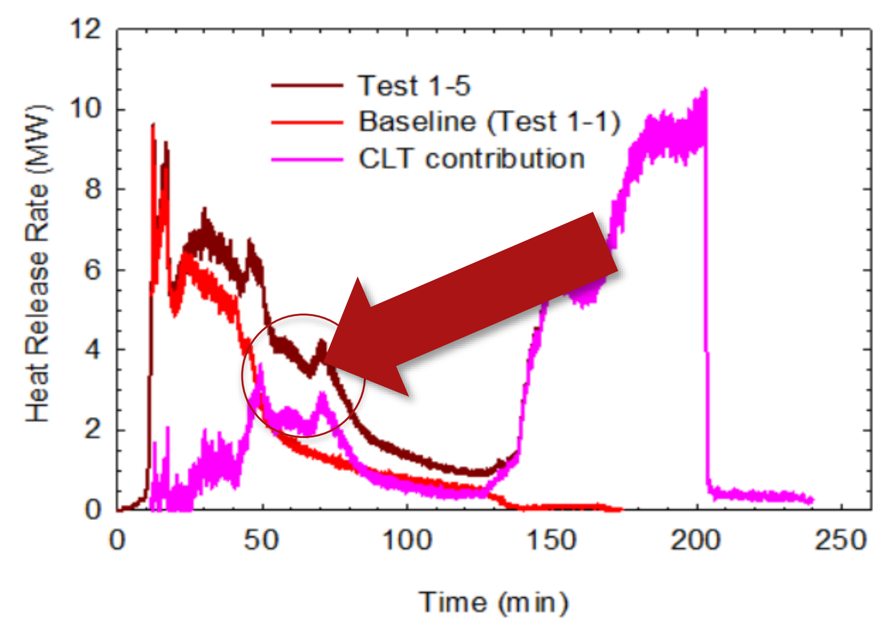


Figure 89. CLT contribution to heat release rate in Test 1-5 (baseline time shifted).

https://www.nist.gov/el/fire-research-division-73300/national-fire-research-laboratory-73306/fire-safety-challenges-0

Test 1-5 – Exposed side wall – 60 min

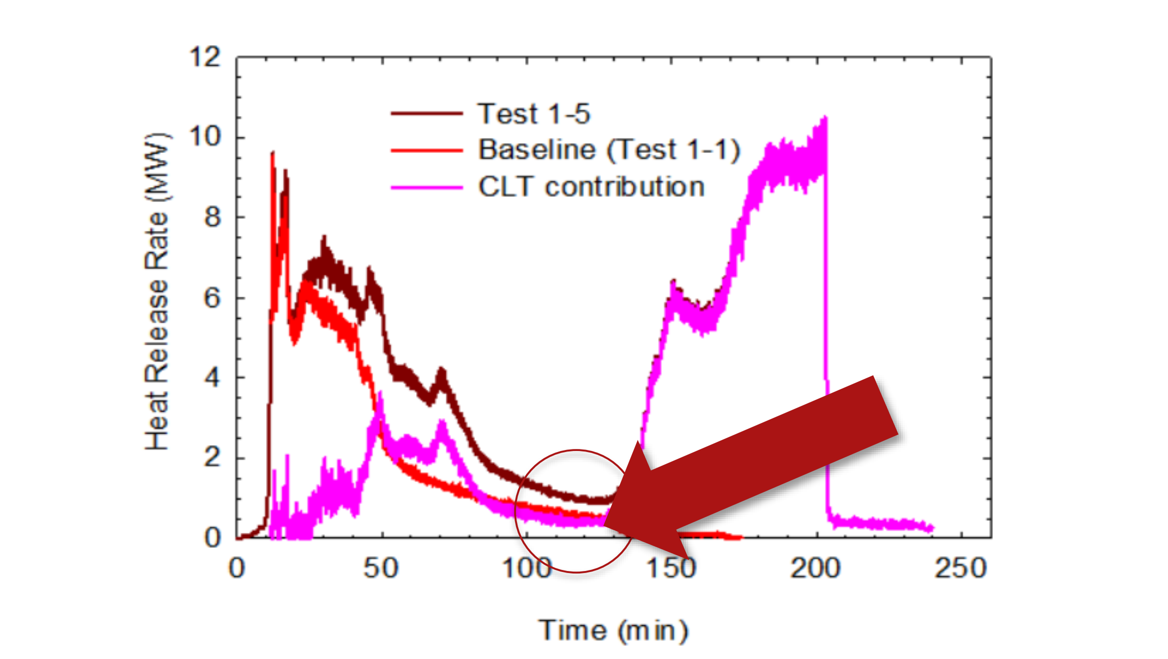


Figure 89. CLT contribution to heat release rate in Test 1-5 (baseline time shifted).

https://www.nist.gov/el/fire-research-division-73300/national-fire-research-laboratory-73306/fire-safety-challenges-0

Test 1-5 – Exposed side wall – 120 min

Test 1-6 – Exposed side wall and ceiling

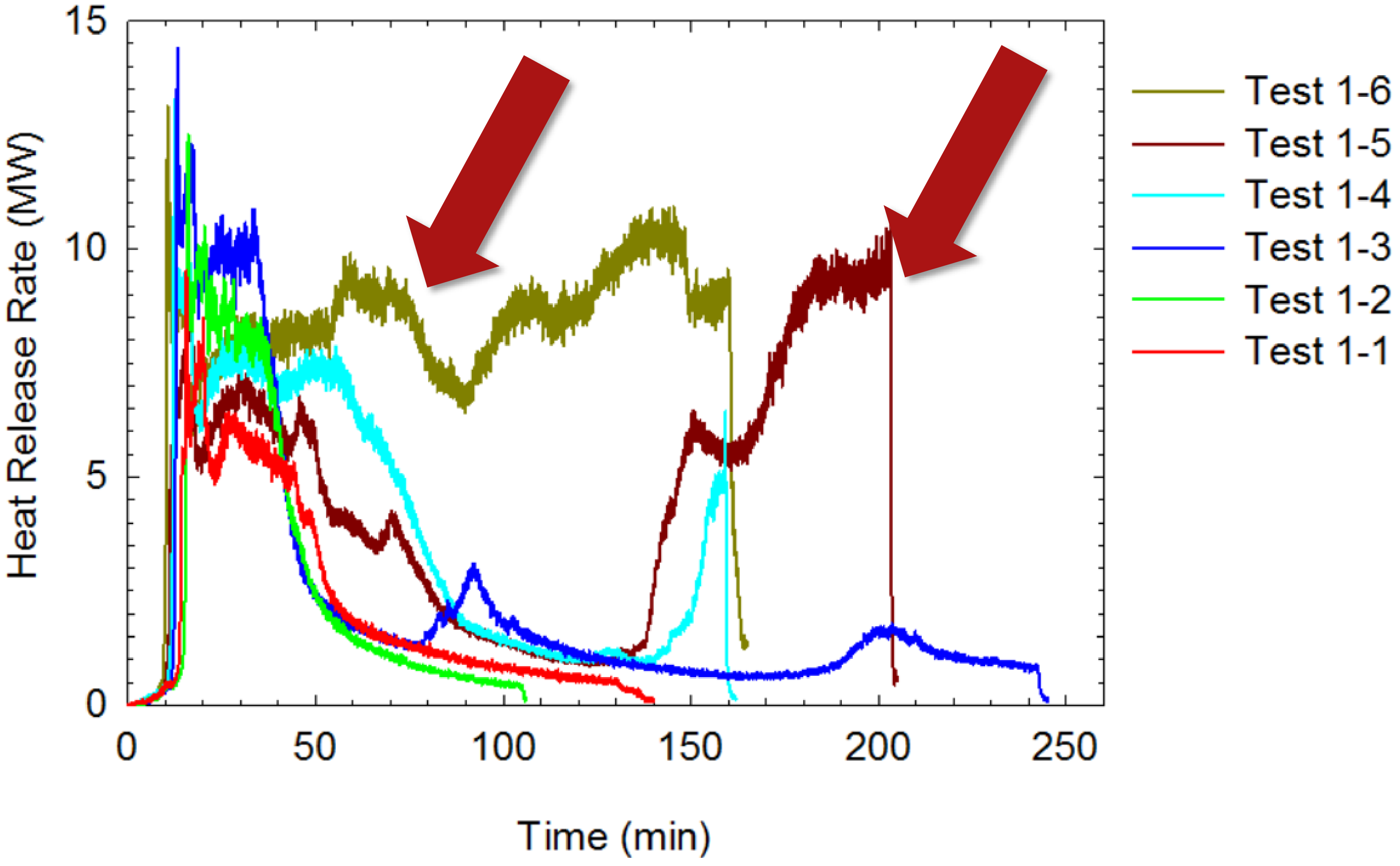


Figure 103. Heat release rates in CLT compartment tests.

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
  - EASS, Estonian Academy of Security Sciences, "Fire Test of a Three-storey House in CLT" Estland, 2017, https://vimeo.com/249077905/ab6bd31630
  - Brandon D, Dagenais C. "*Fire Safety Challenges of Tall Wood Buildings - Phase 2: Task 5 - Experimental Study of Delamination of Cross-Laminated Timber (CLT) in Fire*", NFPA, RISE & FPInnovations, 2018.

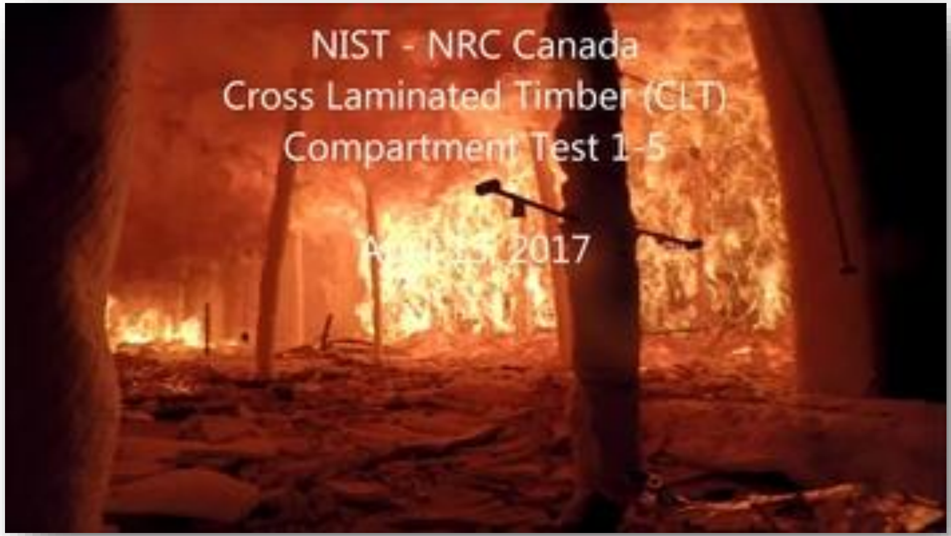
Large Scale Testing - CLT

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

EASS, Estonian Academy of Security Sciences, "Fire Test of a Three-storey House in CLT" Estland, 2017, https://vimeo.com/249077905/ab6bd31630

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?



Task 2 & 3 – Cross Laminated Timber Compartment Fire Tests, National Institute of Standards and Technology (NIST) Gaithersburg, MD, USA, 2018

The Adhesive is Important

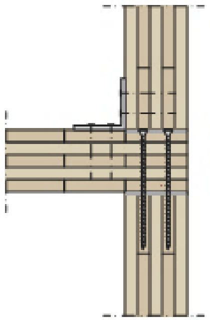
Delamination of Cross-laminated timber and its impact on fire development Focusing on different types of adhesives, Eric Johansson, Anton Svenningsson - 2018

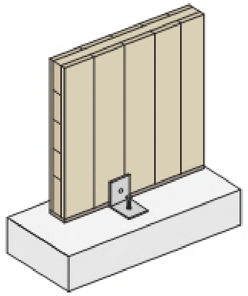
Design Benefits

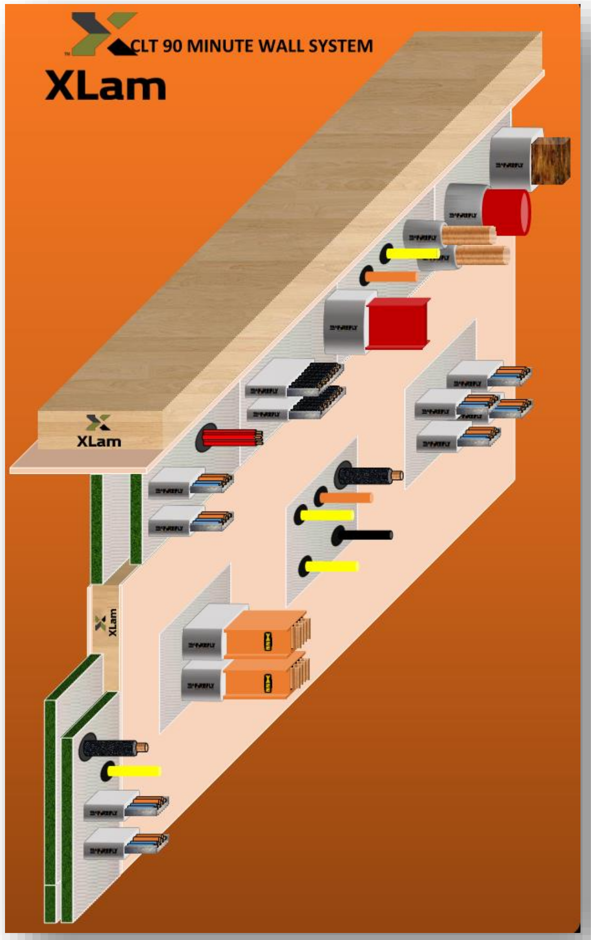
- It takes a long time before the structure lose its loadbearing capacity
- Sprinkler protection is efficient - unlikely to involve timber in a fire

Practical Challenges

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



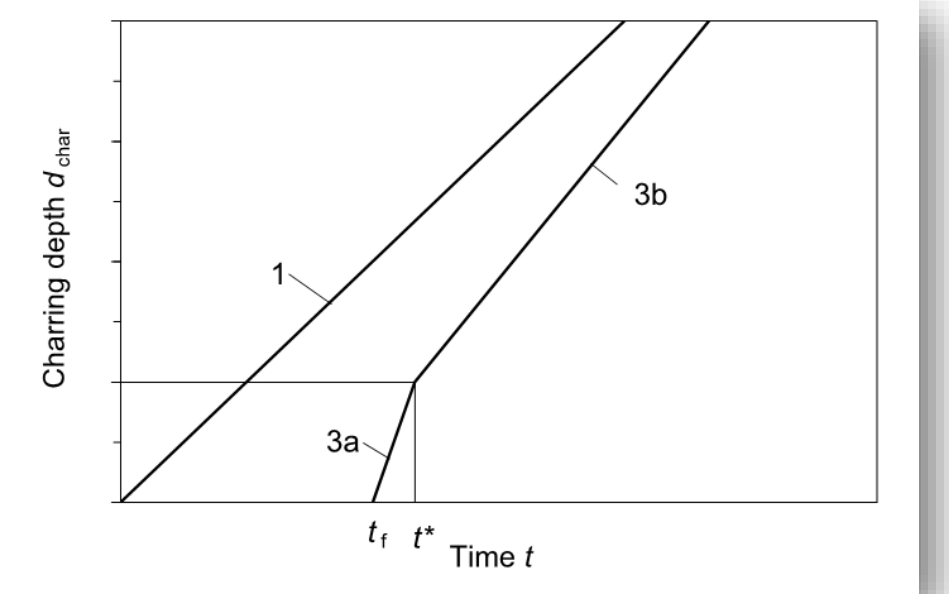




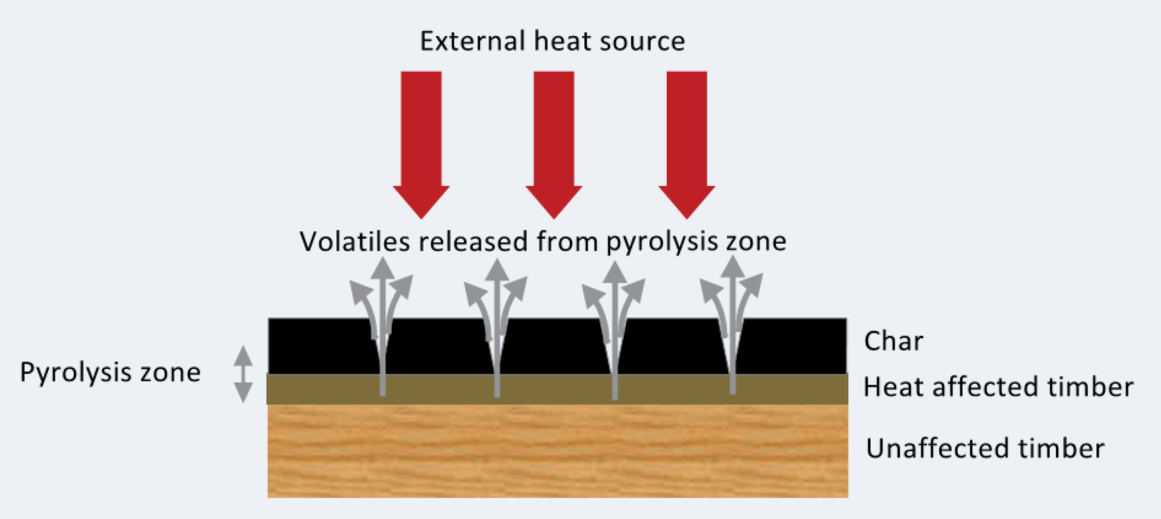
TBA Firefly, Technical Data Sheet 37, Firestopping Xlam CLT Walls

Design Challenges

Charring calculations are not appropriate



Fire safety in timber buildings, Technical guideline for Europe, SP Report 2010:19



Wood Solutions_TD Guide 38_17_10_16

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?

Mjøstårnet, courtesy of Moelven Limtre AS

Acceptable risk for:

- Occupants
- Fire fighters
- Property

Risk =
consequence x probability

Fire Safety Design

Consequence <

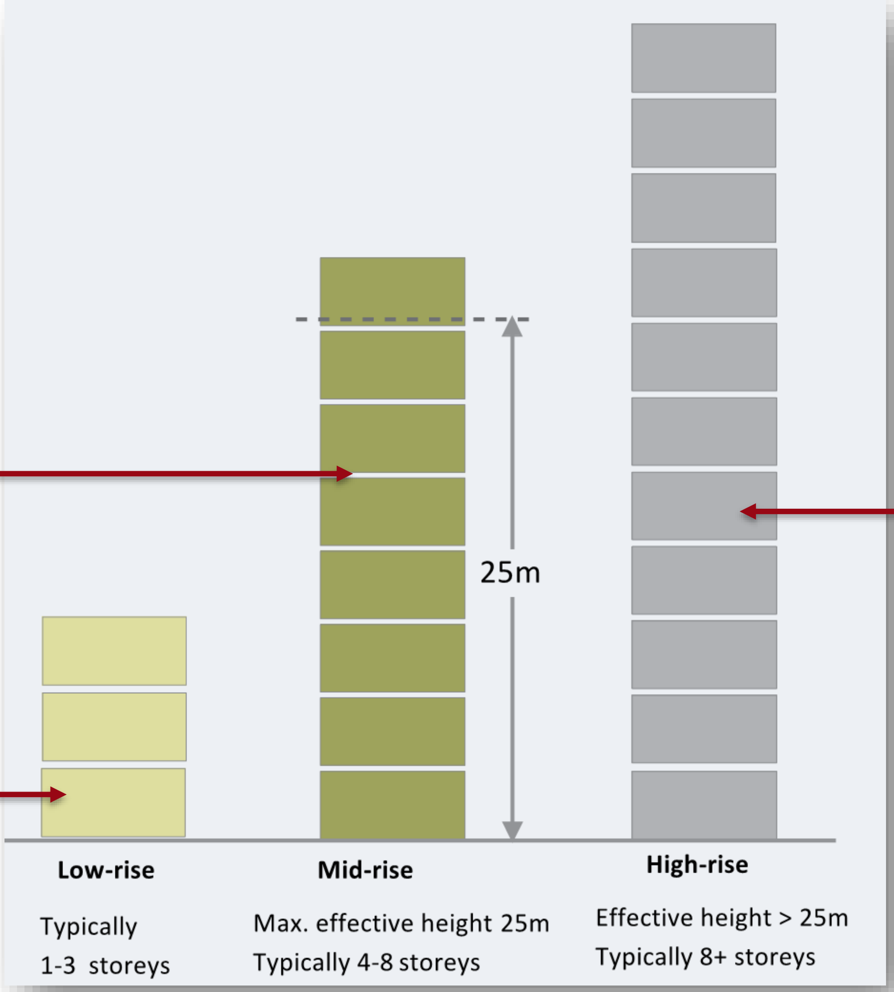
Fire Safety Design

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

> **Consequence**

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.



Technical Design Guide issued by Forest and Wood Products, Australia, Fire Safety Design of Mid-rise Timber Buildings Basis for the 2016 changes to the NCC

- 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.**

Fire Safety Design

"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.**"

A.H. Buchanan, B. Östman, A. Frangi, Fire Resistance of Timber Structures, NIST White Paper, Washington DC, USA, 2014.

Fire Safety Risk Guidelines

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

prINSTA/TS 951 Fire Safety Engineering – Probabilistic Methods for Verifying Fire Safety Design in Buildings, InterNordic Draft Standard, 2017. *To be published 2018*

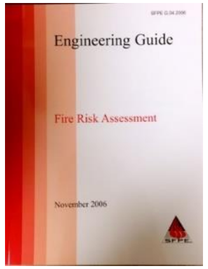
BBRAD, general recommendations on the analytical design of a building's fire protection
https://www.boverket.se/en/start-in-english/building-regulations/translated-building-regulations/bbrad/

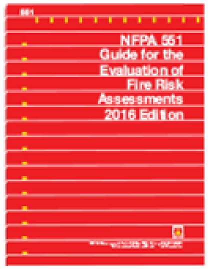
PAS 79:2012 Fire Risk Assessment. Guidance and a recommended methodology

ISO 31000:2018, *Risk management – Guidelines*

NFPA 551: Guide for the Evaluation of Fire Risk Assessments

SFPE Engineering guide,
'Fire risk assessment'; SFPE G04 2006.
https://sfpe.site-ym.com/store/ViewProduct.aspx?ID=4604154





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

Kulturhus I Skellefteå, Sweden, by White Arkitekter
http://noisebreak.com/16-most-fascinating-wooden-skyscraper/

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?

Kulturhus I Skellefteå, Sweden, by White Arkitekter
http://noisebreak.com/16-most-fascinating-wooden-skyscraper/

RED
FIRE ENGINEERS

Thank you

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