Structural Fire Modelling Strategies for Exposed Mass Timber Compartments and Experimental Gaps for Model Validation

Guest Presentation by for Mr. Ethan Philion who cannot be here:

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Motivation

[1]

[2]

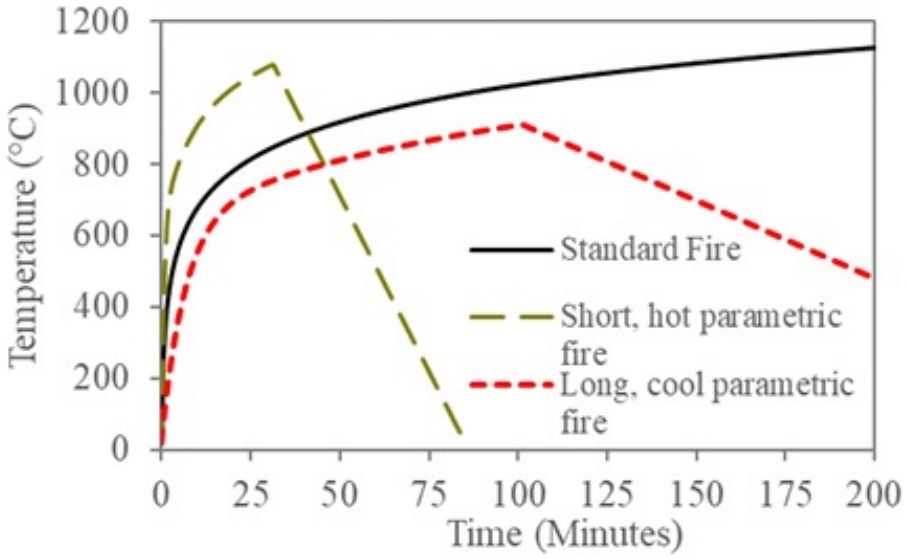
Timber is increasingly becoming a popular structural material promoted by its perceived **sustainability and structural benefits**.

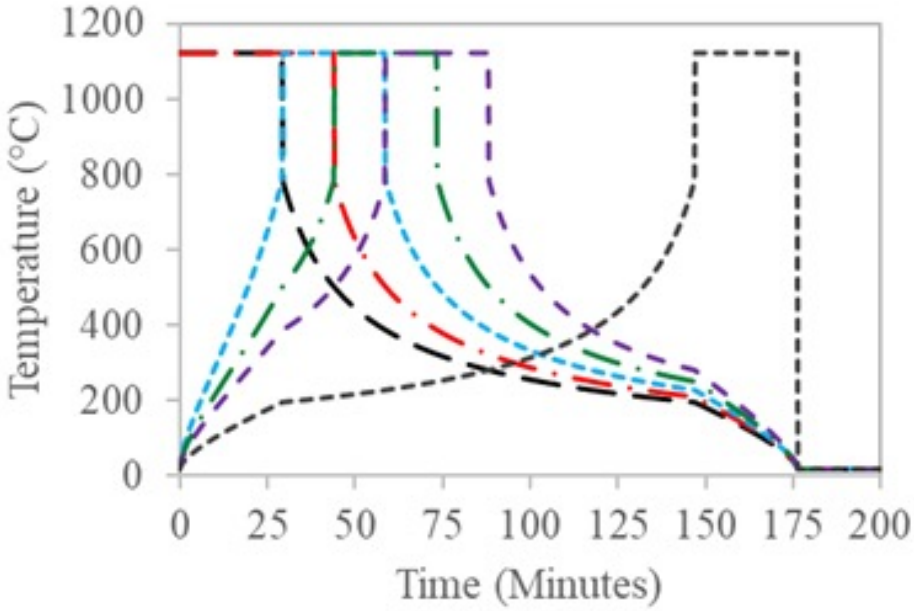
Motivation

[3]

Architectural desire to expose the timber elements due to **health benefits and biophilia**

Compartment Fires

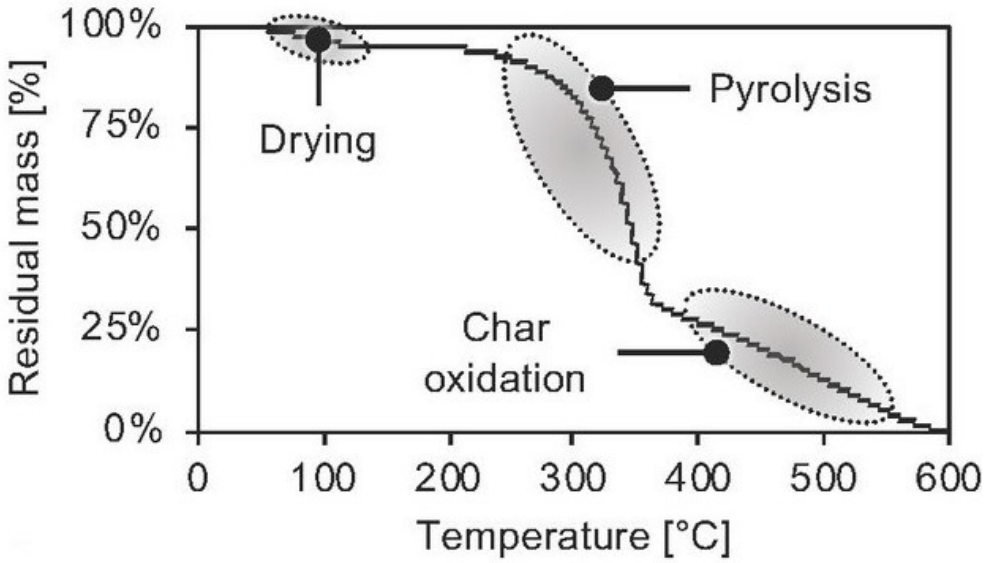


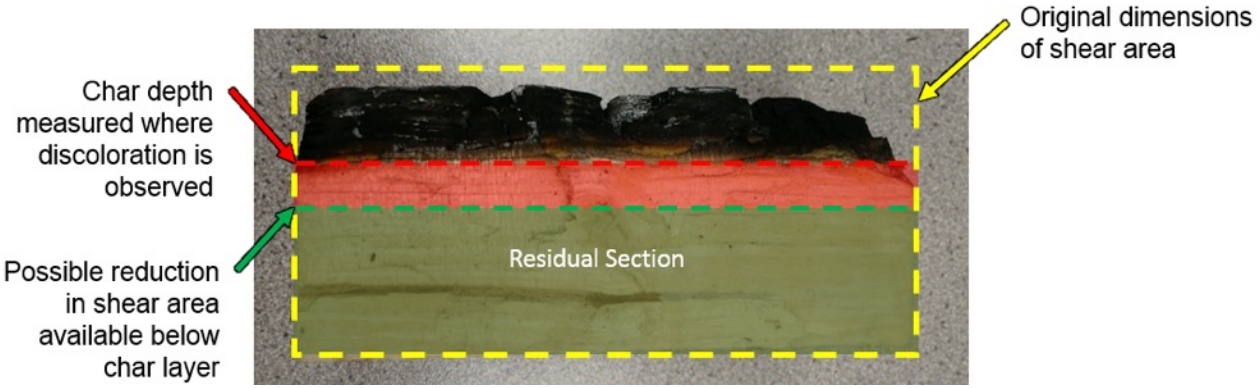


- Standard fire curves are **not representative of real fires**
  - Parametric curves have been proposed to address **different intensities** and the cooling phase
  - Large compartments may experience **a localized fire traveling** through the compartment

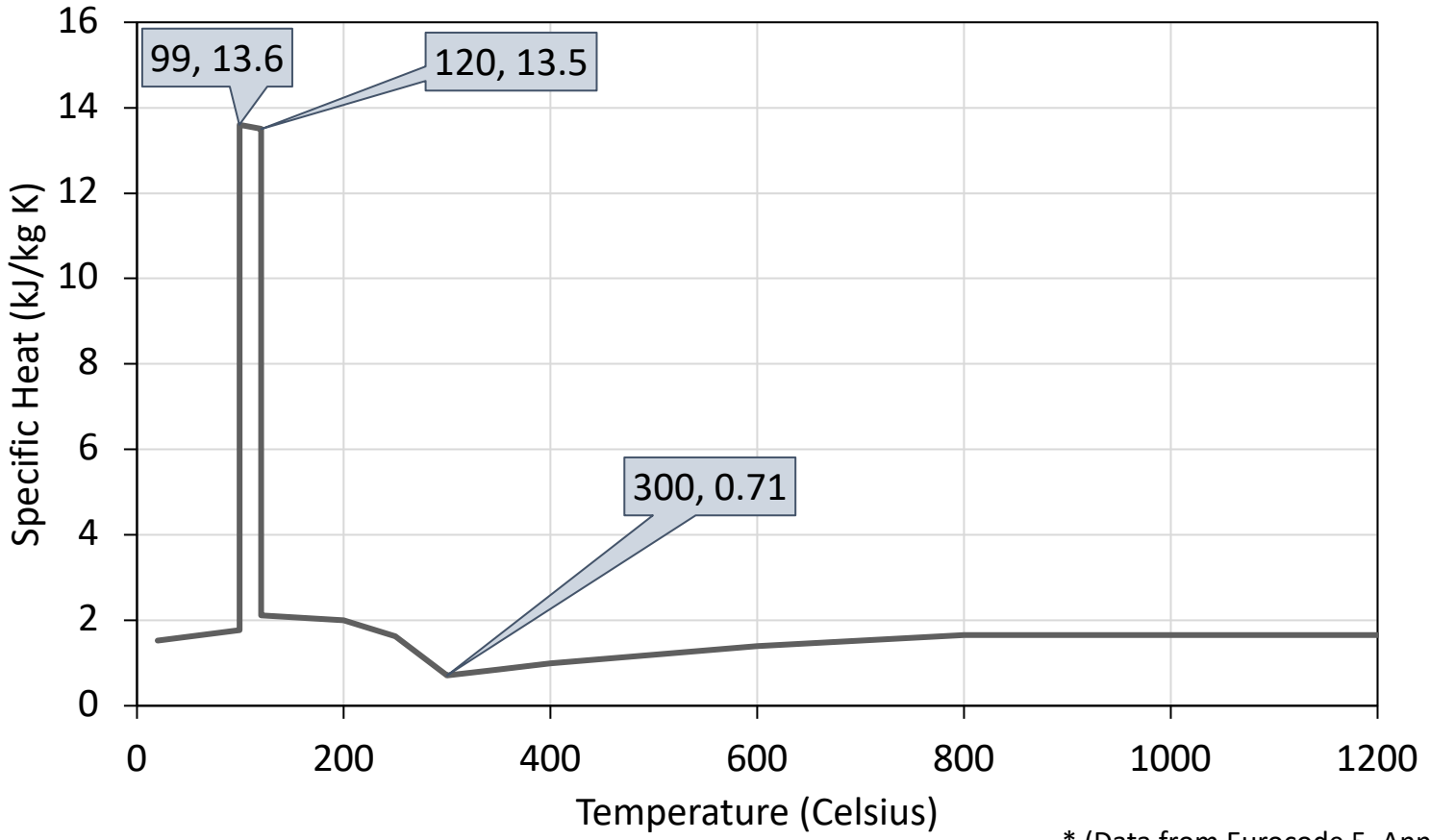
Timber at Elevated Temperatures

- Timber undergoes **pyrolysis at high temperatures** which alters the composition of the material
- Pyrolysis is what produces the gasses which lead to **flaming combustion**
- Char is typically formed at 300 °C, damage to wood occurs at 50°C



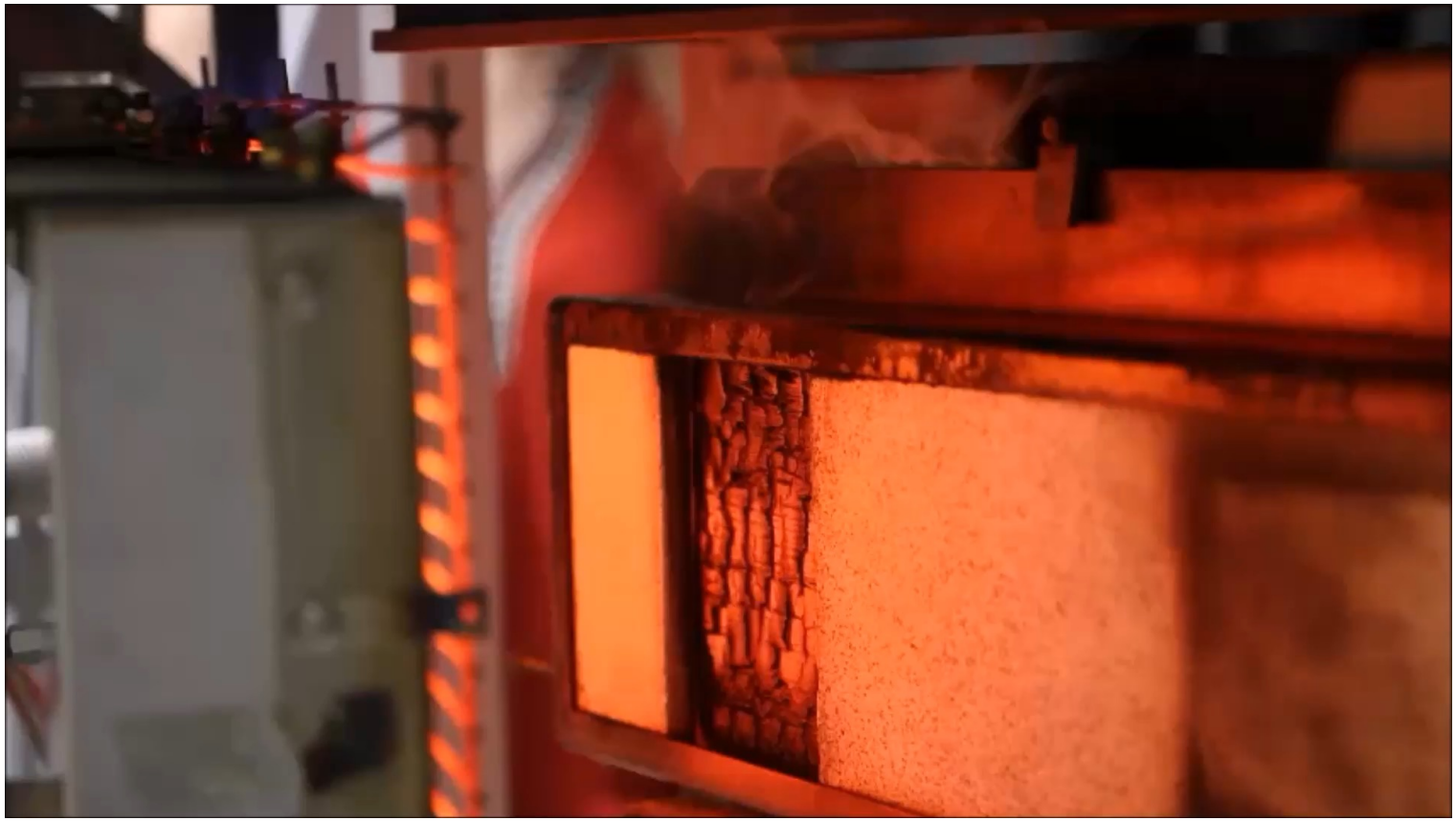


Accounting for Moisture



* (Data from Eurocode 5, Annex B)

Smouldering

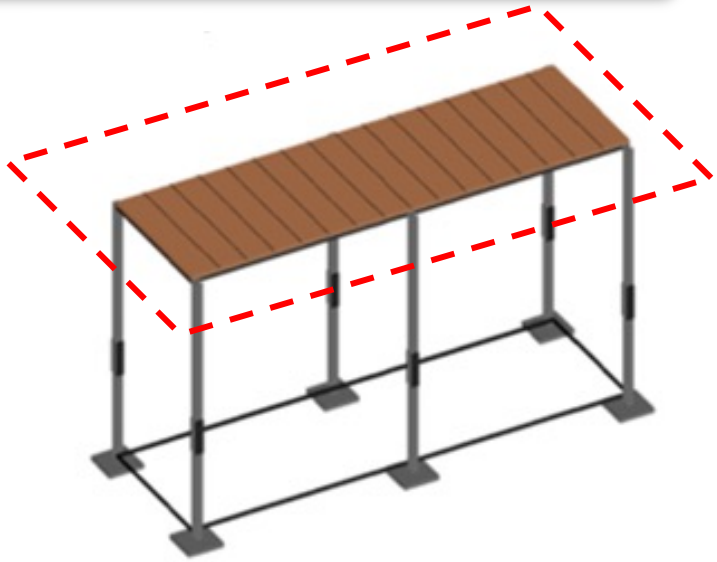


Current State of Timber Modelling

Topic	Thermal Model	Mechanical Model	Pyrolysis	Moisture (Specific Heat)	Moisture (Latent Heat)	Smouldering
# of papers	10	5	5	7	2	2

- 11 papers primarily since 2017 have referred to timber modelling
- 1 paper was not a numerical model for timber, rather it was a semi-probabilistic model of CLT

Development of an A Priori Model



Key Notes:

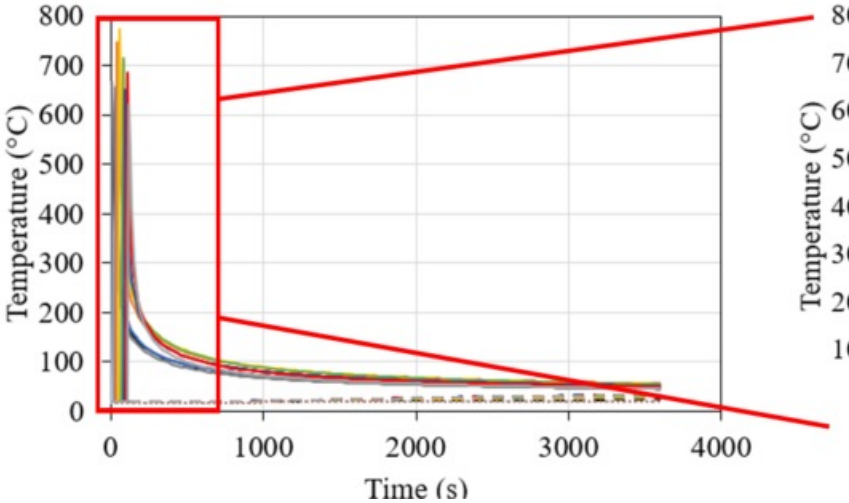
- LS-Dyna was used as the solver
- Mesh size of 3 mm was used
- Ceiling strip is 0.5 m x 0.1 m x 2.4 m
- Delamination was assumed to not occur
- Heat produced from the timber burning was not accounted for
- Little data was available for flame spread and incident heat flux values
  - Flame spread range is based on crib fires in large compartments
- Model was validated against a glulam experiment and a heritage timber experiment

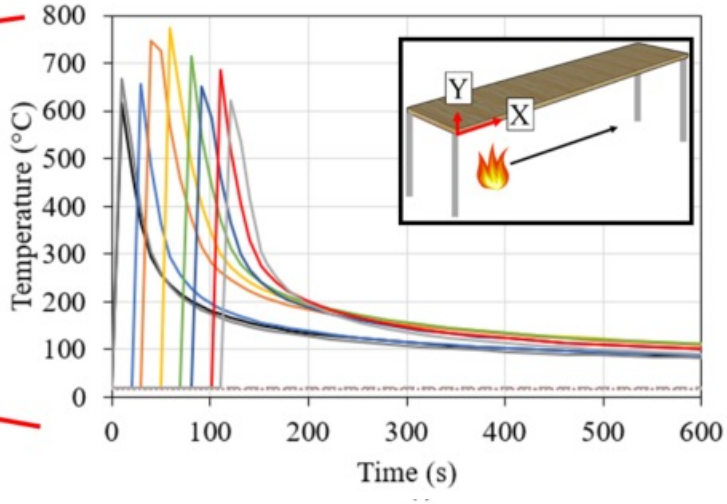
Model char depths were **within 3.5% and 3.7% of the experimental results** respectfully

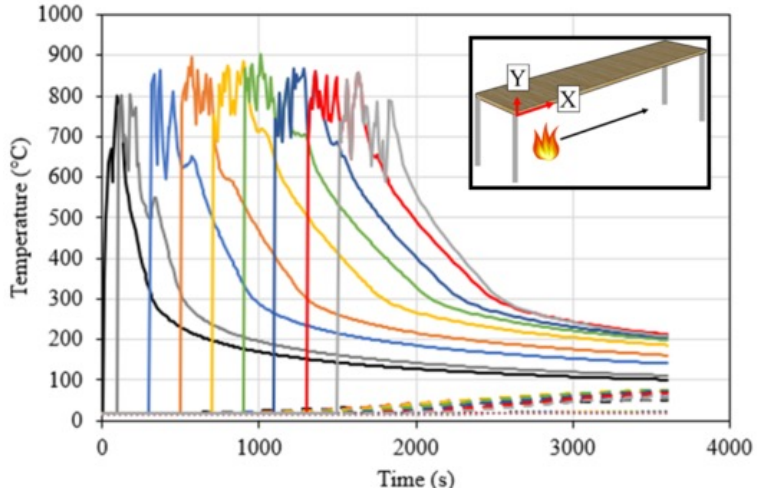
Development of an A Priori Model

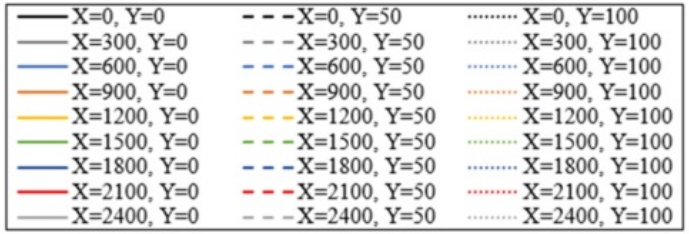
Parameter	Value	Source
Moisture content of CLT	8%	Williams (1999)
Emissivity of timber	0.8	Eurocode 5
Coefficient of heat transfer	25 W/m^2K	Eurocode 1 Part 1-2
Mesh size of elements	3 mm	Through a sensitivity analysis with comparison to Menis (2012) and Thi et al. (2017)
Incident heat flux	Lower: 23.9 kW/m^2	Tewarson and Pion (1976)
	Upper: 77.5 kW/m^2	Petrella (1979)
CLT dimensions	0.5 m x 0.1 m x 2.4 m	Selected as it can be replicated in future experiments
Fire spread rates	Lower: 1.5 mm/s Upper: 19.3 mm/s	Rackauskaite et al. (2015) and Kirby et al. (1999)
Trailing edge rate	Lower: 1.17 mm/s Upper: 19 mm/s	Heidari et al (2020)

Results



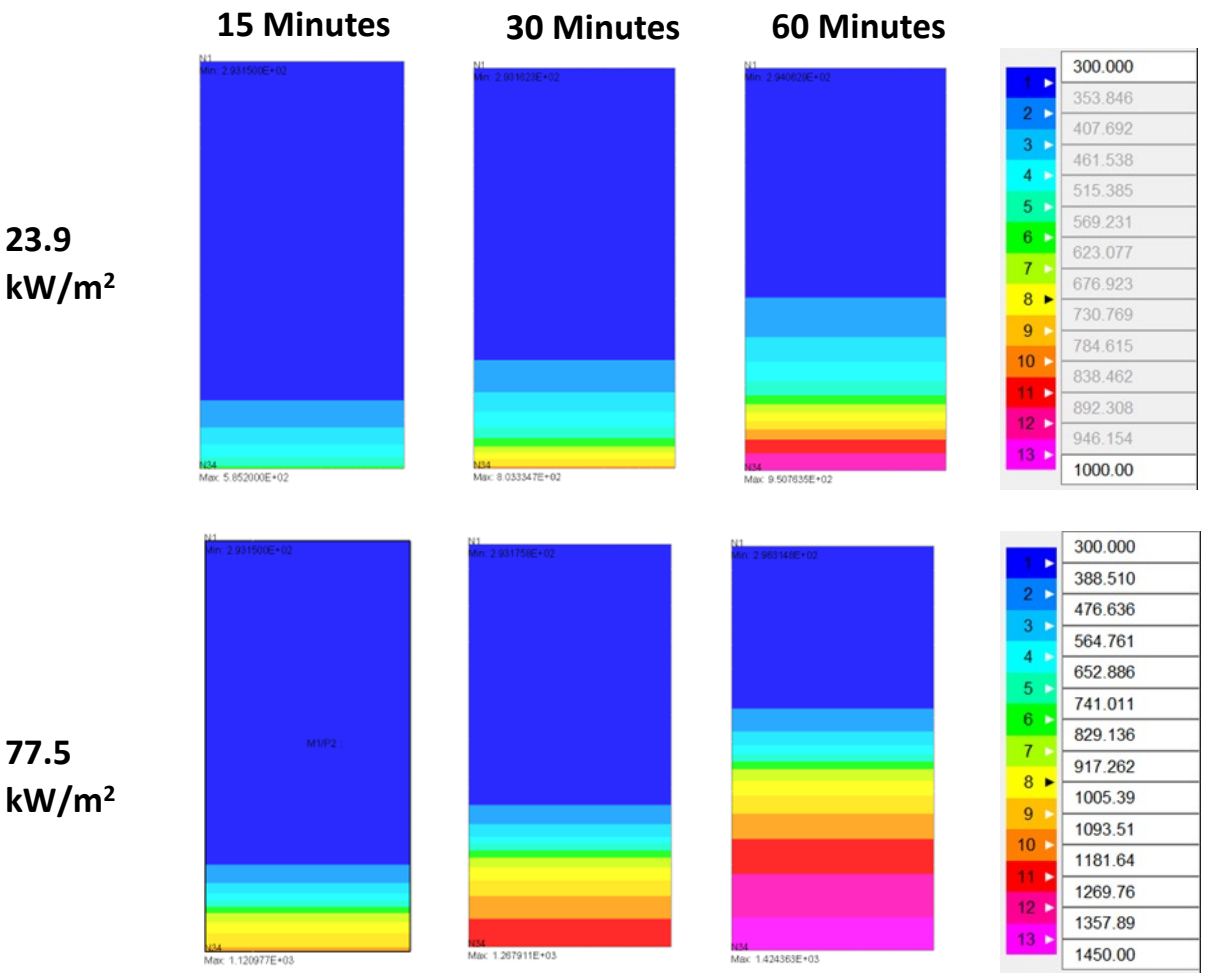






- Temperature gradient through CLT slabs assuming a flame spread rate of **19.3 mm/s (top) and 1.5 mm/s (bottom)**

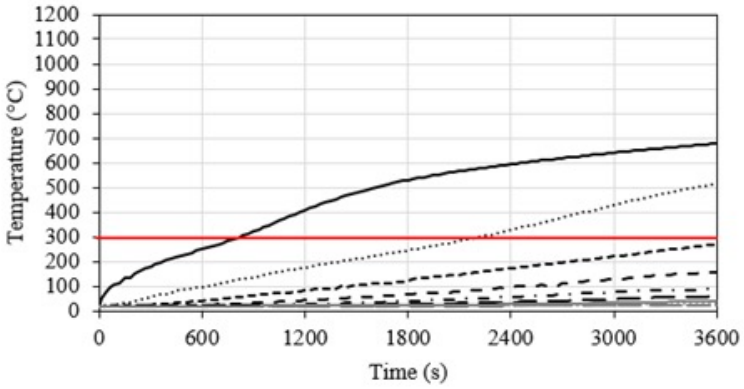
Results



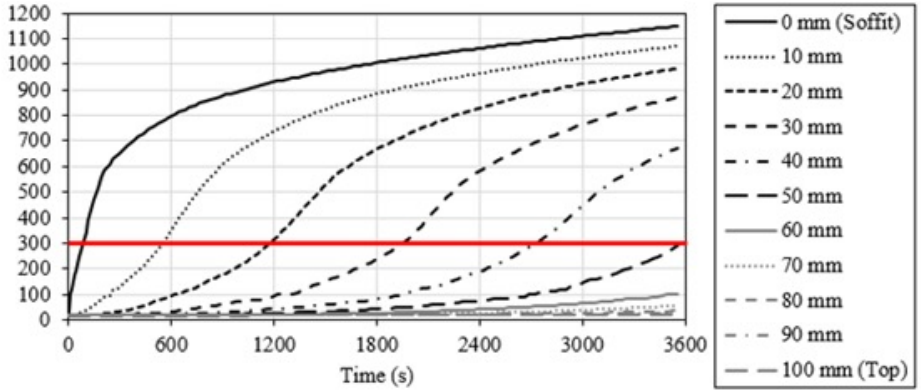
- Temperature distributions throughout the CLT when exposed to **different applied heat fluxes**

Results

23.9 kW/m^2



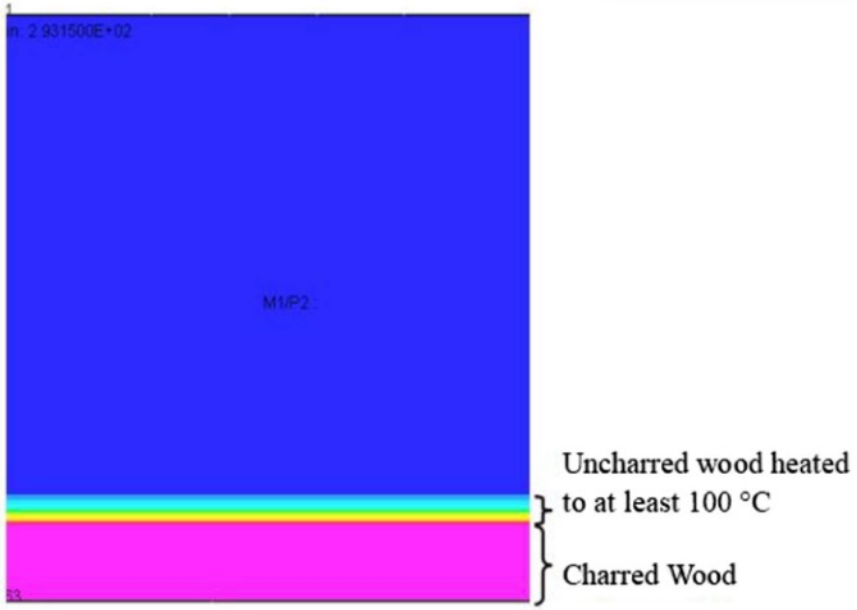
77.5 kW/m^2



- Temperature distributions throughout the CLT when exposed to **different applied heat fluxes**

Conclusions

- Current best practices leave thermal models inaccurate
- To better calibrate models several datasets are recommended to be collected:
  - Char rates at extreme heat fluxes
  - Heat flux produced by the timber (flaming and smouldering combustion)
  - Incident heat flux at floor level
- Stronger understanding of the burnout and extinction criteria of timber is needed



For more information

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Questions

ARUP

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Image Credits

[1]Acton Ostry Architects. (2022). Limberlost Place. https://www.actonostry.ca/project/george-brown-college-the-arbour/

[2] Remi Network. (2016, August 22). *Construction milestone for UBC Brock Commons*. Retrieved January 27, 2022, from https://www.reminetwork.com/articles/construction-milestone-for-ubc-brock-commons/

[3] Hufton and Crow. (2022). Blue-Sky Thinking. Architecture Today. https://architecturetoday.co.uk/blue-sky-thinking/