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Fire behaviour of a timber composite with GFRP reinforcement

A comparison with unreinforced laminated timber

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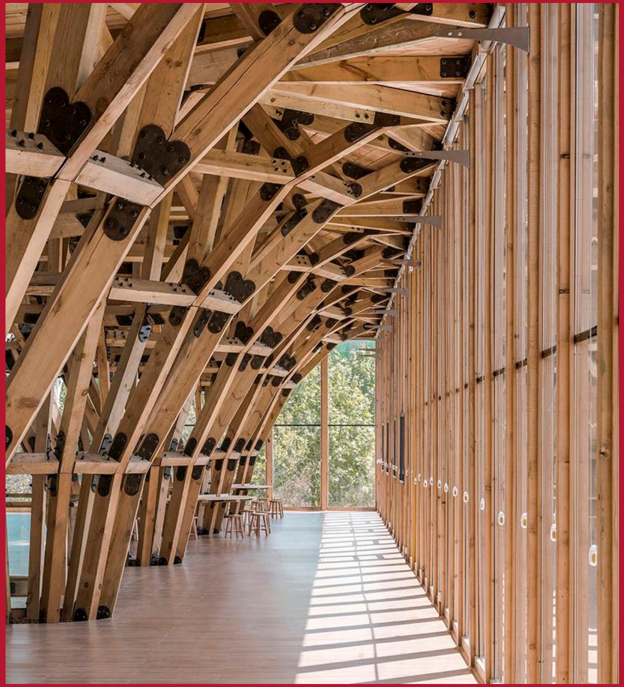
Why timber?

- Design & economical advantages



www.designboom.com/

- Architecture and design
- Suggests natural and healthy living
- Rapid and clean assembly
- Potential for lower transportation cost

Why timber?

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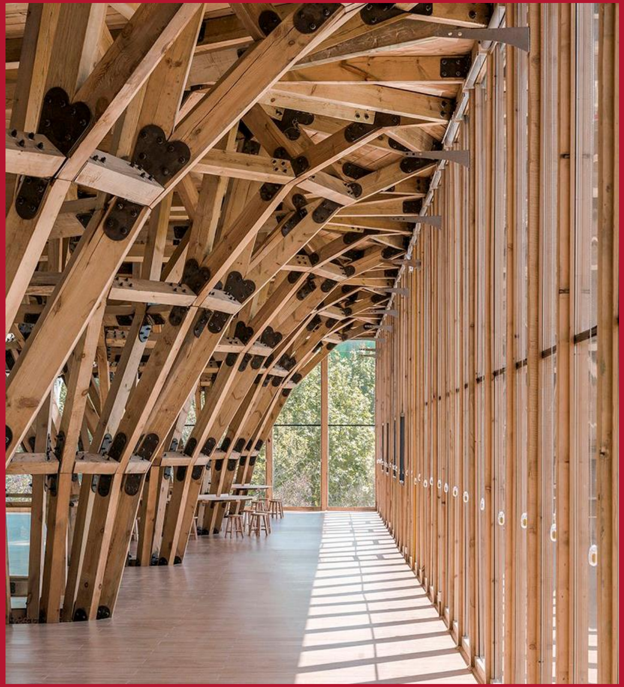

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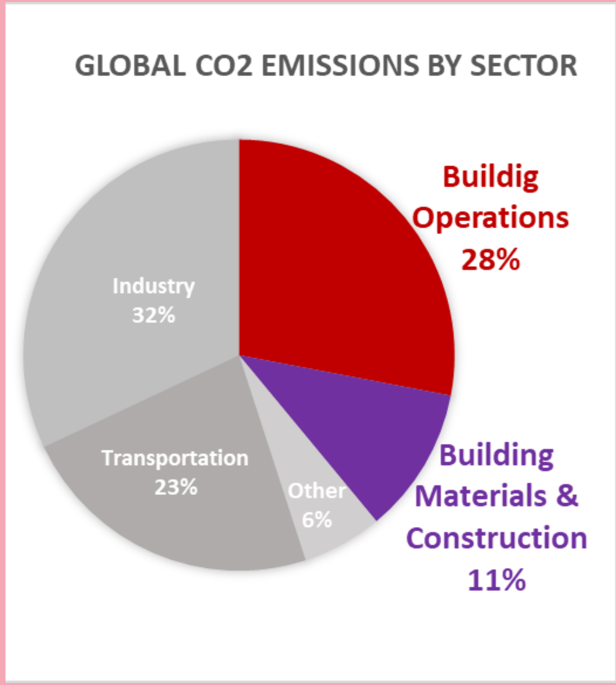
- Climate challenges & sustainability



www. architecture2030.org/

- Lower impact on the environment, e.g. lower CO_2 emissions
- Forest rotations of 35-70 years

Why timber?

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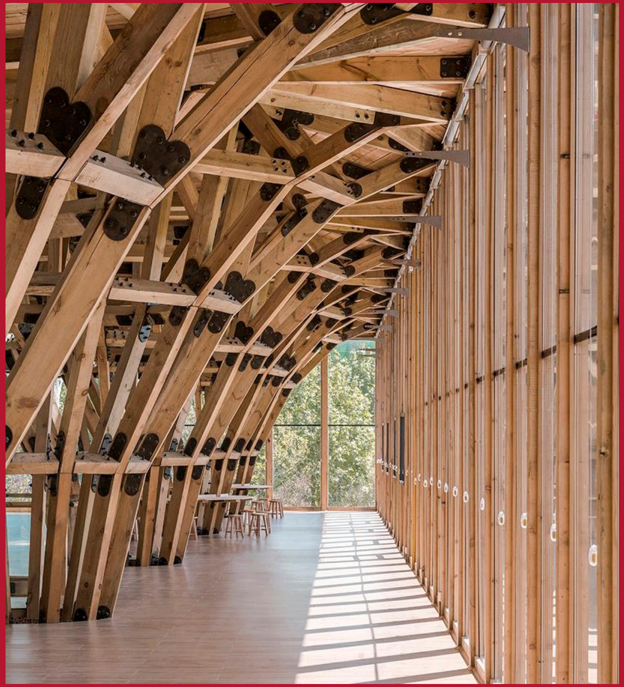

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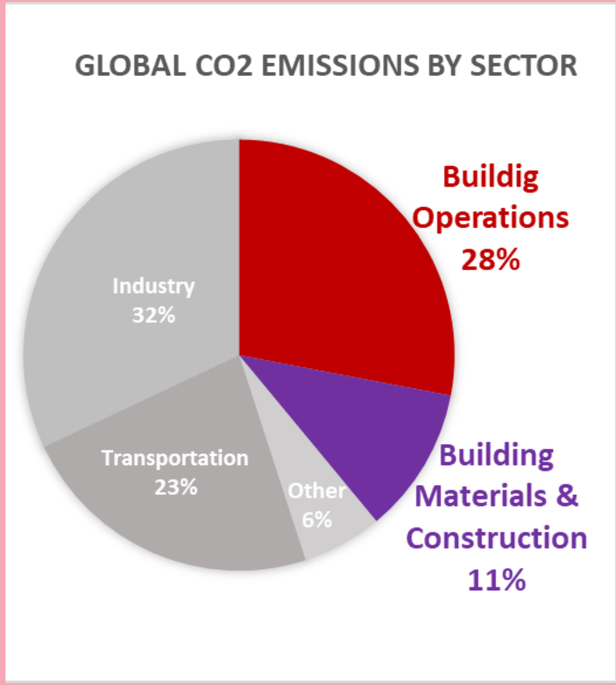


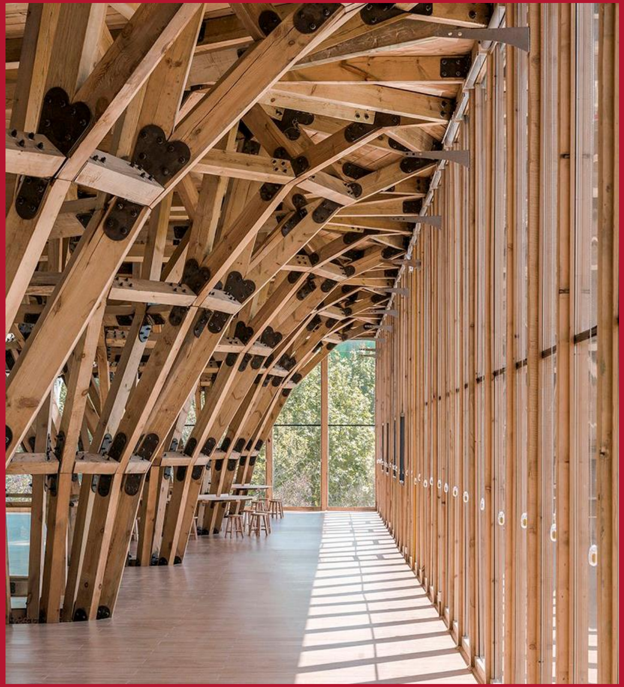
www. architecture2030.org/

„Timber is the only widely used building material that can be considered to be truly sustainable.“

M. Ramage in The wood from the trees: The use of timber in construction

Why **fibre glass** with timber?

- Design & economical advantages



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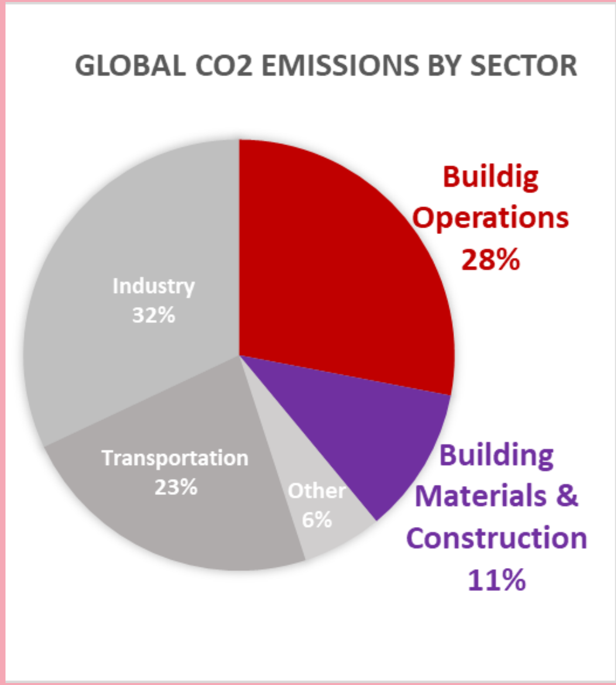
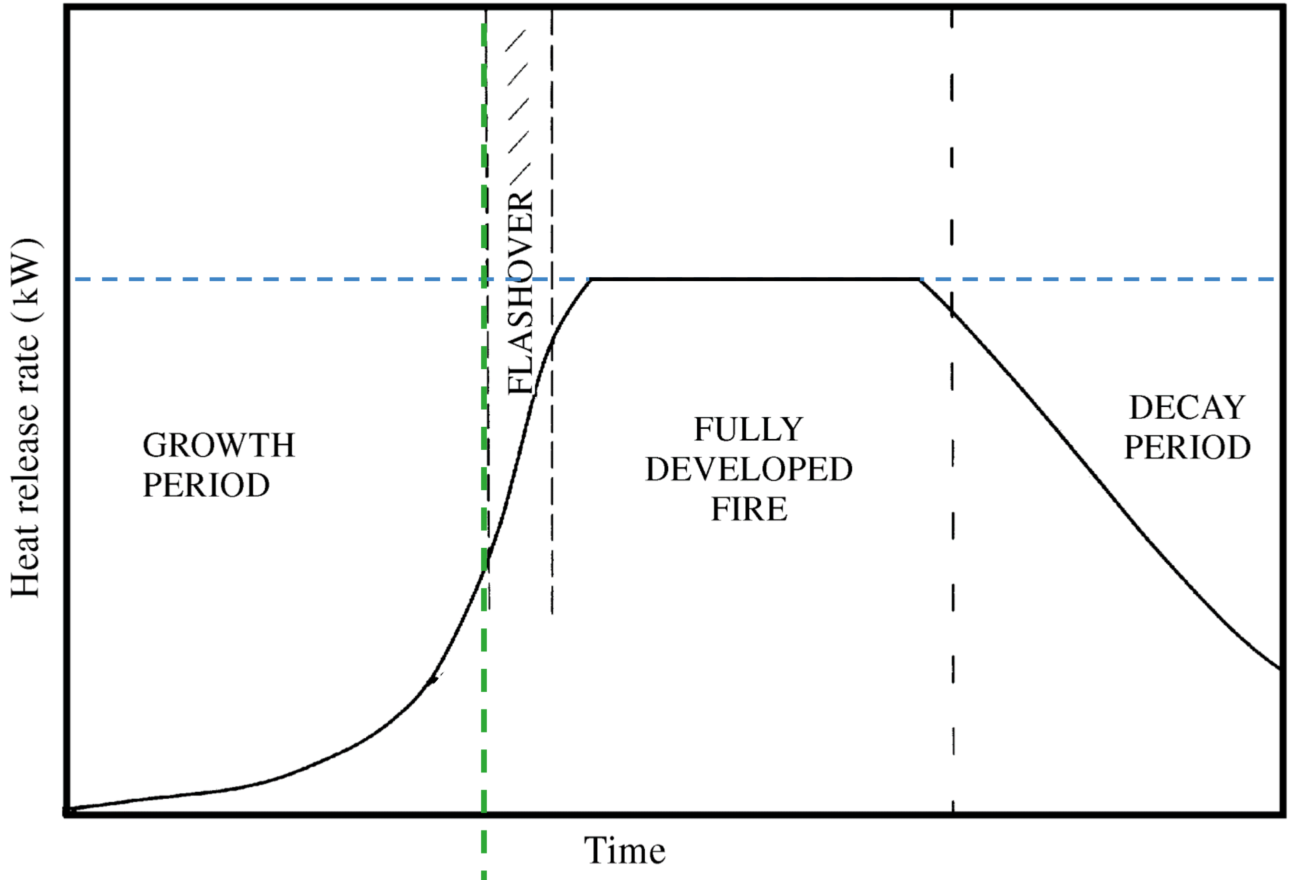


www. architecture2030.org/

- But safety is an issue!

www.architectsjournal.co.uk/

„Classical“ compartment with non-combustible lining



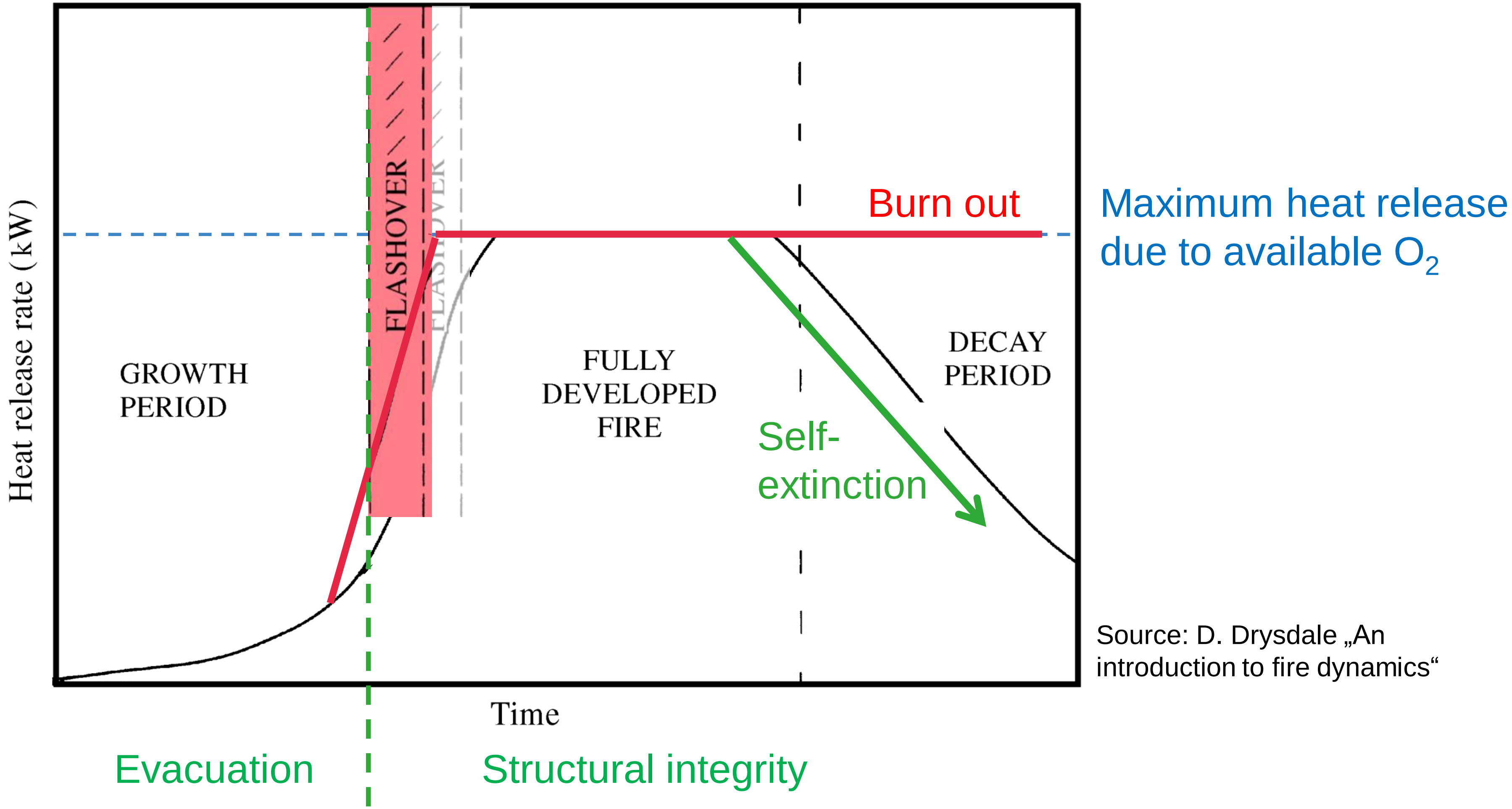
Maximum heat release due to available O_2

Source: D. Drysdale „An introduction to fire dynamics“

Evacuation

Structural integrity & Compartmentation

Compartment with exposed timber



Source: D. Drysdale „An introduction to fire dynamics“

Objective of this research:

Improve the performance of engineered timber products under fire condition

- Reaction to fire (Ignition and fire growth)
- Fire resistance (Loss of load-bearing section)
- Potential for self-extinction

Using novel composite solutions

Engineered timber (LVL)

Laminated veneer lumber

Timber and adhesive

- Cost effective
- Combustible but charring

Glass fibre

- Non-combustible

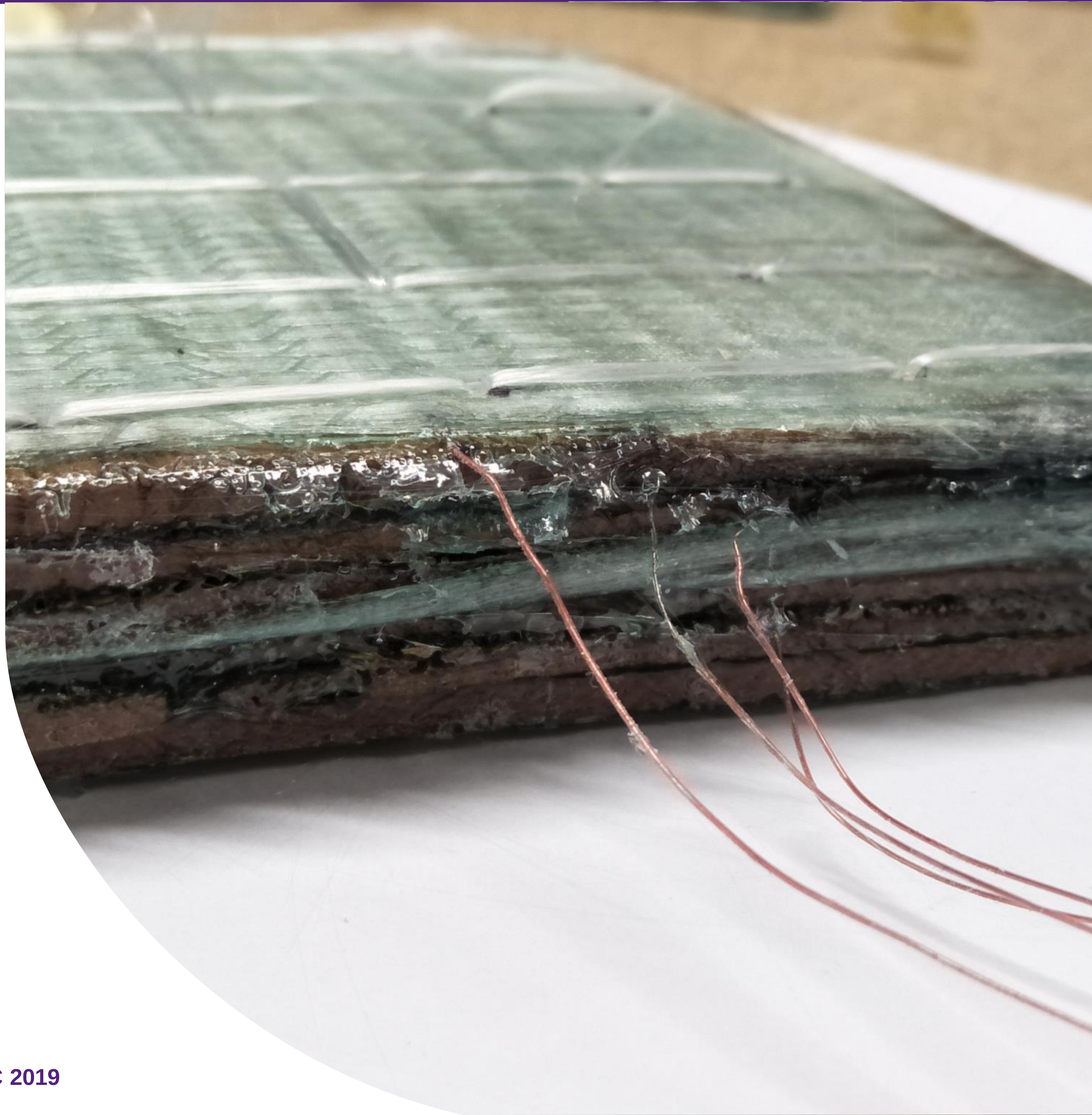
= Does not burn

- To hinder oxidation of timber in case of fire
- To hold charred timber layers together (to maintain integrity)
  - To act as an insulation for deeper layers


www.fabricgateway.com/

Engineered timber & Glass fibre in combination:

Improved timber composite product

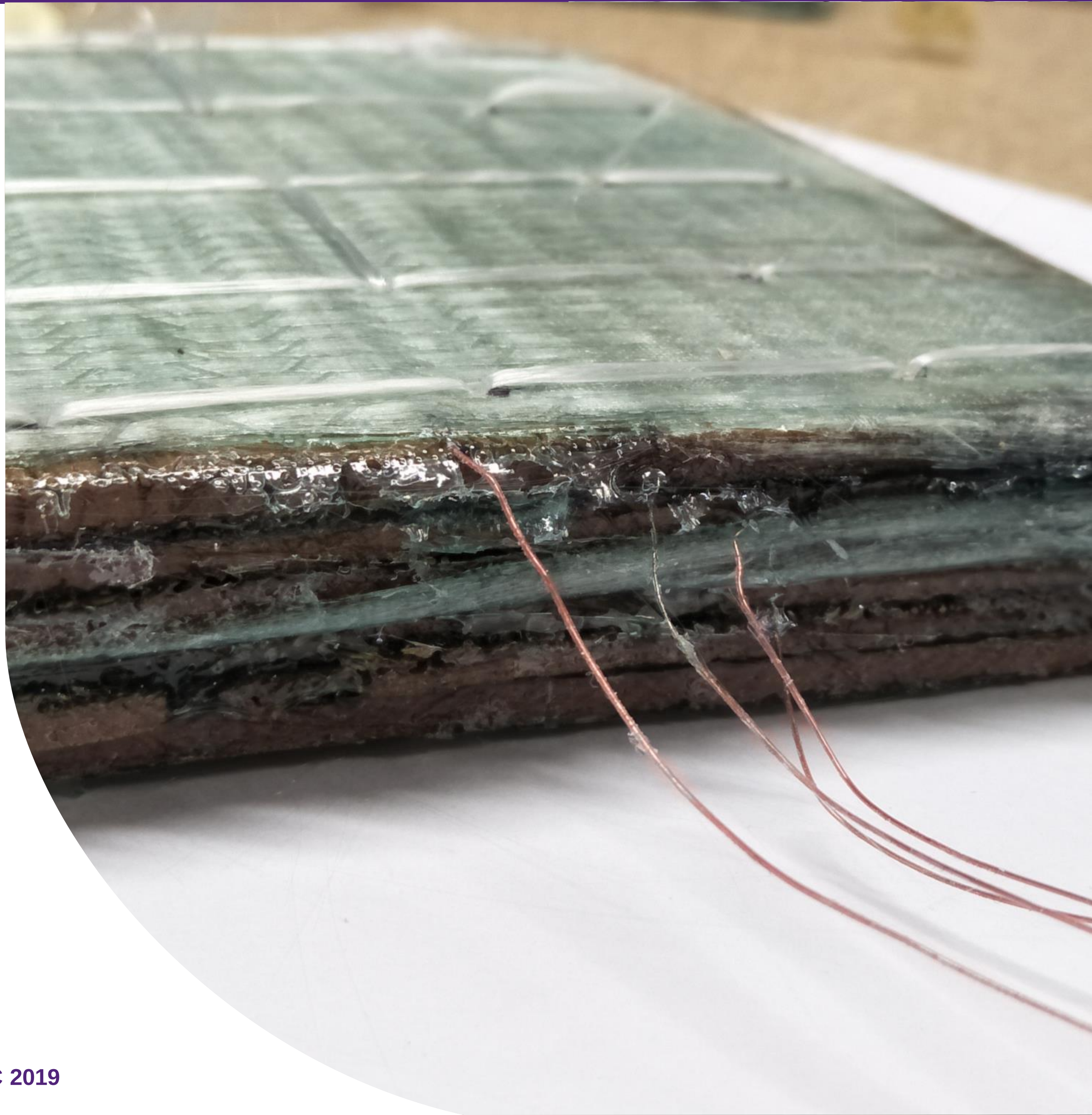


8 specimen

Each sample:

- 6 timber veneers (each 2 mm thick)
- 7 glass fibre mats
- Epoxy

- Total thickness: 19 mm



Instrumentation

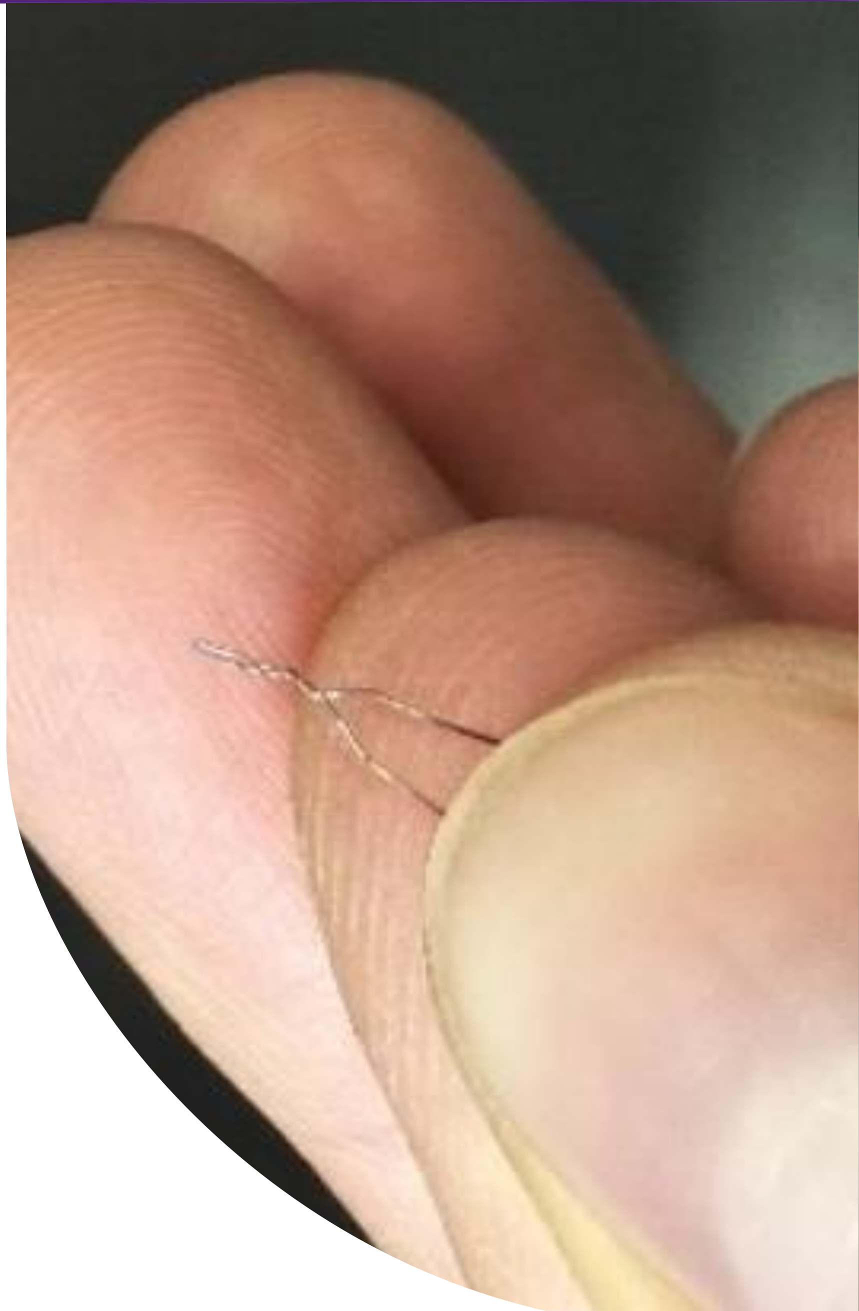
Thermocouple wire (welded) between layers:

- Top surface
- Back surface
- Every 3 mm in between

- To measure in-depth temperature throughout samples during fire exposure

Ultra-thin (0.13 mm)

for minimum impact on burning behaviour



Picture source: www.fpl.fs.fed.us

Experimental Setup

Cone Calorimeter

- Horizontal position
- Heater on top:
  - Constant 35 kW/m² on top surface only

    (representative for heat flux during a l ocalised fire, pre-flashover)

- Piloted ignition (spark)
- Analysis of exhaust gases

Results: Time to ignition

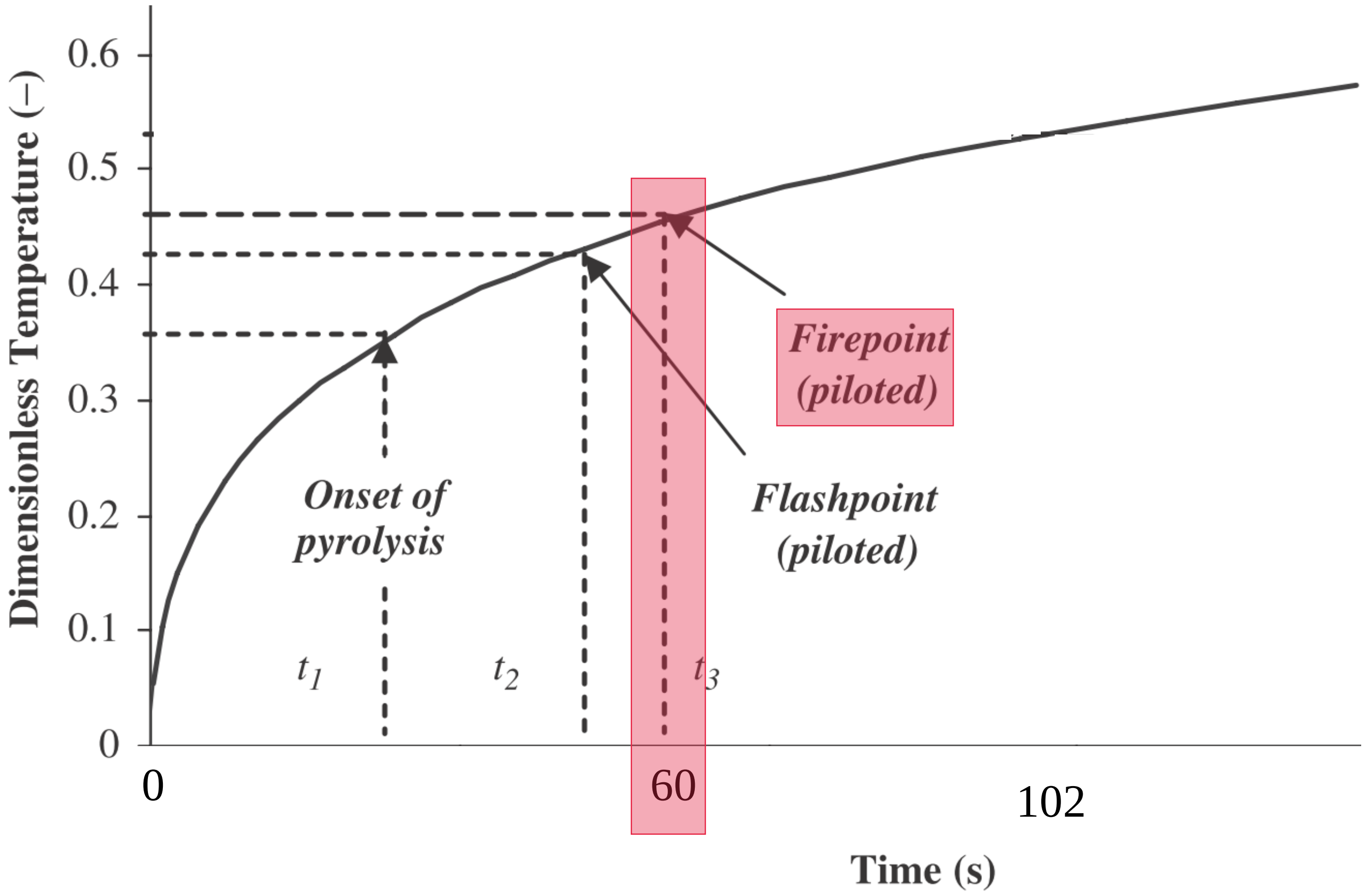
Time to ignition	Without glass fibre	With glass fibre	
	-	< 400 g/m²	1015 g/m²
Average (s)	**60.5** ± 4,5	**69.25** ± 11.25	**102.5** ± 1.5
Increase		+14.5 %	**+69.4 %**

Up to **+70 % later ignition with glass fibre**

Depends on type of glass fibre

Results:
Time to ignition

$$t_{ig} = \frac{\pi}{4} k\rho c \frac{(T_{ig} - T_0)^2}{\dot{Q}_R''^2}$$



Temperature at the surface of a semi-infinite solid exposed to a convective heat flux

Source: D. Drysdale „An introduction to fire dynamics“

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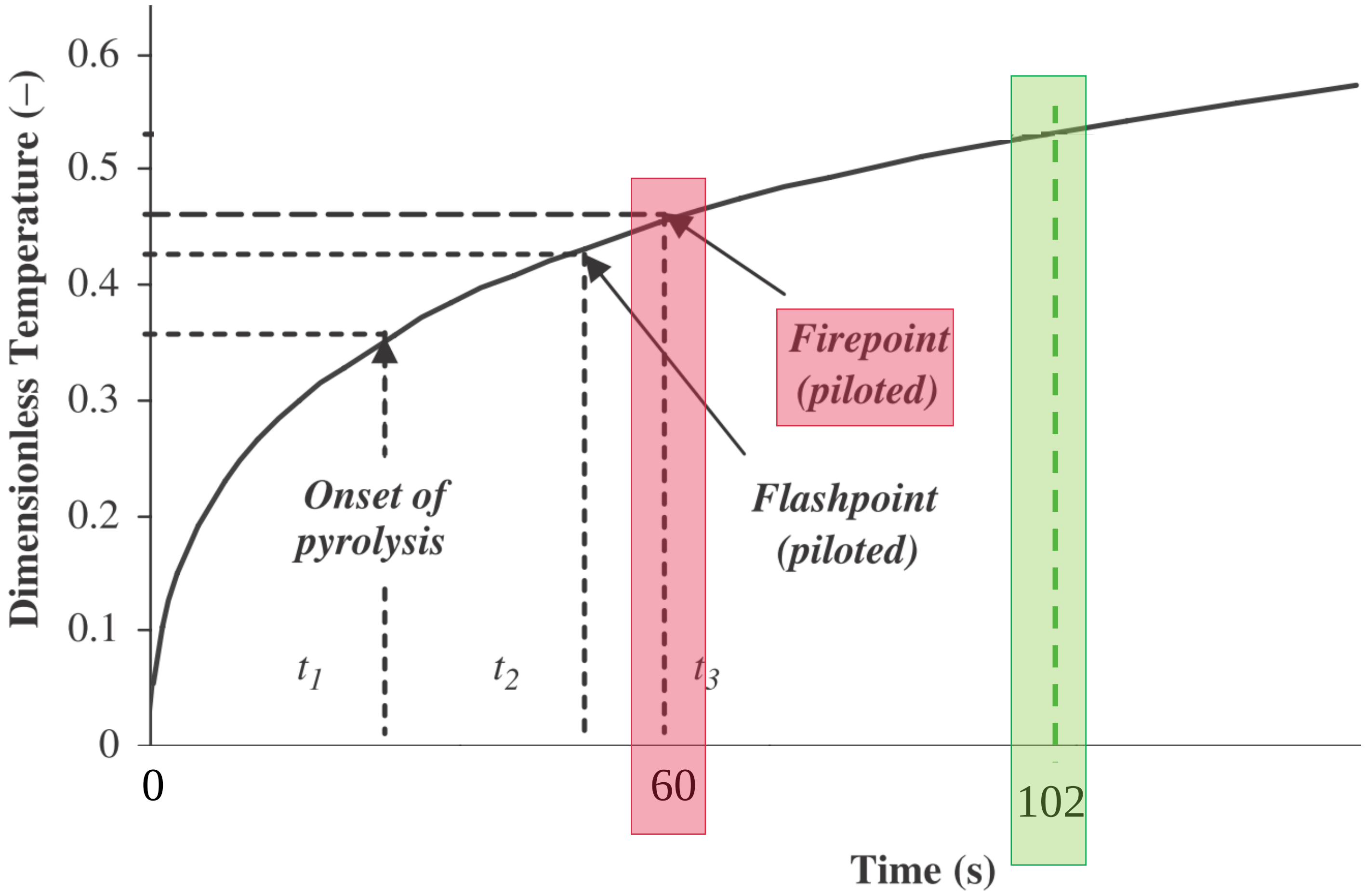

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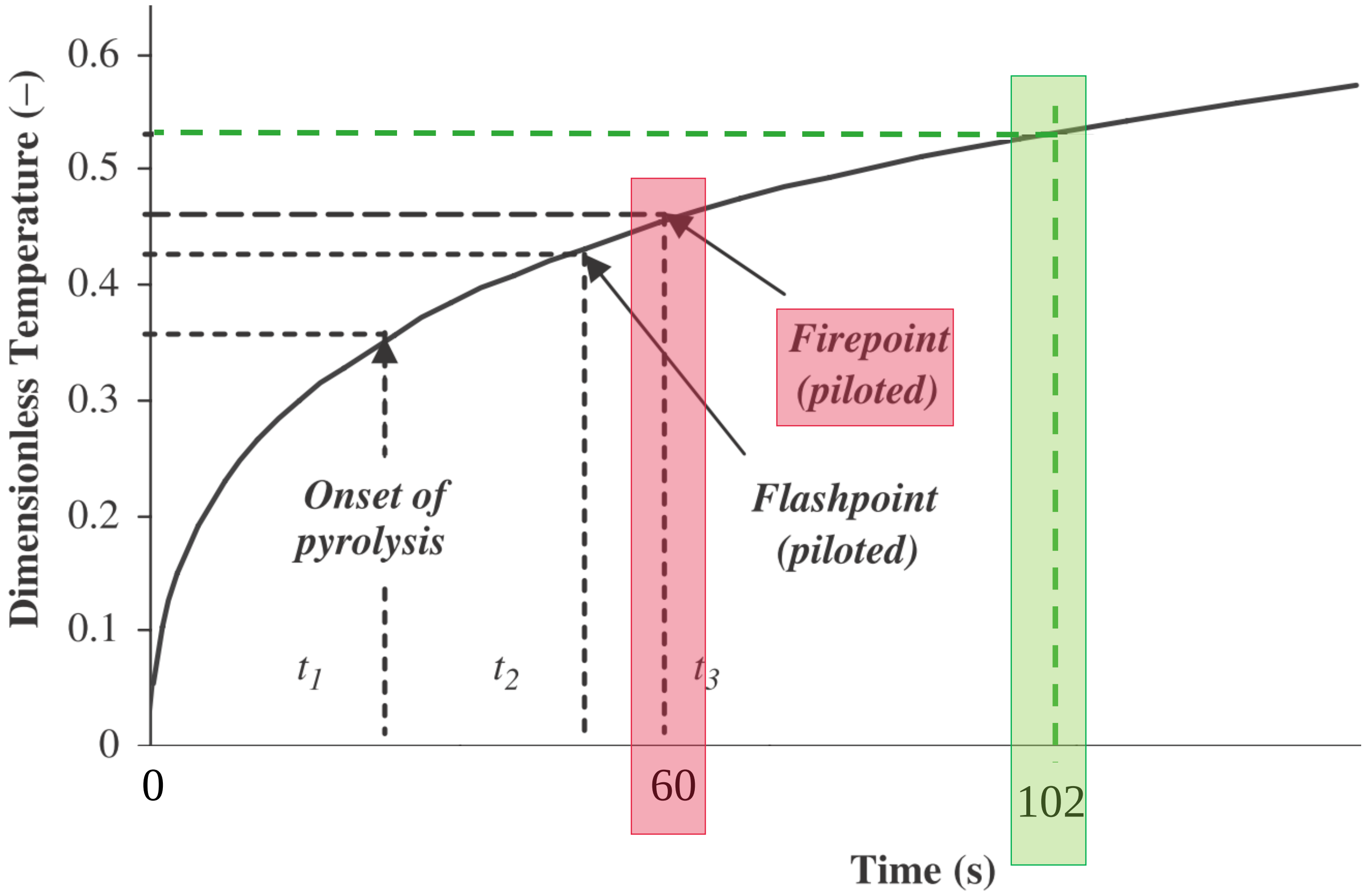

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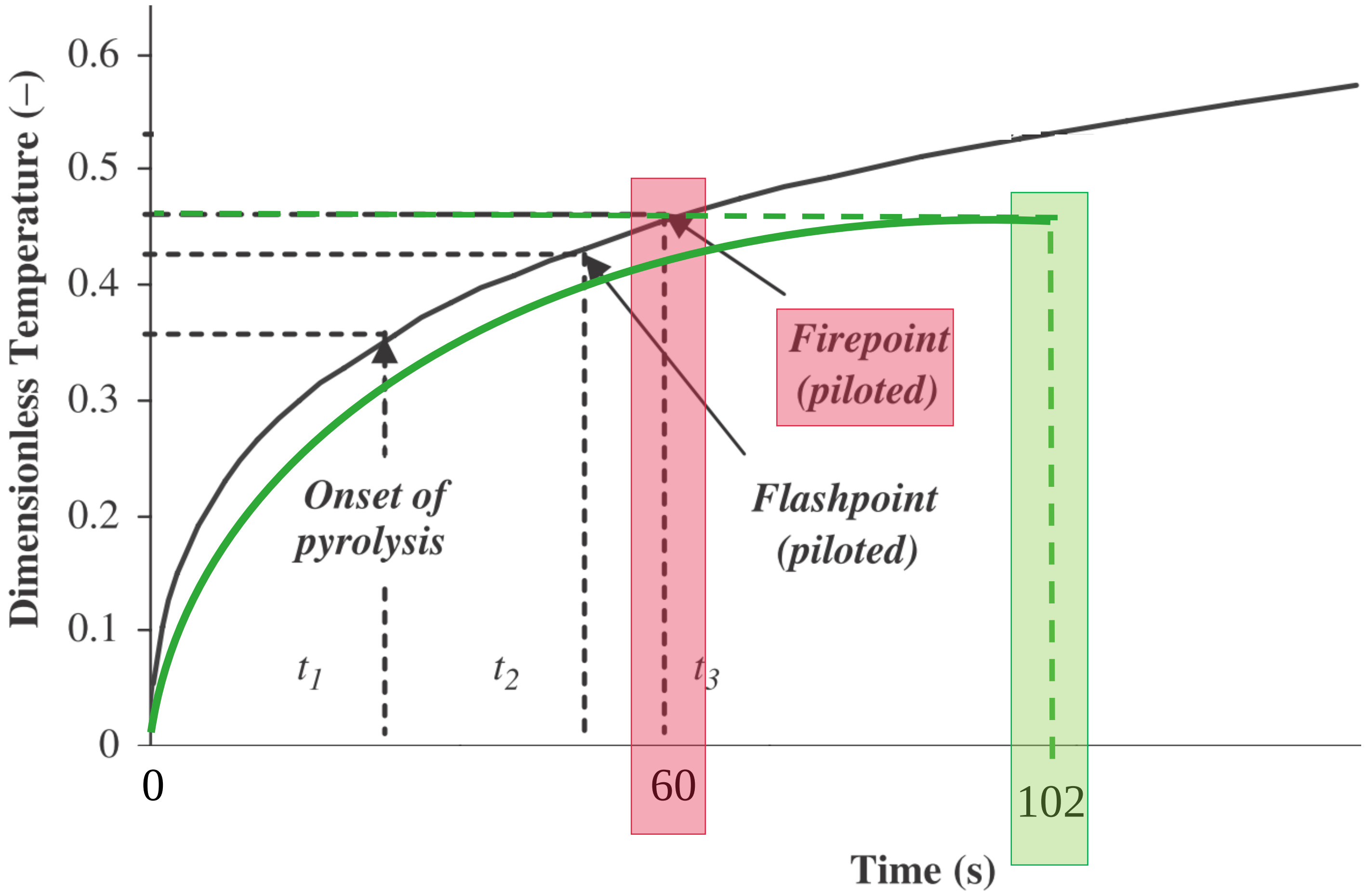

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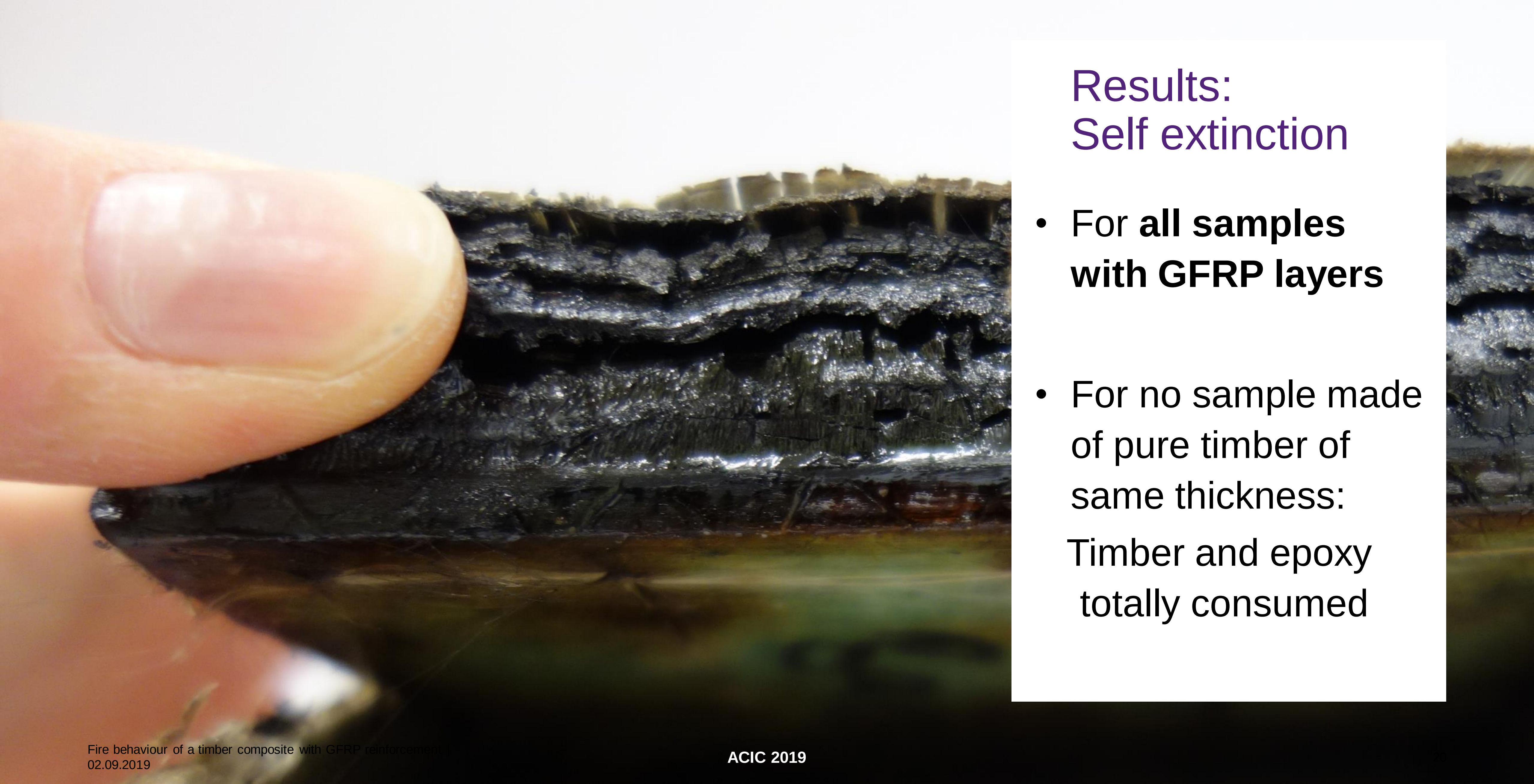


Results:
Self extinction

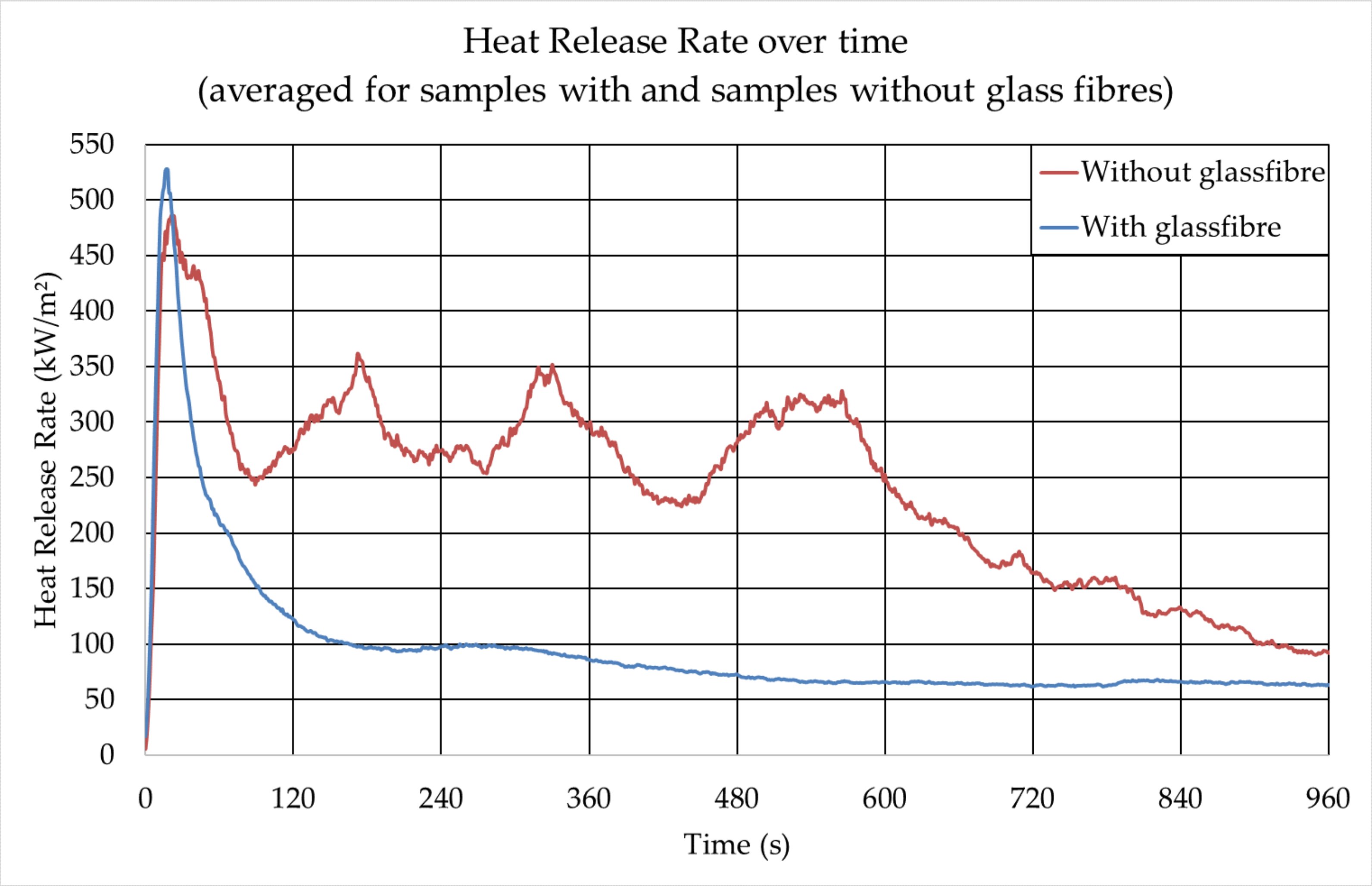
- For **all samples with GFRP layers**

- For no sample made of pure timber of same thickness:

  Timber and epoxy totally consumed

Results: Fire contribution

- Similar initial peak for both sample types (500 kW/m²)
- With GFRP: rapid decline
- Fluctuation for samples without glass fibre (delamination)



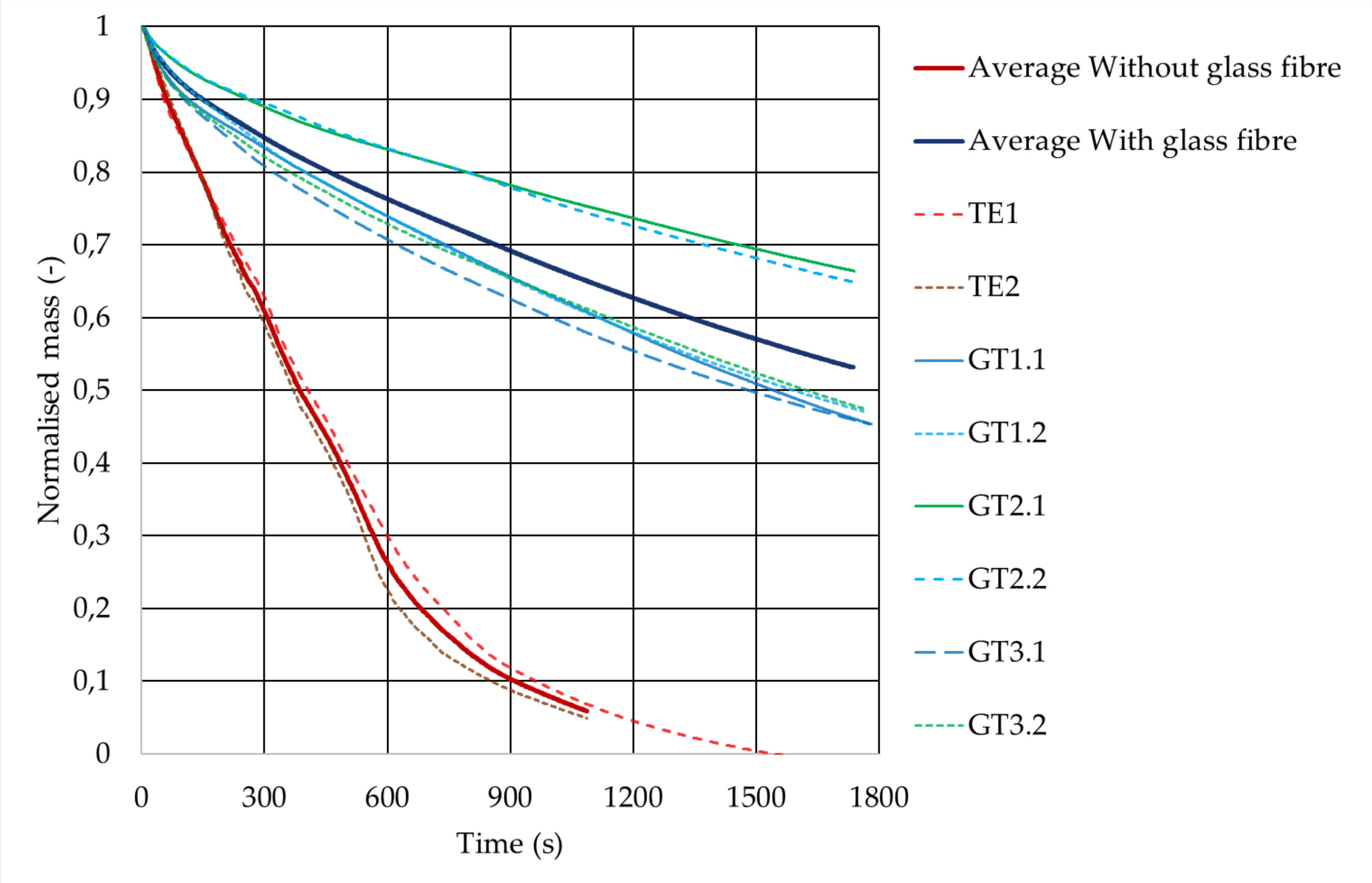
Results:
Loss of structural section

With GFRP

- Flame self-extinction between 45-65 % mass

Without GFRP

- Over 90 % of mass burned after 15 min
- Eventually all mass consumed



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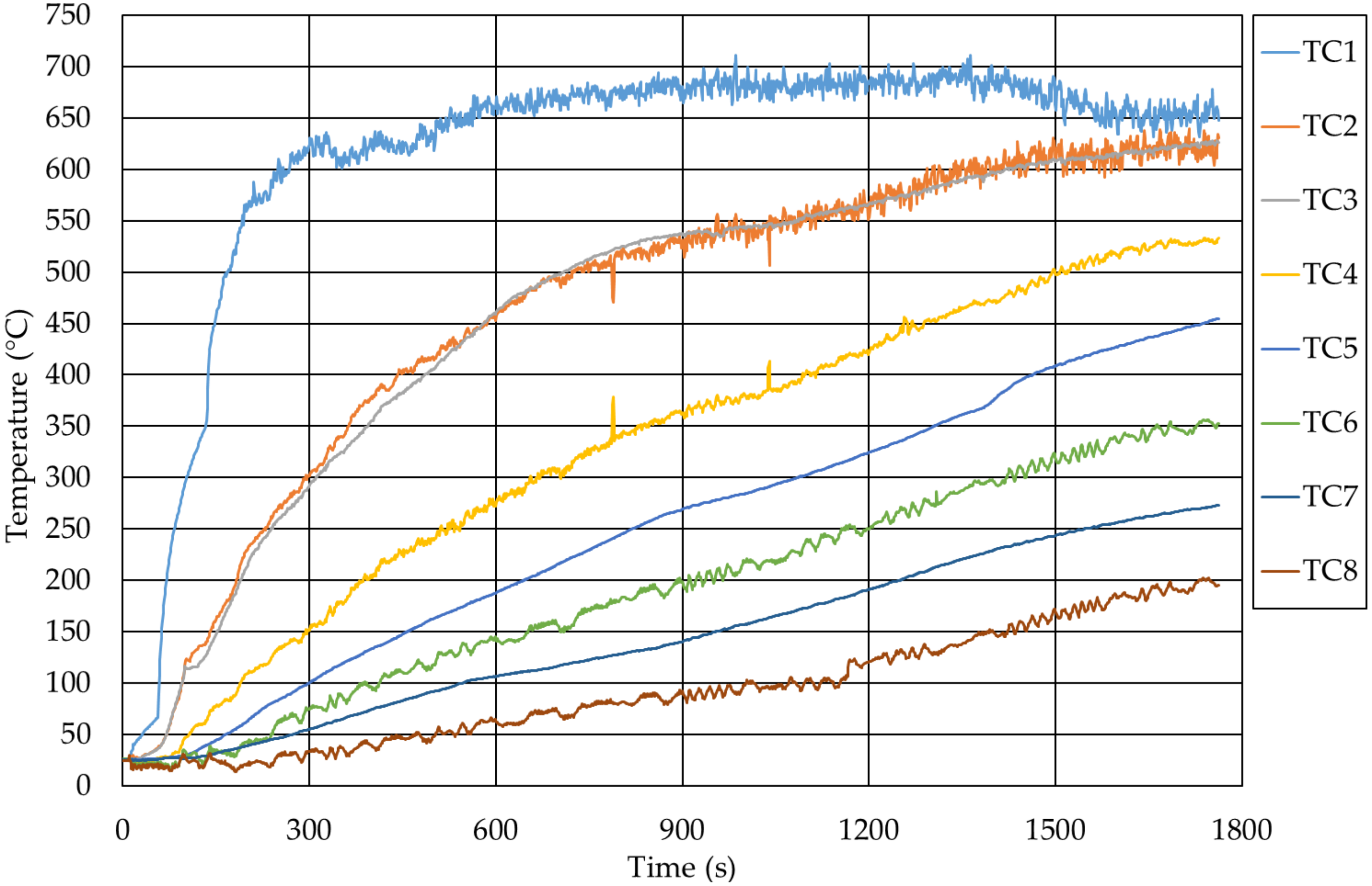
Results: Temperature gradient

Over time

With GFRP



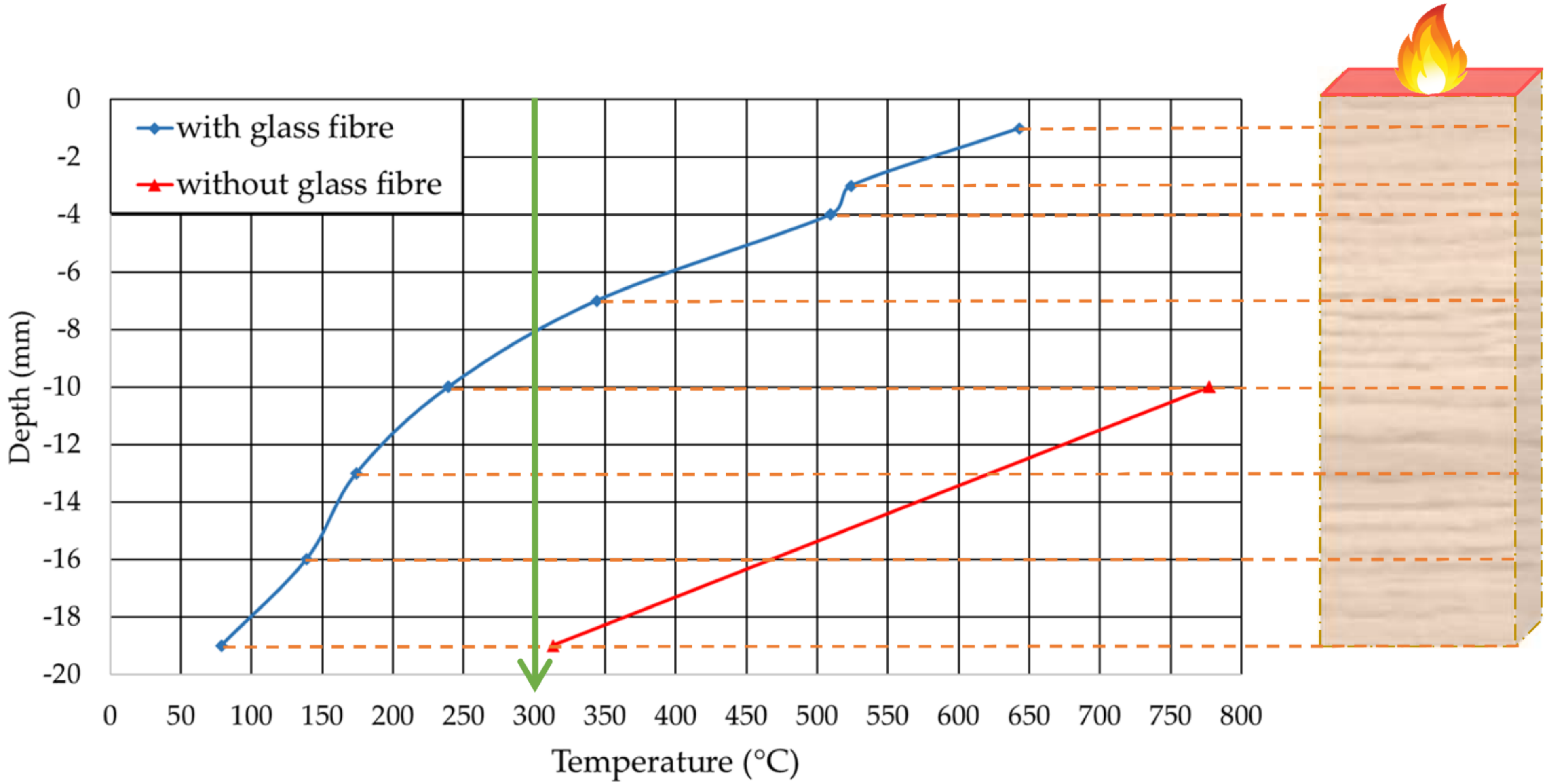
Results:
Temperature gradient

In-depth

after 800 s

With GFRP

Without GFRP



Limitations

Only proof of concept

Samples not fully representative of engineered timber produced in industry

Future Work

Research performed at UQ at the moment

My Masters thesis

starting January 2020

(Comments and support are most welcome!)

Conclusions

Longer ignition times

All types of glass fibre mat resulted in **longer time to ignition**, ranging from a 10 to 69 % increase.

Conclusions

Longer ignition times

& lower fire contribution

Same **peak HRR for both types** (ca. 500 kW/m²).

Samples **with glass fibres**

- **three times lower average HRR**
- than samples without glass fibre mat
- from 2 min after ignition

Conclusions

Longer ignition times

& lower fire contribution

Longer evacuation times for occupants

Conclusions

Longer ignition times

& lower fire contribution

Longer evacuation times for occupants

Lower loss of structural section

After extinction

Samples with glass fibre mat

- **weighed 45 to 75 %** of their initial mass
- the **thickness** of these samples almost unchanged

Conclusions

Longer ignition times

& lower fire contribution

Longer evacuation times for occupants

Lower loss of structural section

Mass loss rate

- approximately **50 % lower** for samples with glass fibres
- from 2 minutes after ignition

Conclusions

Longer ignition times

& lower fire contribution

Longer evacuation times for occupants

Lower loss of structural section:

Almost entire cross section for structural purpose

More efficient desgin

Conclusions

Self-extinction

- for all 1.9 cm thick timber composite samples
- **containing glass fibre mat**
- exposed to a heat flux of 35 kW/m².

Timber samples without glass fibres

- **of the same thickness**
- under the **same heat flux,**

continued **decomposition until burnout**.

Extinction potential & integrity

Conclusions

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Extinction potential

& integrity

Limitation of fire spread

(Compartmentation)

& residual capacity

Conclusions

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Longer evacuation times for occupants

Lower loss of structural section:

Almost entire cross section for structural purpose

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& residual capacity

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The University of Queensland
AUSTRALIA
CREATE CHANGE

Thank you

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The International Master of Science in Fire Safety Engineering

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Results:
Loss of structural section

With GFRP

- Mass loss rate significantly declines:

<10 g/m²s after 2 min