Fire risk of Cross Laminated Timber (CLT)

Need for sprinkler protection

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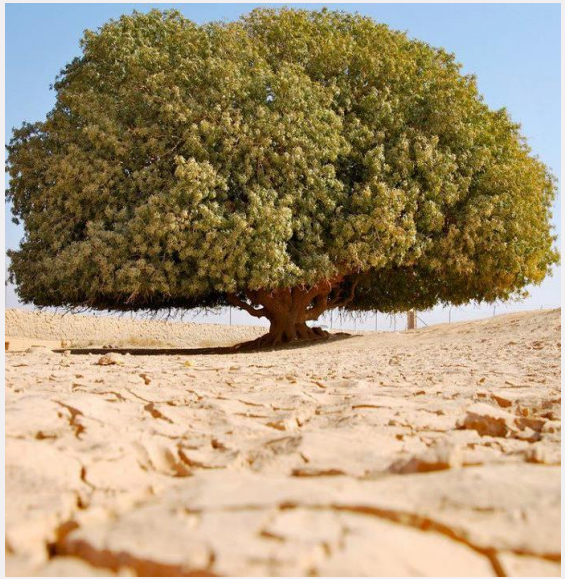
Popularity of wooden buildings

Living wood



CO_2: -

Dead wood

CO_2: 0

Burnt wood

CO_2: +

What was the problem with wooden buildings?

Can we handle this problem?

Performance based: objectives

Risk subsystems:

- Safety of third party properties (neighbouring plots)
- Safety of building occupants and fire service (escape routes and attack routes)
- Safety of the building (load bearing structure) → LOD
- Limiting spread of fire (compartmentation) → LOD
- Limiting smoke propagation (sub compartmentation) → LOD
- Limiting fire development (reaction to fire) → LOD

LOD:

- Line of Defence

Performance based: assessment criteria

For each risk subsystem, project specific assessment:

$$AST > RST \times \gamma$$

γ = safety factor
AST = available safe time [min] / [min SFC]
RST = required safe time [min] / [min SFC]

LOD's with a large safety factor ensure fire resilience

CLT in residential buildings

Walls and floors are load bearing structure

Walls and floors are separation constructions of (sub)compartments

Rule based:

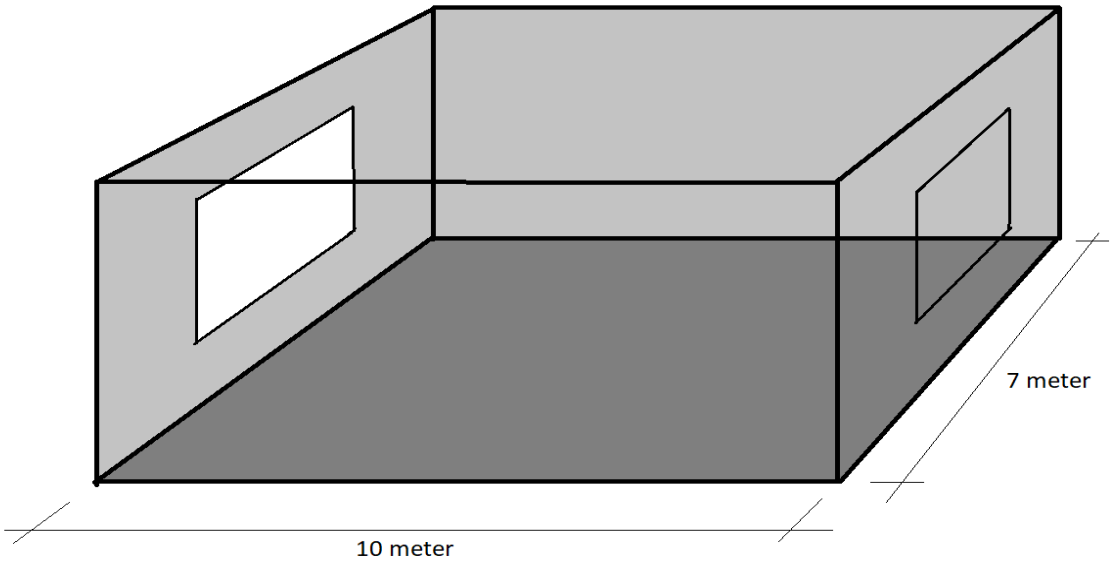
- CLT exposed to fire can be sufficiently fire resistant (meets fire resistance criteria according to EN 13501-2)

Performance based:

- Does the fire stop after the standard fire duration? (self extinguishing effect)

CLT in residential buildings

Simulation natural fire: Traditional vs. exposed CLT



CLT in residential buildings

Simulation natural fire: Traditional vs. exposed CLT

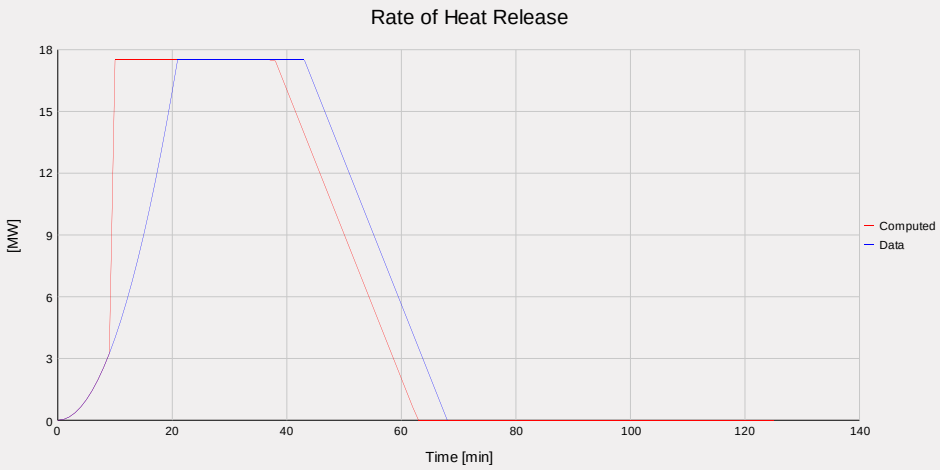
Boundary condition		Traditional	CLT
Permanent fire load (average)	[MJ/m^2]	-	400 (2)
Variable fire load (average)	[MJ/m^2]	780 (1)	780 (1)
Rate of Heat Release density	[kW/m^2]	250 (1)	250 (1)
Time constant fire development	[s]	300 (1)	300 (1)
Combustion value	[MJ/kg]	17,5 (3)	17,5 (3)
Stoichiometric constant	[kg/kg]	1,27 (3)	1,27 (3)
Combustion efficiency	[-]	0,8 (3)	0,8 (3)
Collapsed daylight openings h x b	[m]	1,5 x 8,2 (total)	1,5 x 8,4 (total)

(1) According to NEN-EN 1991-1-2/NB
(2) Assuming a characteristic permanent fire load of 500 MJ/m^2
(3) According to NEN 6055

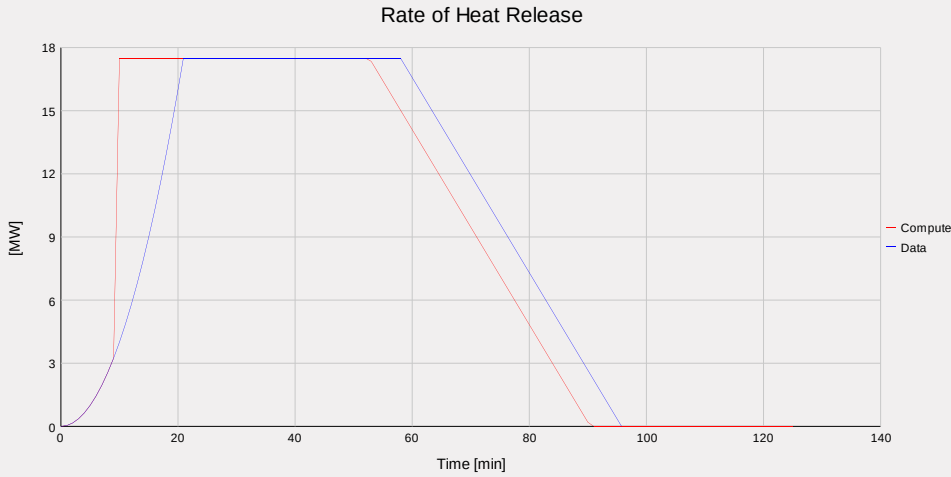
CLT in residential buildings

Thermal action caused by fire

Thermal action by fire (traditional)



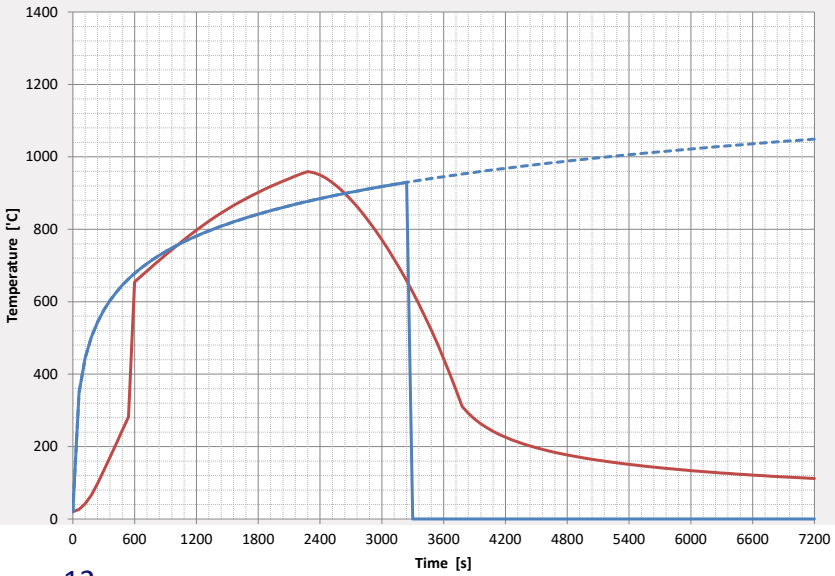
Thermal action by fire (CLT)



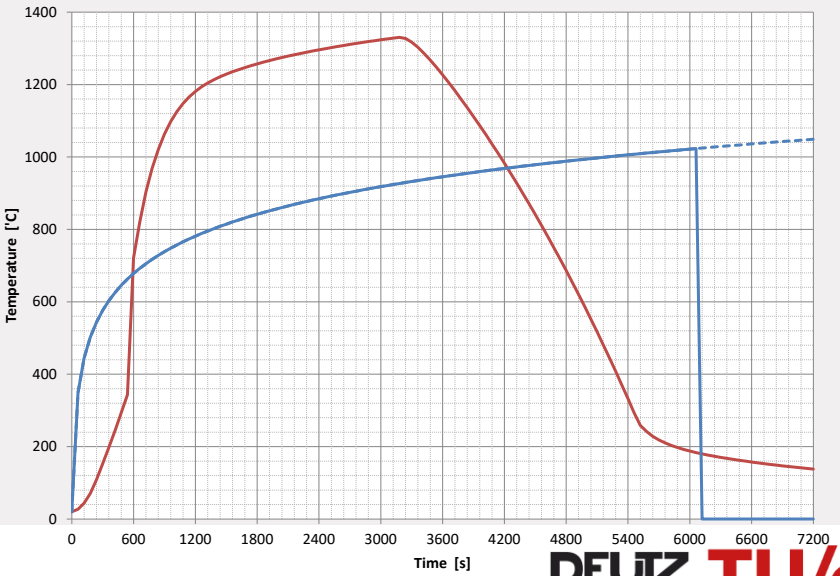
CLT in residential buildings

Thermal action caused by fire

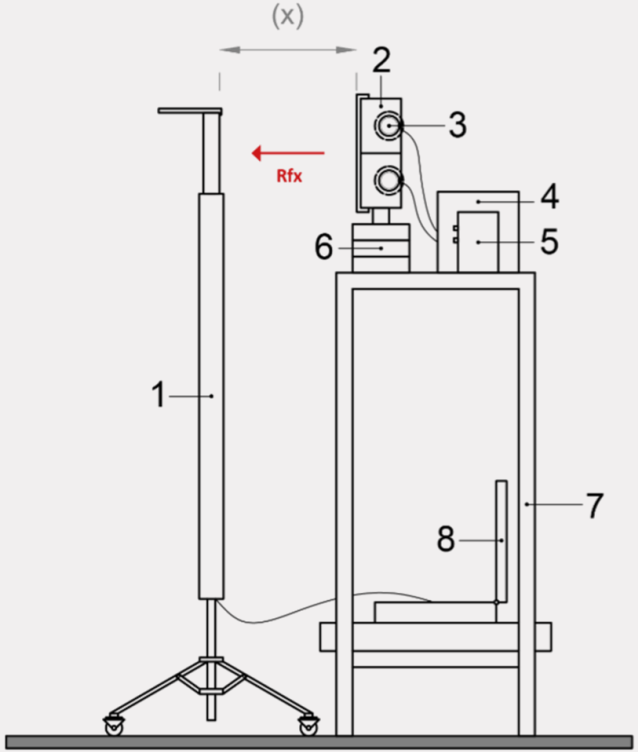
Thermal action by fire (traditional) 55 min SFC



Thermal action by fire (CLT) 101 min SFC



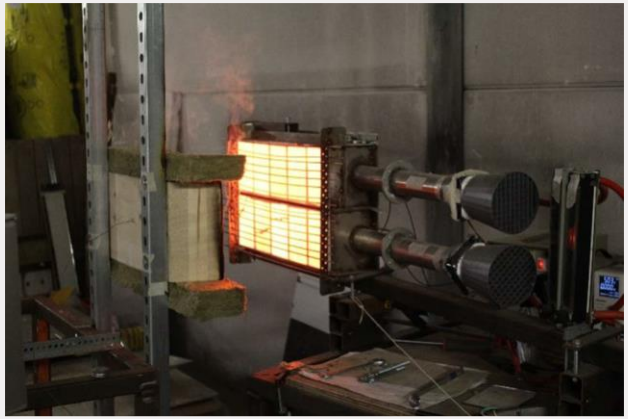
Lab research



Elevation Key

1 infrared radiation sensor - 2 radiant panel (480mm x 270mm)- 3 ventilation tubes
4 voltage regulator - 5 PID temperature controller - 6 cold-reolled profile (40mm x 40mm)
7 cold-rolled table (40mm x 40mm) - 8 Graphtec GL 240 Midi data logger

DERIX



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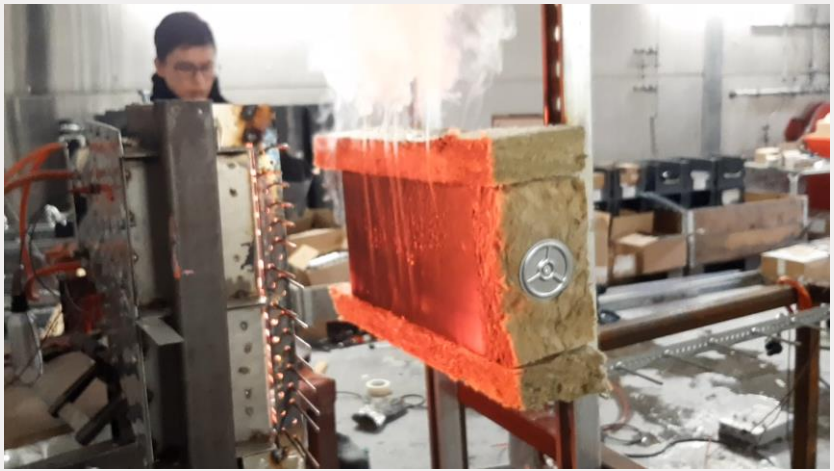
Lab research

Self extinguishing effect and delamination



Andrés Berdugo Calderon (Politecnico Torino)

Delamination: lamella falls off (ME glue)

Lab research

Results:

- Q_{rad} = 100 kW/m^2 → no measurement possible
- Q_{rad} = 25 kW/m^2 → burn in speed: 0,3 mm/min (flaming/smouldering)
- Q_{rad} = 15 kW/m^2 → burn in speed: 0,15 mm/min (smouldering)
- Q_{rad} = 10 kW/m^2 → burn in speed: 0,15 mm/min (smouldering)
- Q_{rad} = 5 kW/m^2 → burn in speed: 0,15 mm/min (smouldering)

Transition from flaming to smouldering combustion (CLT):

- Burn in depth: 3 – 8 mm

All experiments (90 min): continuous smouldering combustion in CLT samples

- No self extinguishing effect was found!

Adjusted simulation

Thermal action by fire

Modeled contribution of permanent fire load (CLT):

- Fully developed fire: 0.6 mm/min (assumption)
- Decay phase: 0.3 mm/min (flaming combustion)
- Variable fire load combusted: 0.15 mm/min (smouldering combustion)

Fully developed fire:

- RHR density: 250 kW/m^2
- Increases due to CLT to: 435 kW/m^2 (factor 1.74)
  (façade openings enlarged to full façade width)

Adjusted simulation

Thermal action by fire

Modeled contribution of permanent fire load (CLT):

- Fully developed fire: 0.6 mm/min (assumption)
- Decay phase: 0.3 mm/min (flaming combustion)
- Variable fire load combusted: 0.15 mm/min (smouldering combustion)

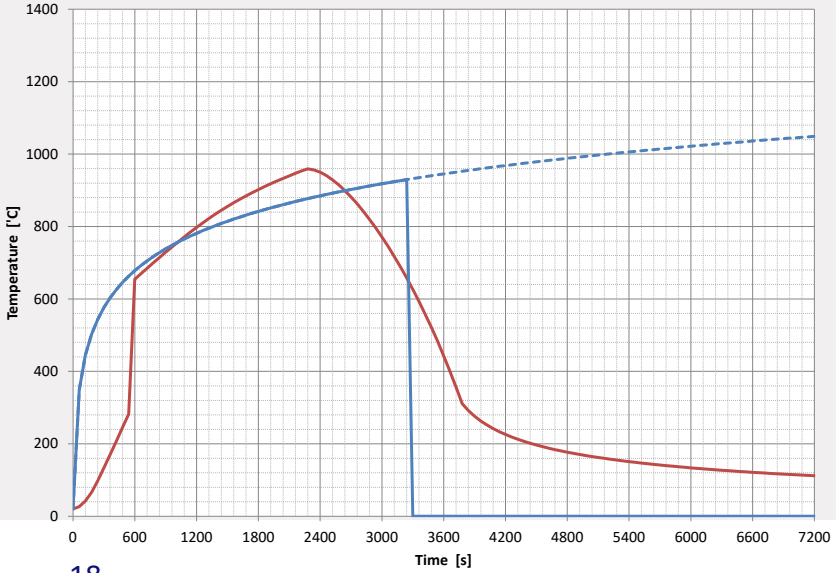
After 2 hours natural fire (Ozone simulation):

- Burn-in depth: 34 mm
- Corresponds to permanent fire load density 530 MJ/m^2 floor area

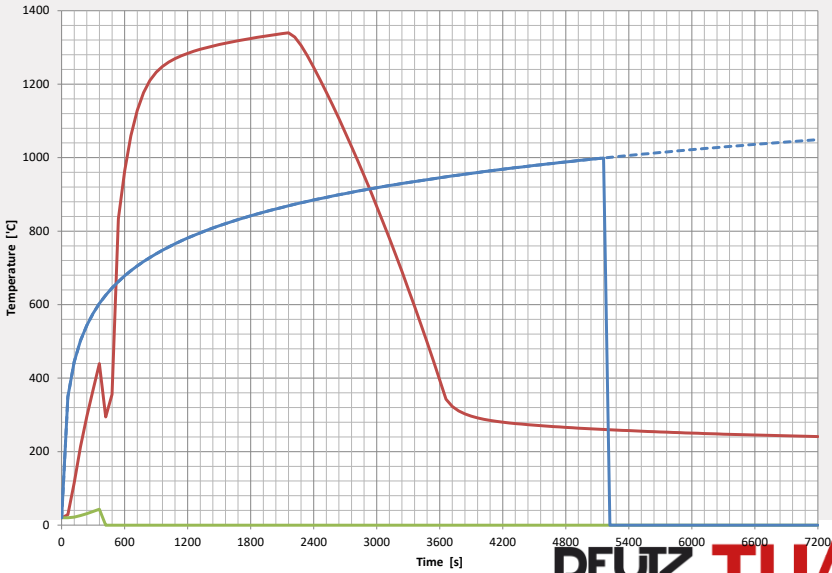
Adjusted simulation

Thermal action by fire

Thermal action by fire (traditional) 55 min SFC



Thermal action by fire (CLT) 86 min SFC



Conclusions

CLT exposed to fire

- Exposed CLT can be fire resistant (EN 13501-2, SFC), but:
  - Failure probability of fire compartmentation increases
  - Probability of burn down scenario increases:
    CLT building is less fire resilient than a traditonal building
  - Stay-in-place concept / partial evacuation: not possible
  - Probabilty of fire spread to neighbouring plots increases
  - More water needed for fire suppression

Conclusions

CLT exposed to fire

- Exposed CLT can be fire resilient:
  - Prevent flashover by sprinkler protection

- Residential sprinkler:
  - T_{act} = 68 ^{o}C – RTI = 35 $(m.s)^{0.5}$
  - Increased spray density
    LH: 2.25 mm/min → 3.94 mm/min

Robust solutions

Active reduction of thermal action: sprinkler protection

Passive protection of CLT construction: fire resistant cladding

Need for research:

- What is the critical radiation flux for self extinguishing effect of CLT due to the char layer?

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