Protection of timber structures – start time of charring and failure time

Alar Just

Tallinn University of Technology

RISE Research Institutes of Sweden

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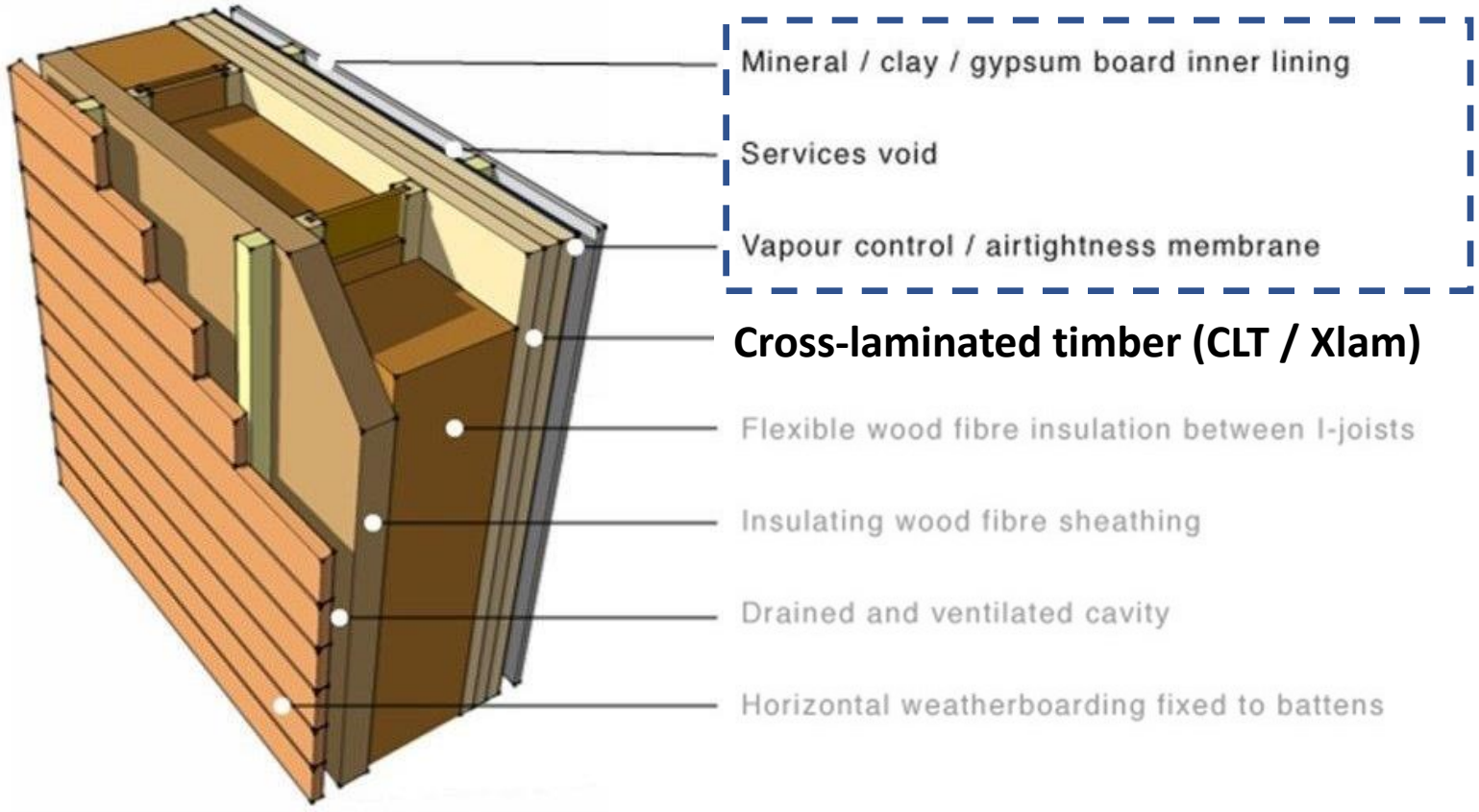
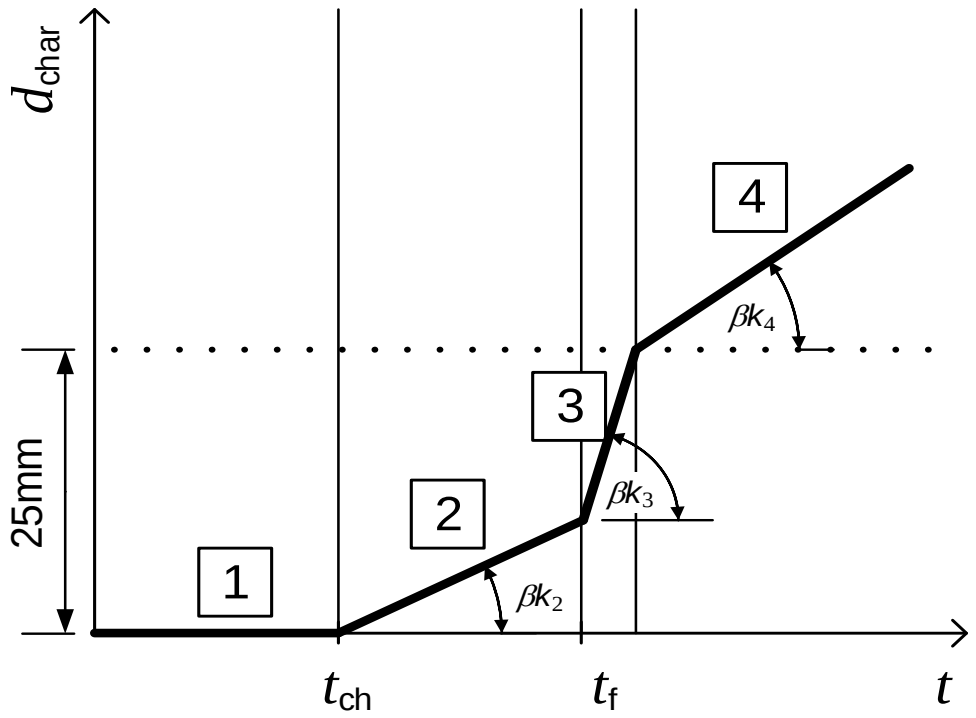
External wall with CLT load-bearing core



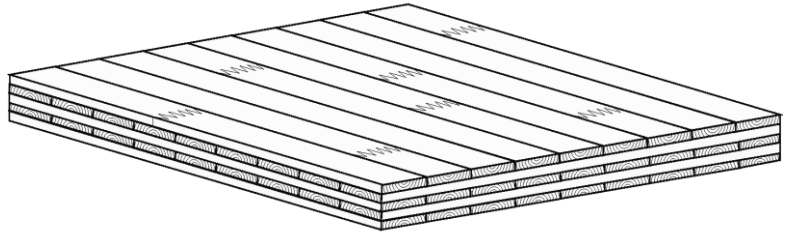
Fire protection system

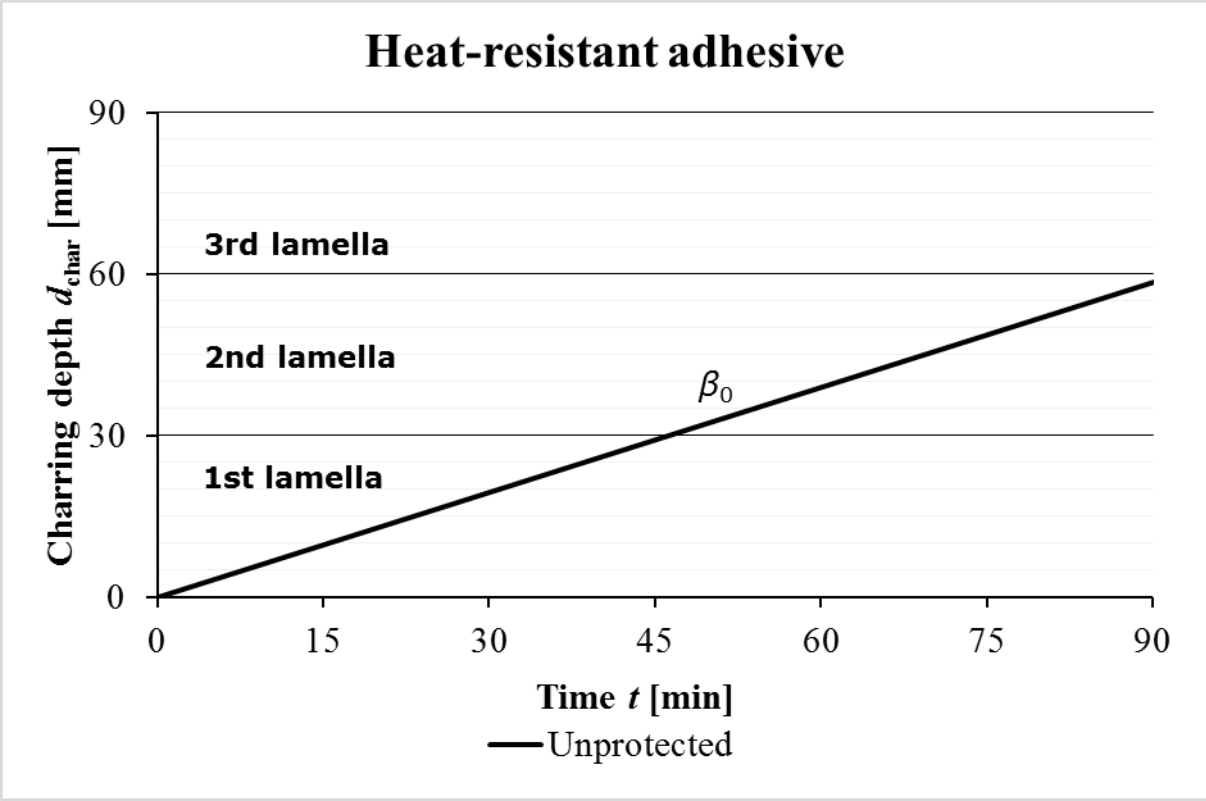
Photo source: GreenSpec UK

Charring of initially protected timber structures



Charring of CLT: Adhesive behaviour





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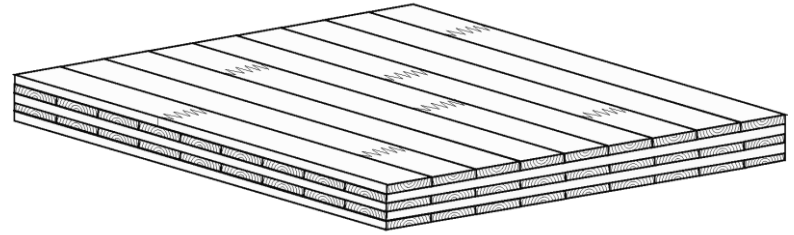

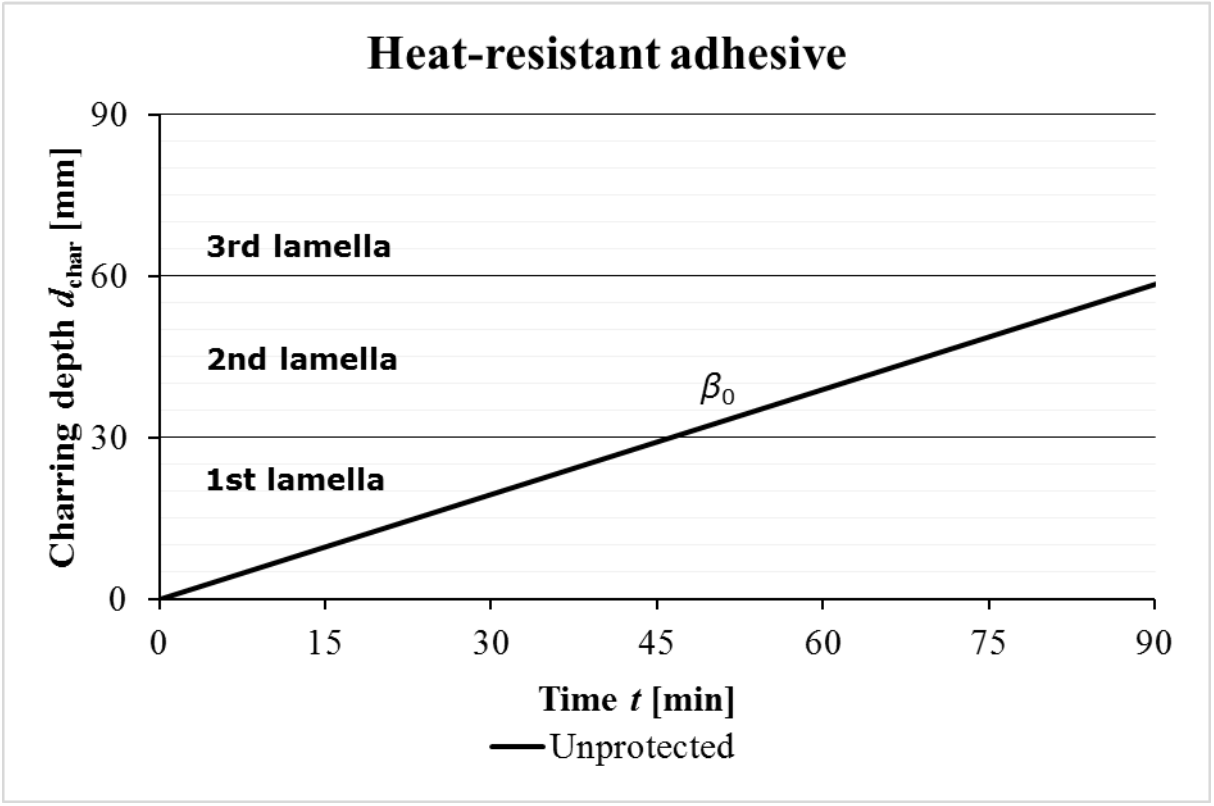

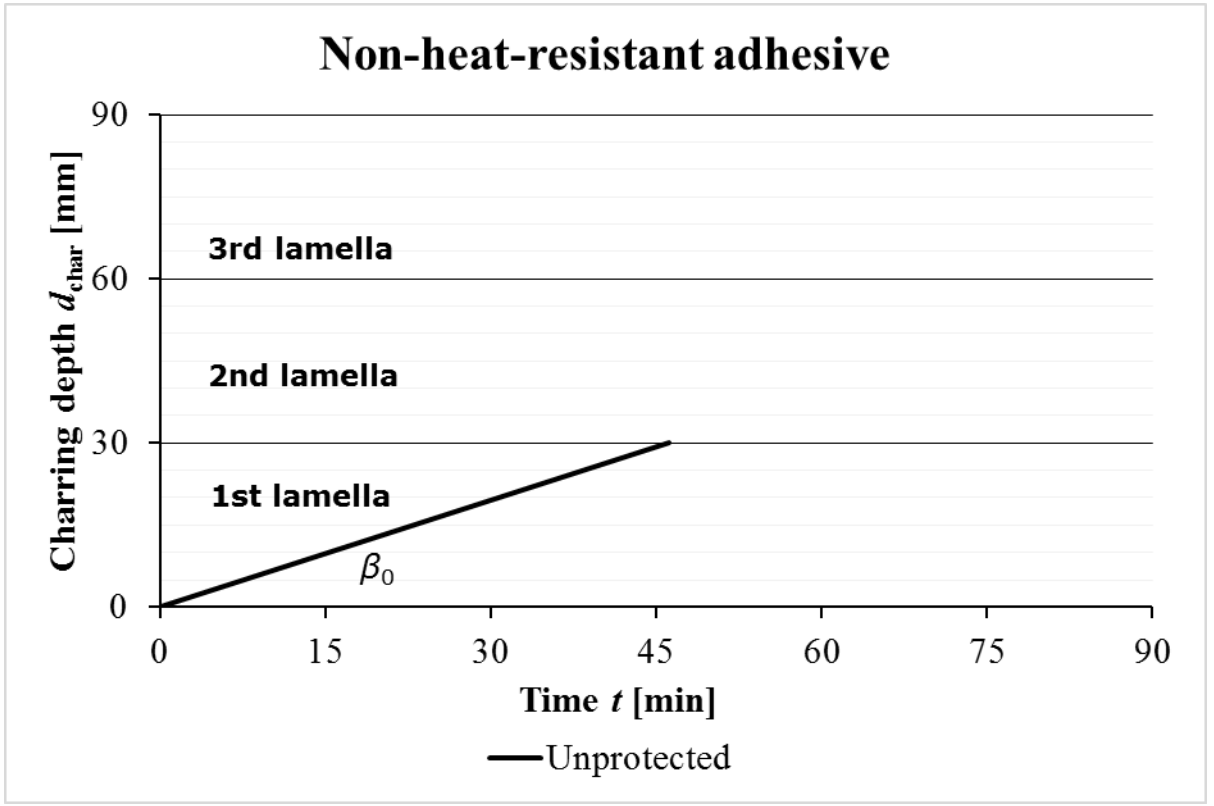

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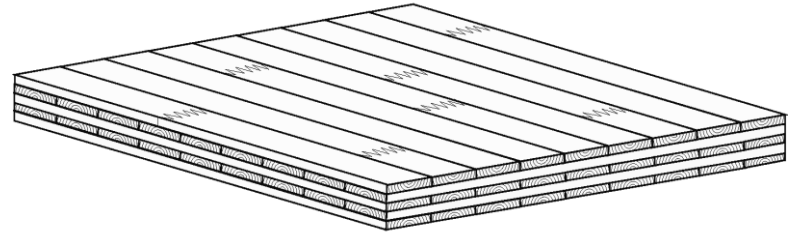
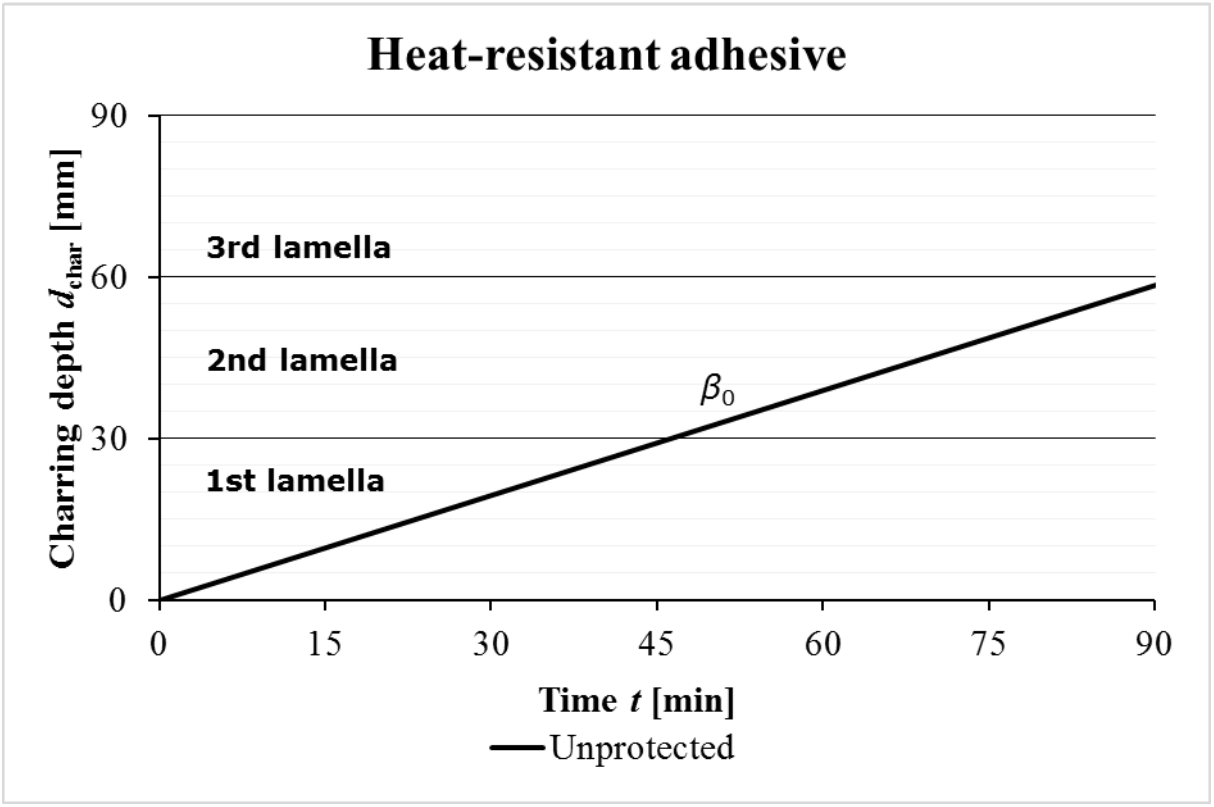
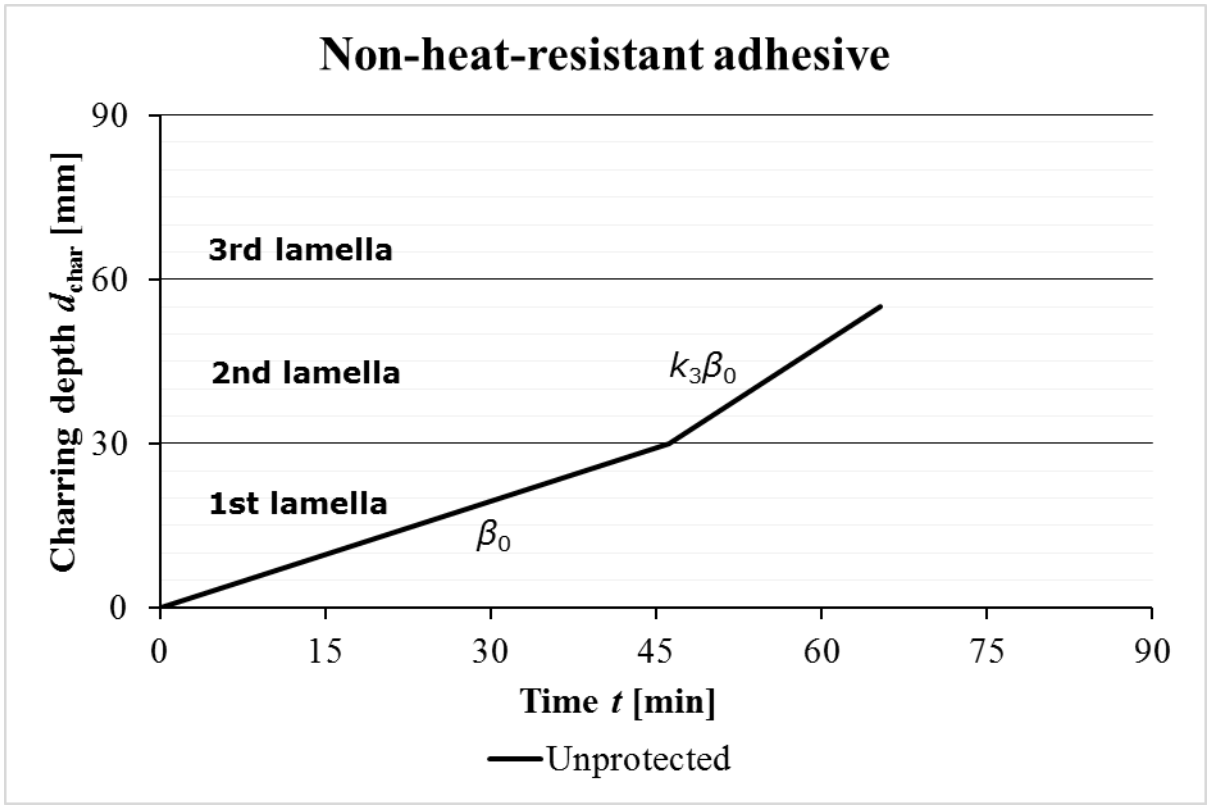


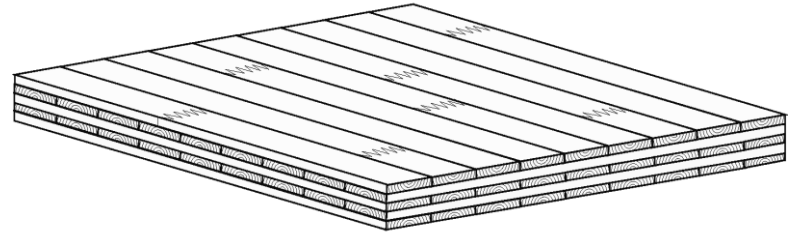


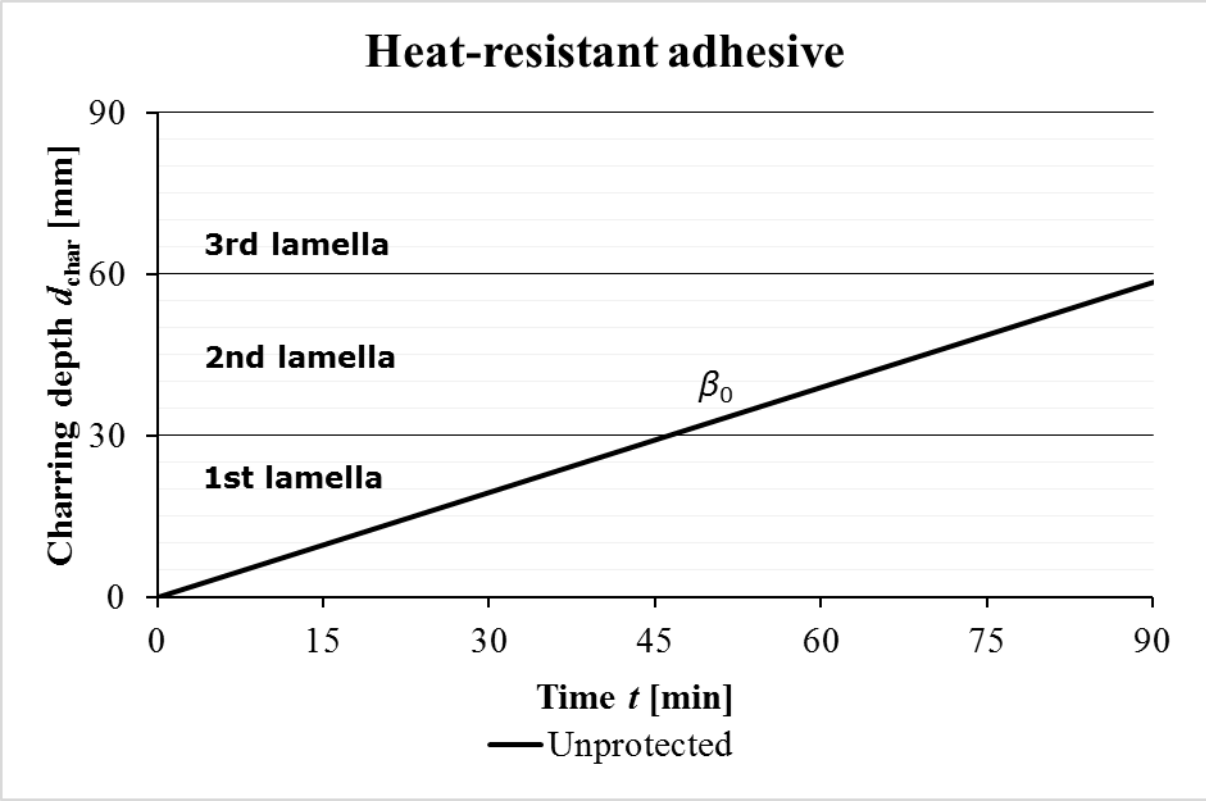


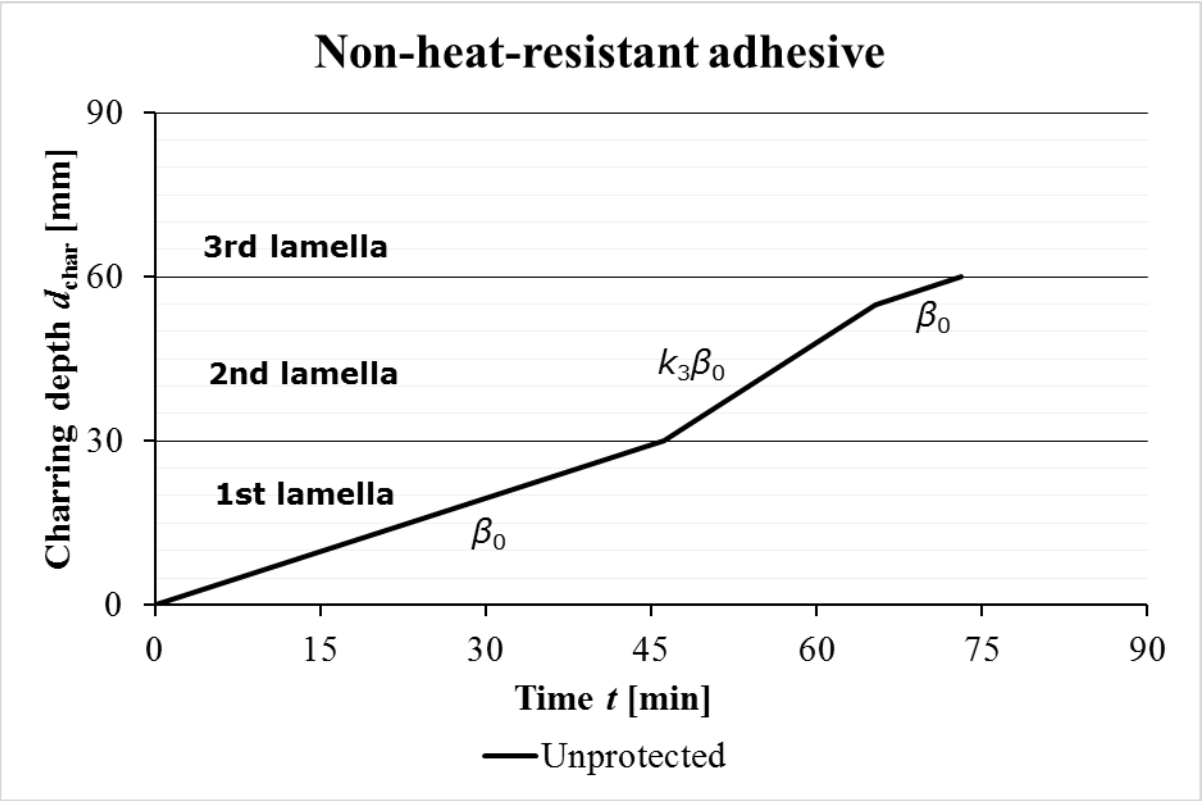
Non-heat-resistant adhesive

Falling off of charred lamellas

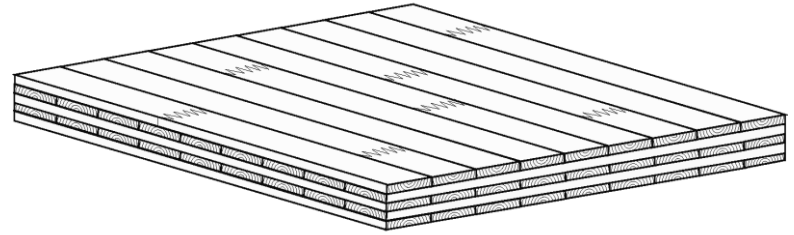
Charring of CLT: Adhesive behaviour

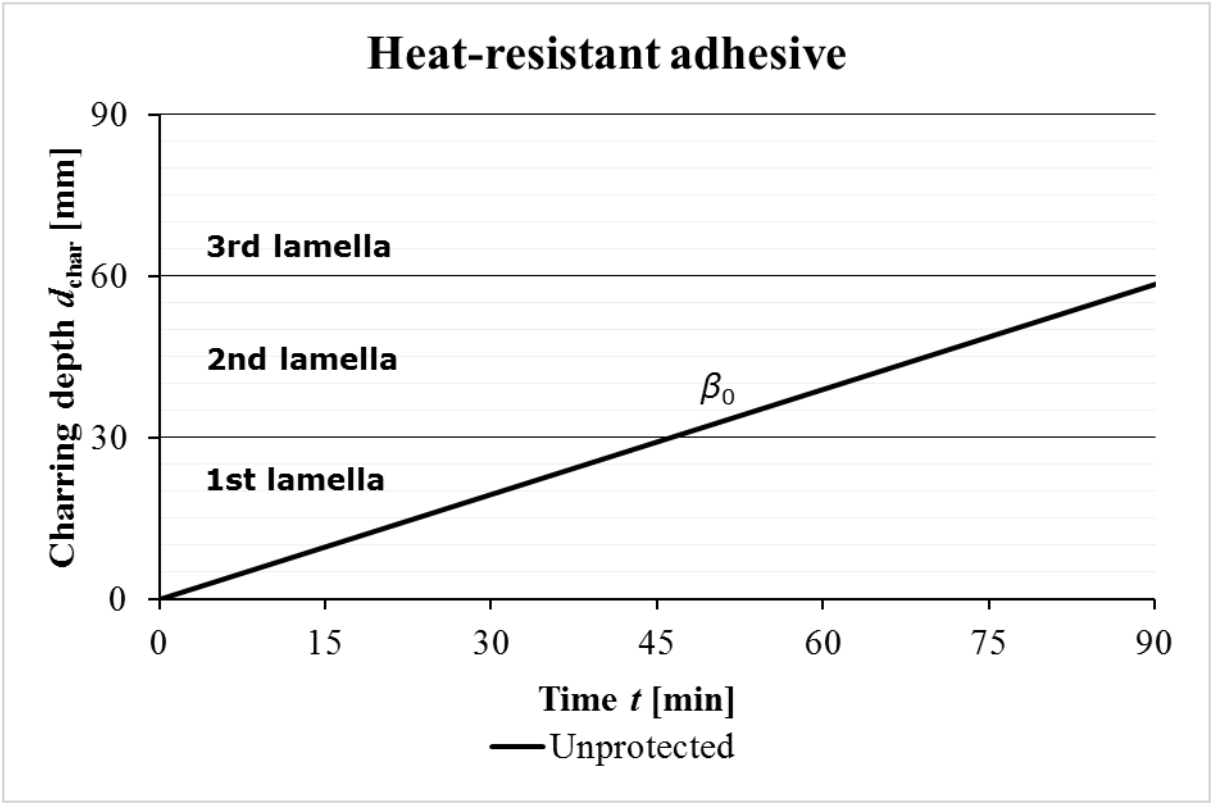


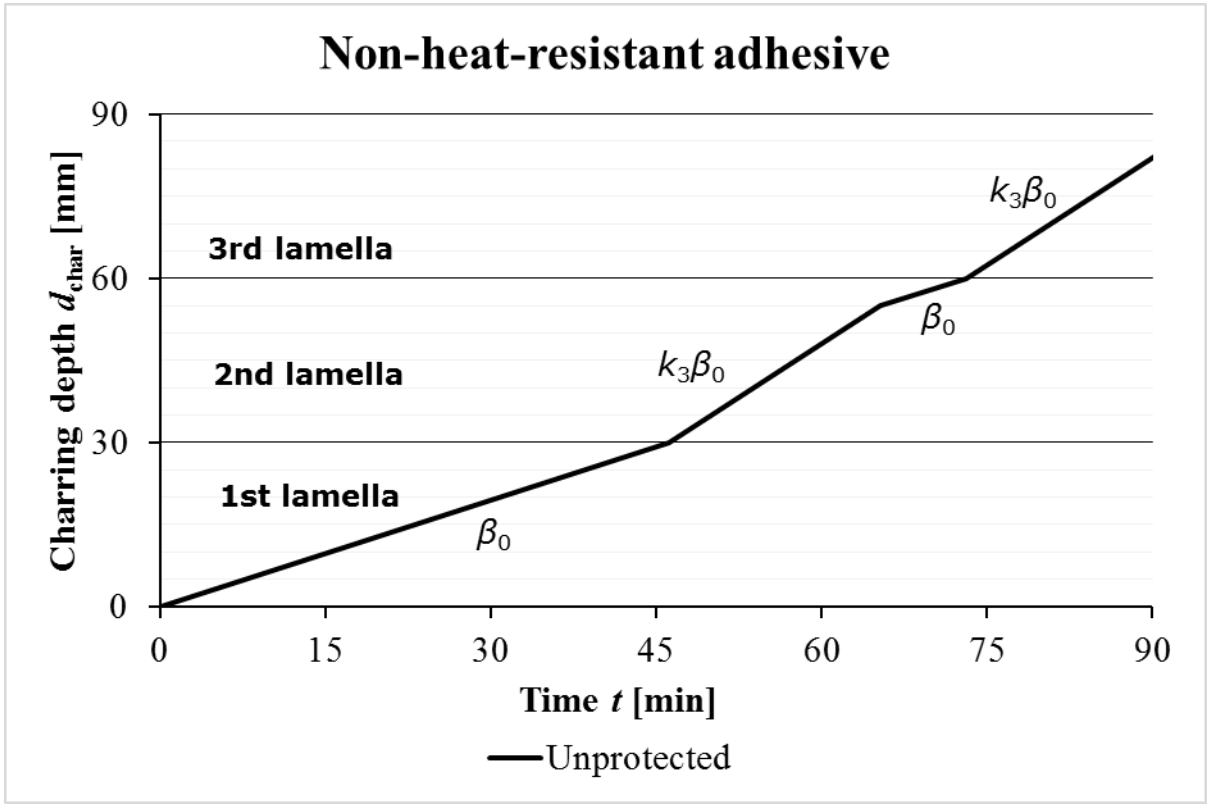




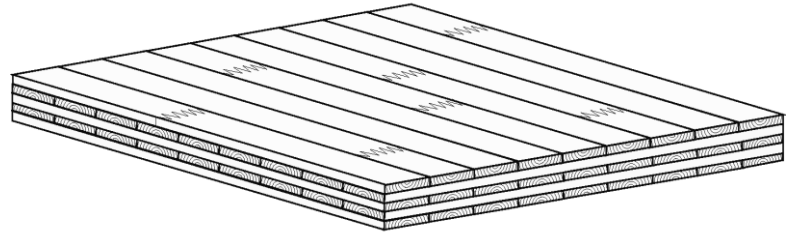
Charring of CLT: Adhesive behaviour

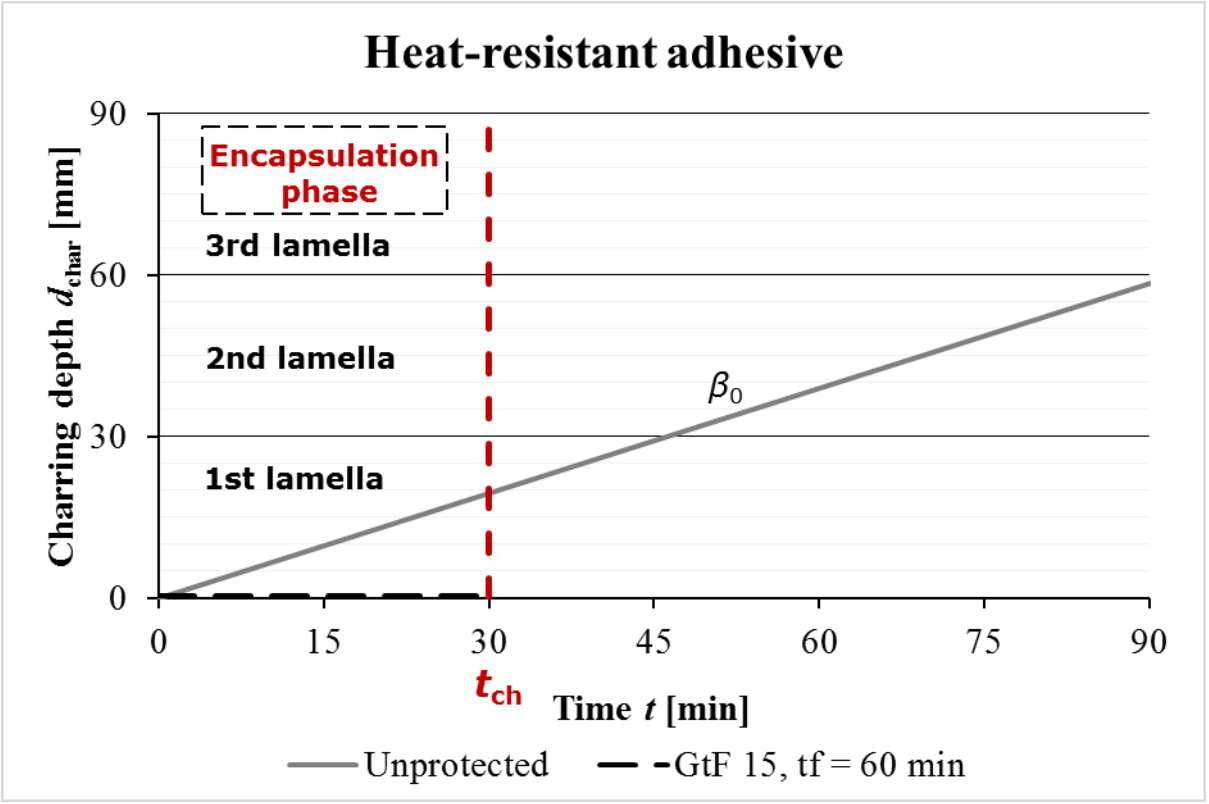


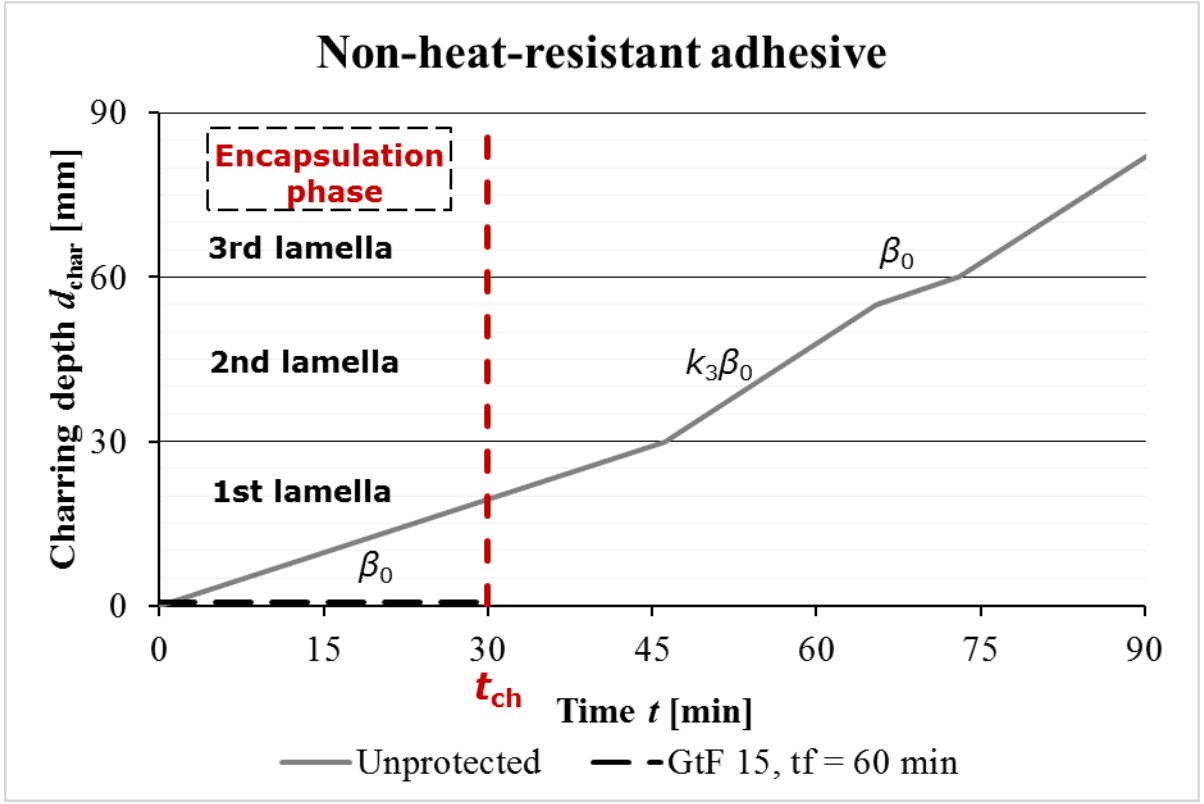




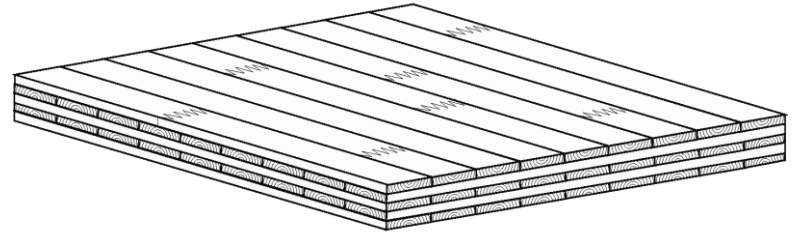
Charring of CLT:
Charring phases

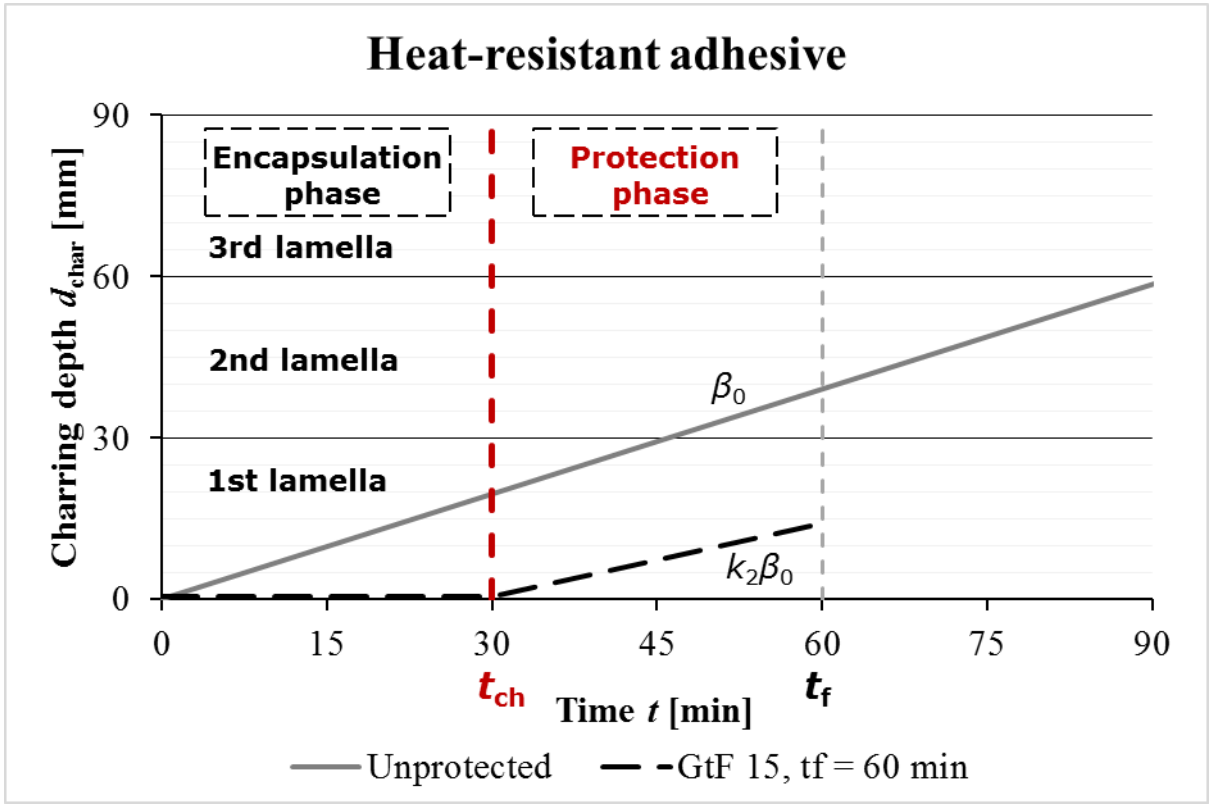


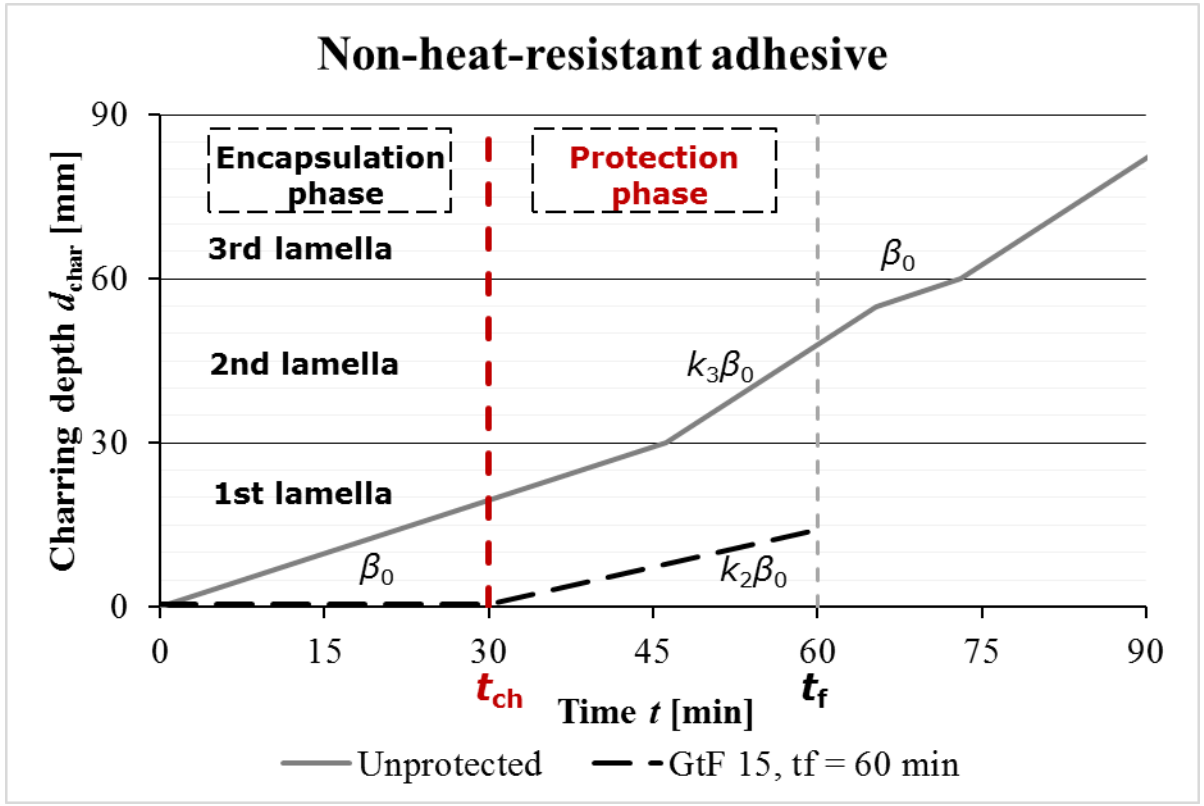




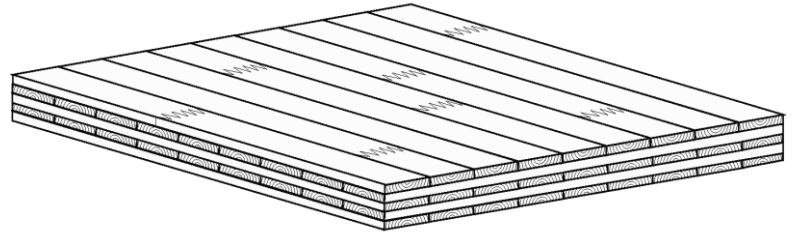
Charring of CLT:
Charring phases

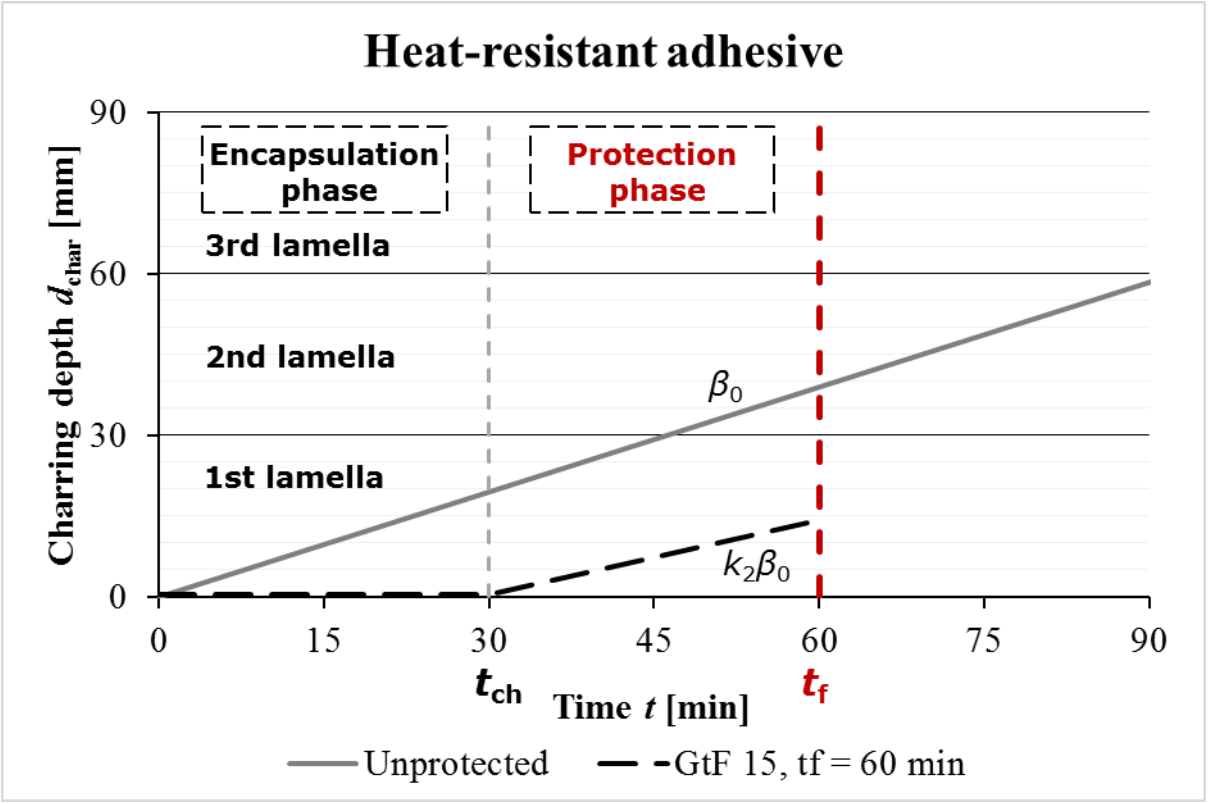


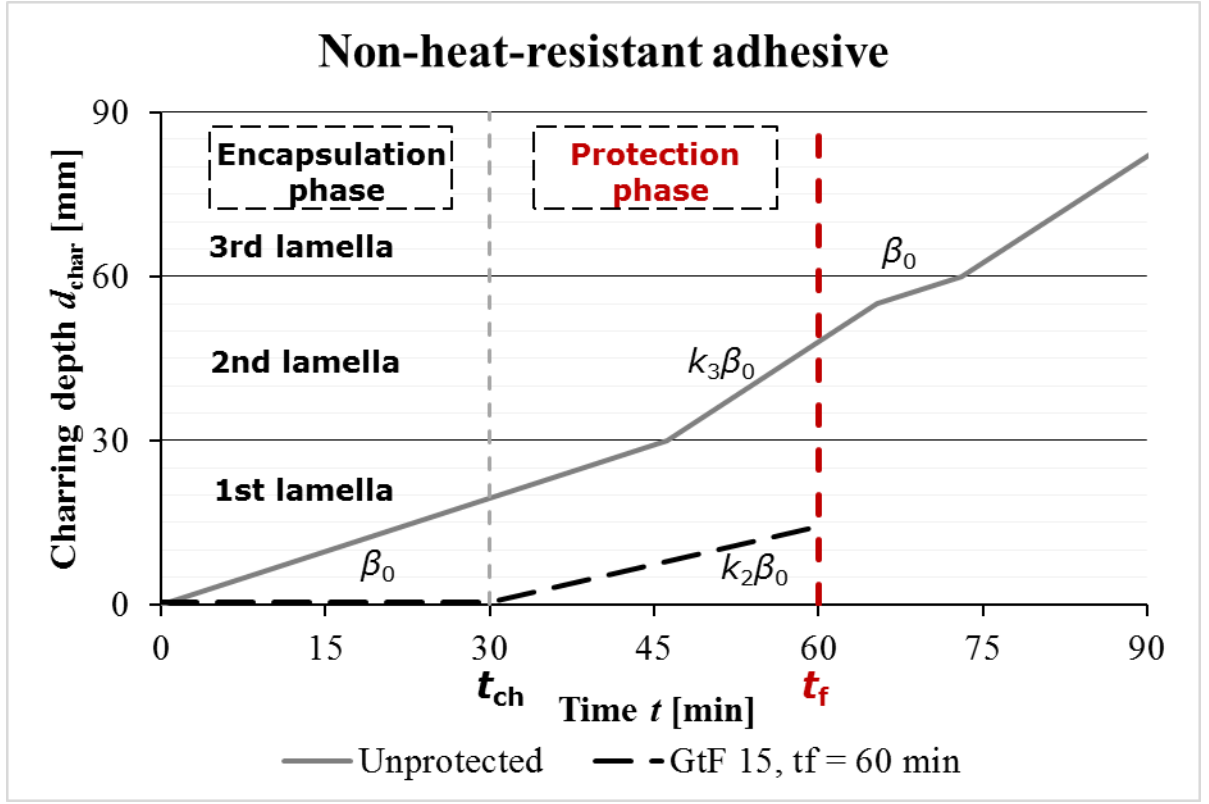




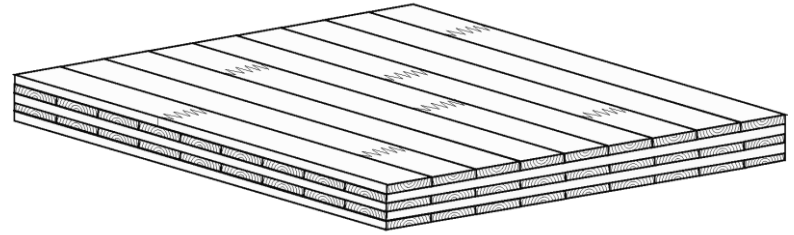
Charring of CLT:
Charring phases

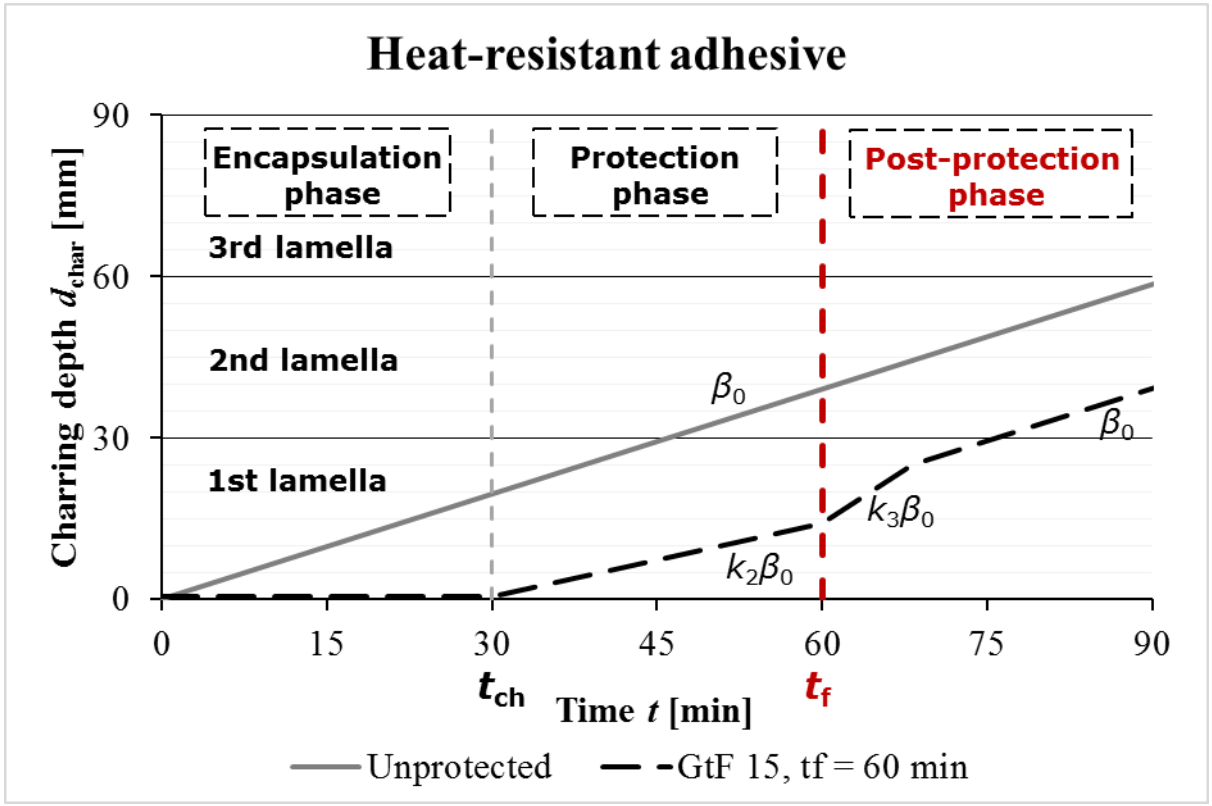


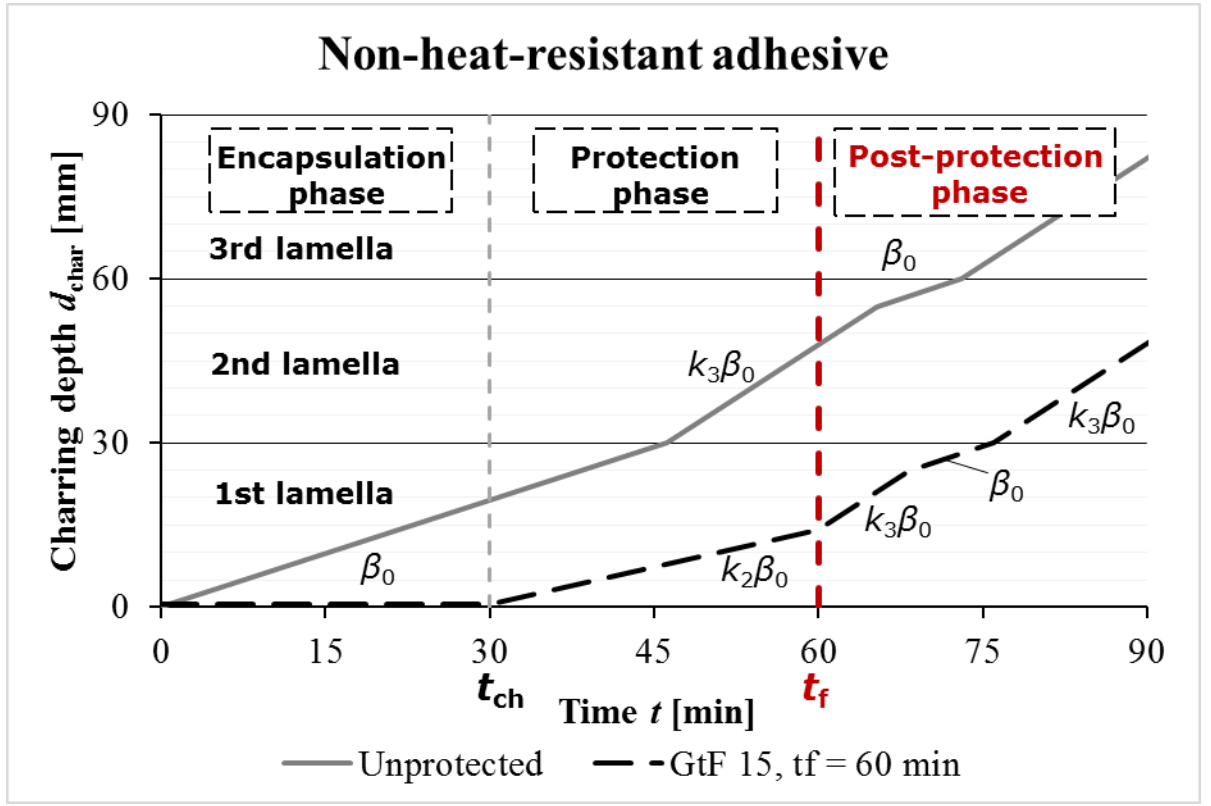




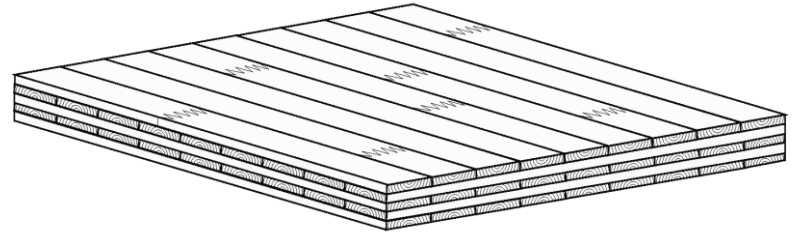
Charring of CLT:
Charring phases

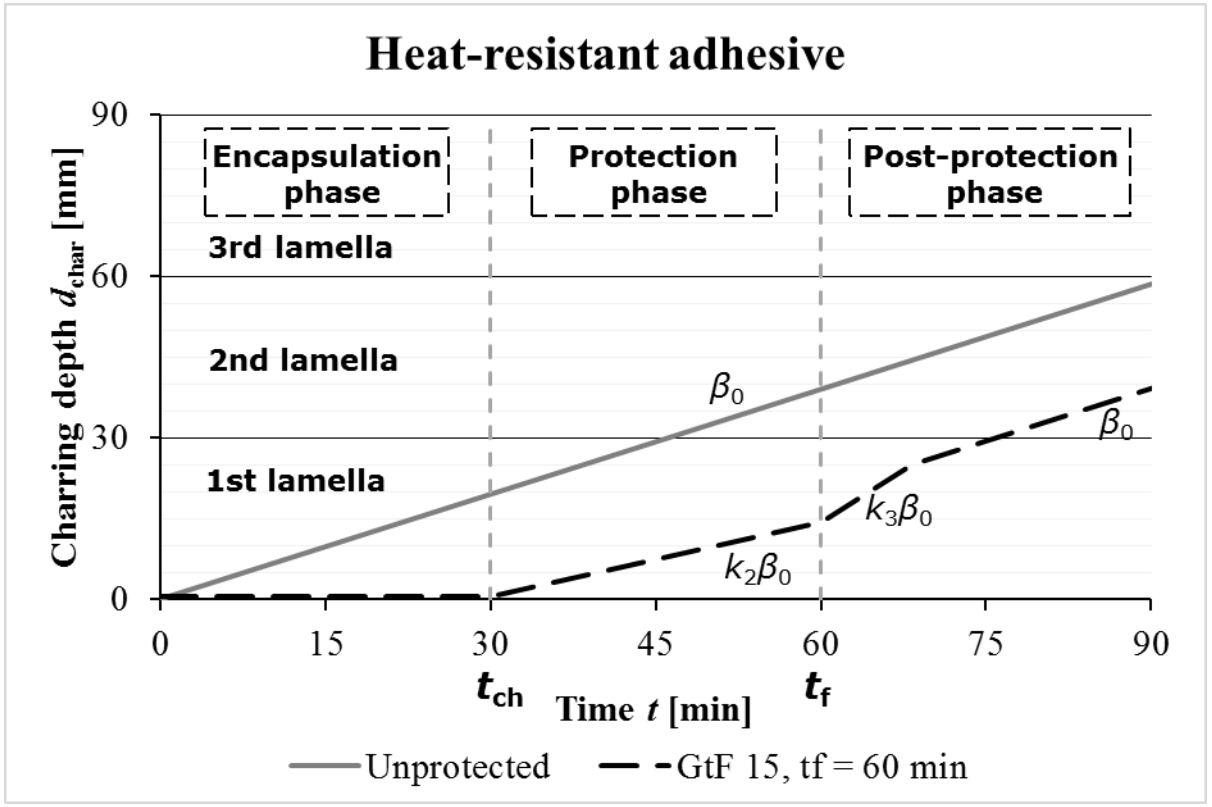


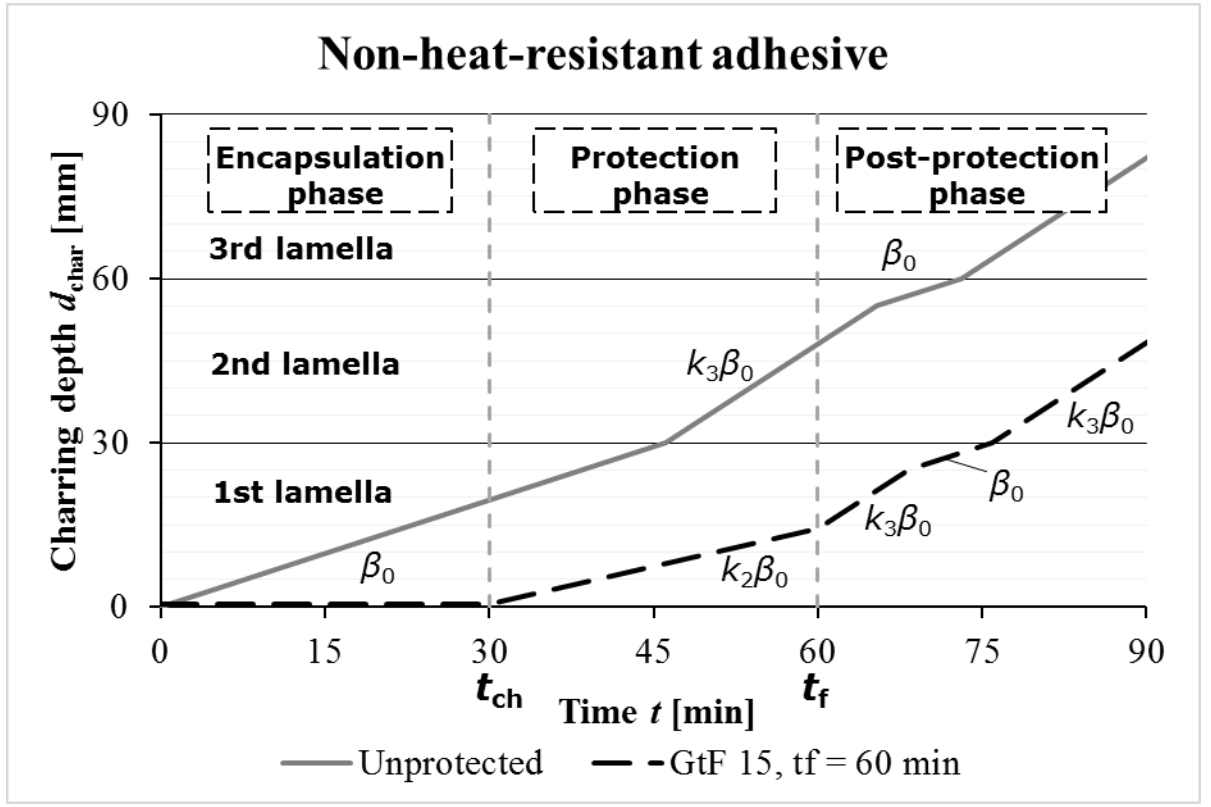


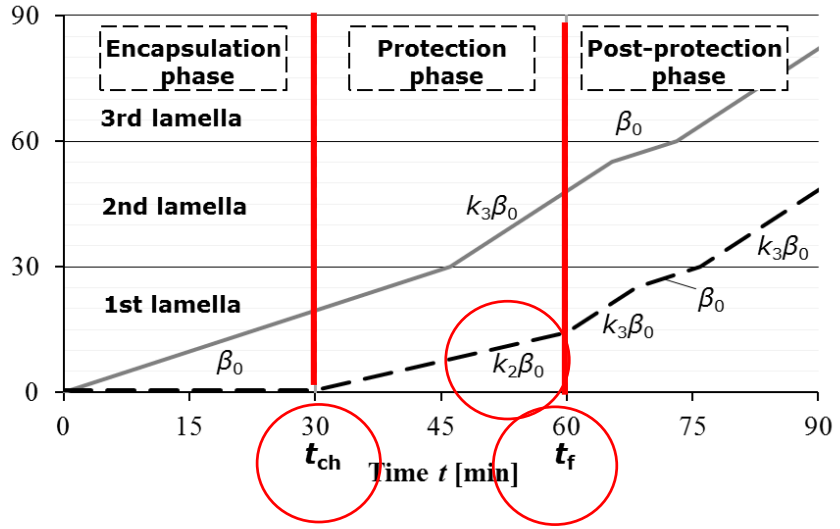


Charring of CLT: Initially protected







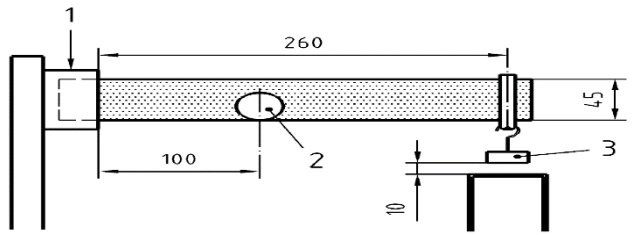

90
60
30
0
Encapsulation phase
Protection phase
Post-protection phase
3rd lamella
2nd lamella
1st lamella
β_0
$k_3\beta_0$
$k_2\beta_0$
0
15
30
45
60
75
90
t_{ch}
t_f
Time t [min]

$t_{ch} < t < t_f$

$t > t_f$

Gypsum boards

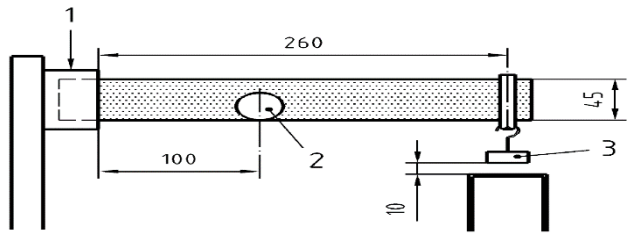
- EN 520



Ca 15 min

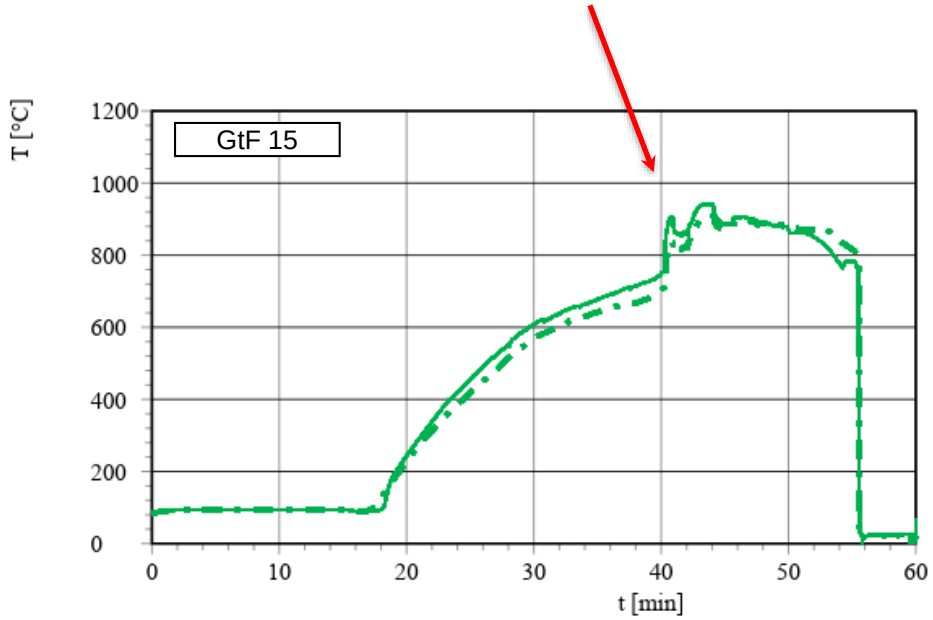
Gypsum boards

- EN 520



Ca 15 min

Ca 40 min



Start time of charring behind protection

t_{ch}

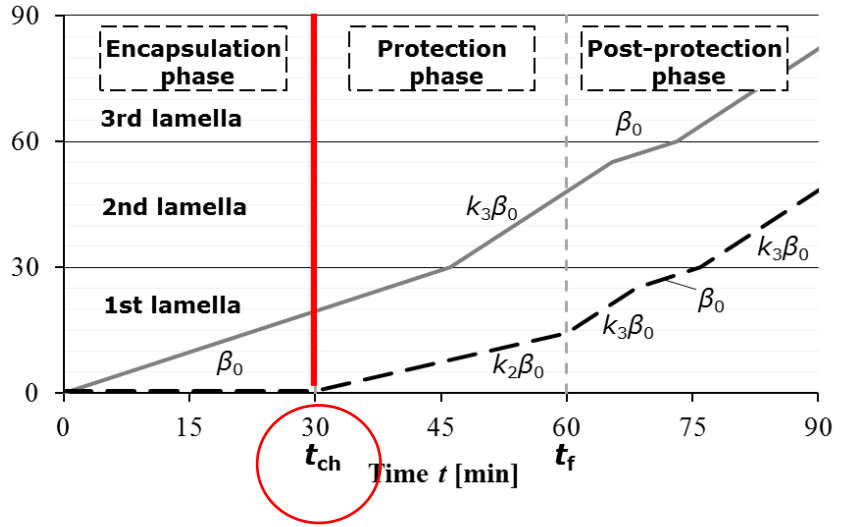
- Tested values for specific products
  - EN 13381-7
  - K-classes (EN 13501-2, defined times only!)


SVENSK STANDARD
SS-EN 13381-7:2019

Fastställd/Approved: 2019-07-02
Utgåva/Edition: 1
Språk/Language: engelska/English
ICS: 13.220.50;91.080.20

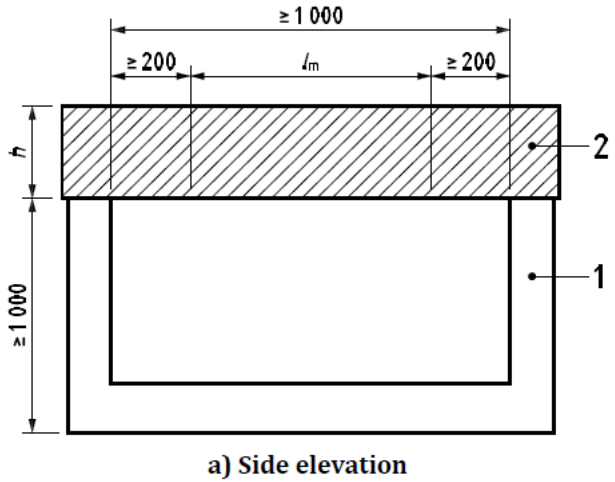
Brandteknisk provning av byggnadsdelar – Bidrag till brandmotstånd –
Del 7: Skydd av träkonstruktioner

Test methods for determining the contribution to the fire resistance of structural members –
Part 7: Applied protection to timber members

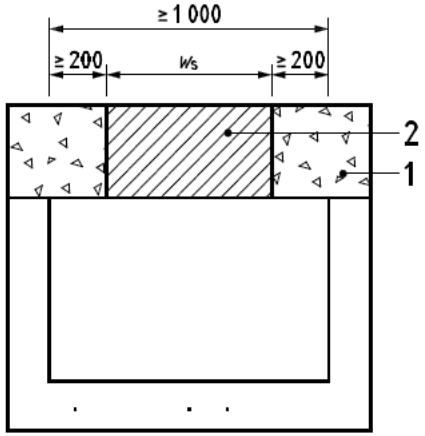


EN 13381-7:2019

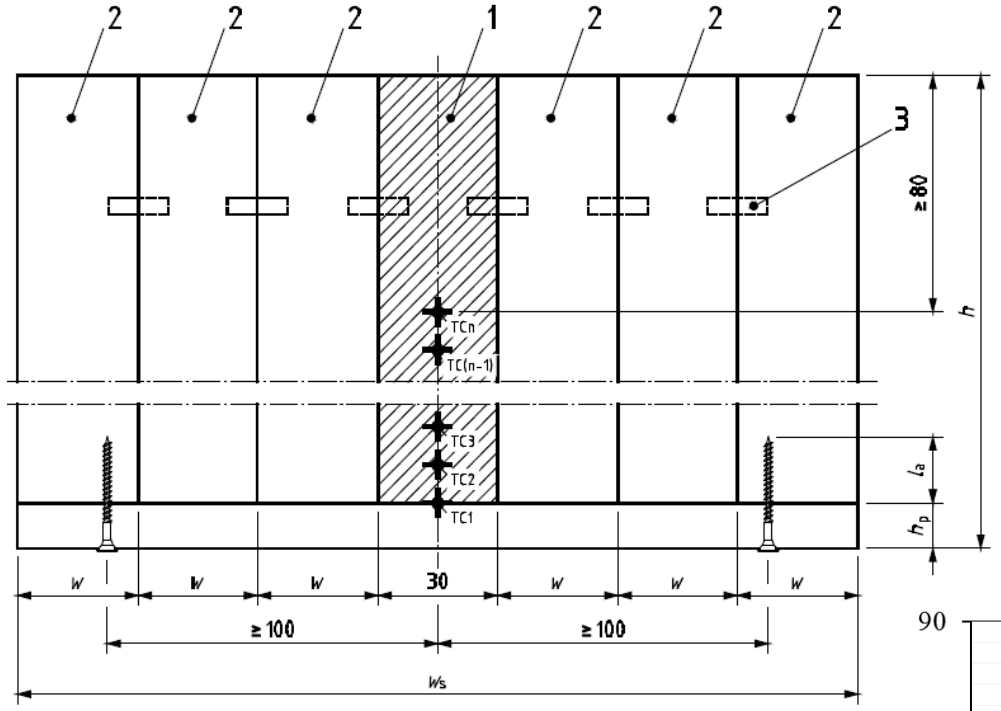
Model scale test



a) Side elevation



b) End elevation

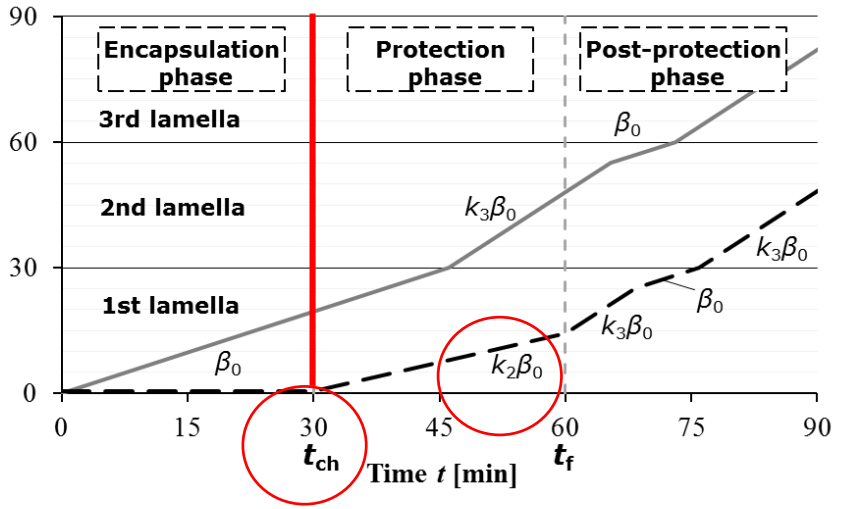


y

instrumented timber beam (centre beam)
side timber beams
wood dowels (optional)
depth of the charring specimen
thickness of the fire protection system

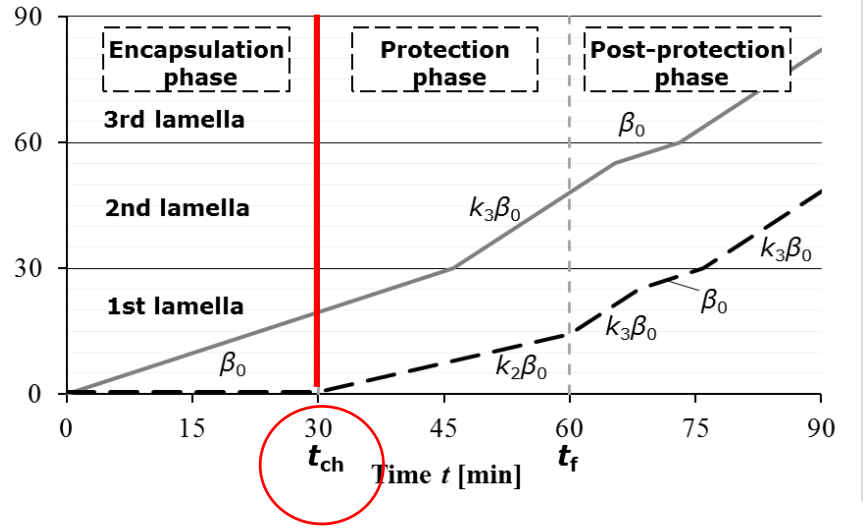
anchorage length of the mechanical fixation in wood at $t = 0$

Start time of charring (t_{ch}) and charring rate (k_2)



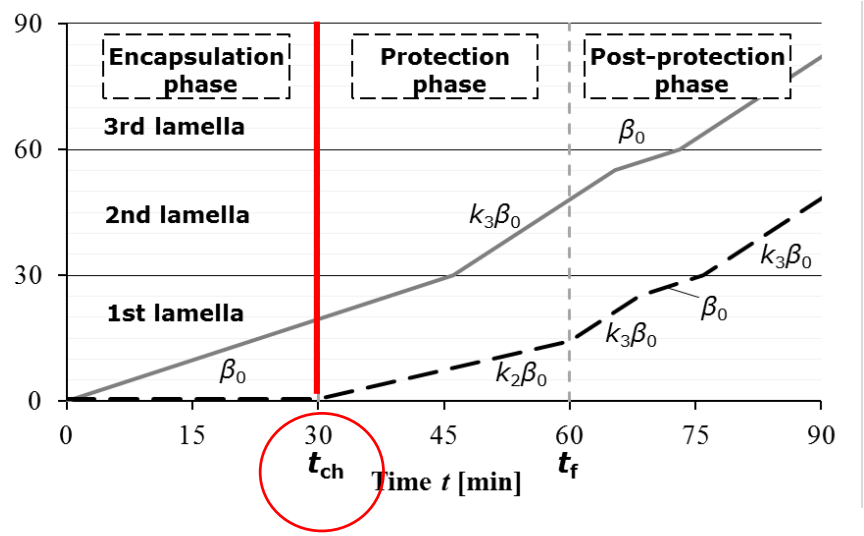
Start time of charring behind protection
t_{ch}

- Tested values for specific products
  - EN 13381-7



Start time of charring behind protection
t_{ch}

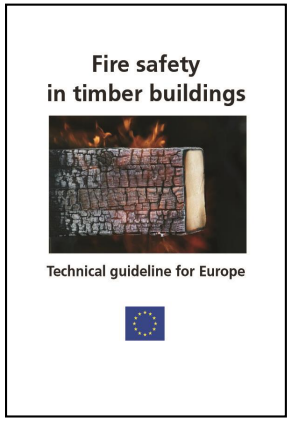
- Tested values for specific products
  - EN 13381-7
  - K-classes (EN 13501-2, strict!)
- Generic values
  - EN 1995-1-2:2004
  - **EN 1995-1-2:2022** (coming soon)
  - **Sum of protection times**

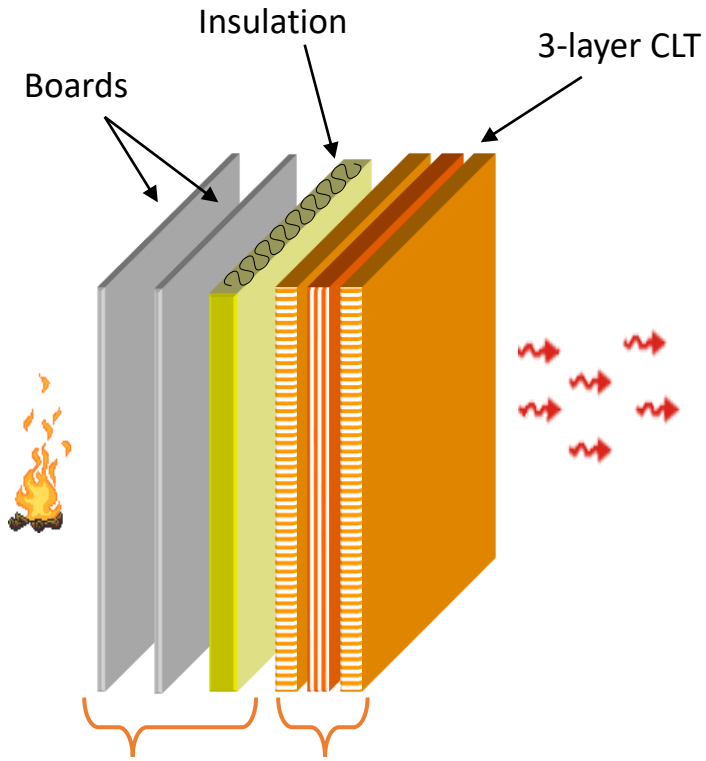


Separating Function Method

Calculations

$$t_{ch} = \Sigma\, t_{prot,\ cladding}$$





Fire protection system

$T_{prot} = 270°C$

Initially protected CLT

$T_{ch} = 300°C$

$$t_{prot,i} = \left(t_{prot,0,i} \cdot k_{pos,exp,i} \cdot k_{pos,unexp,i} + \Delta t_i\right) \cdot k_{j,i}$$

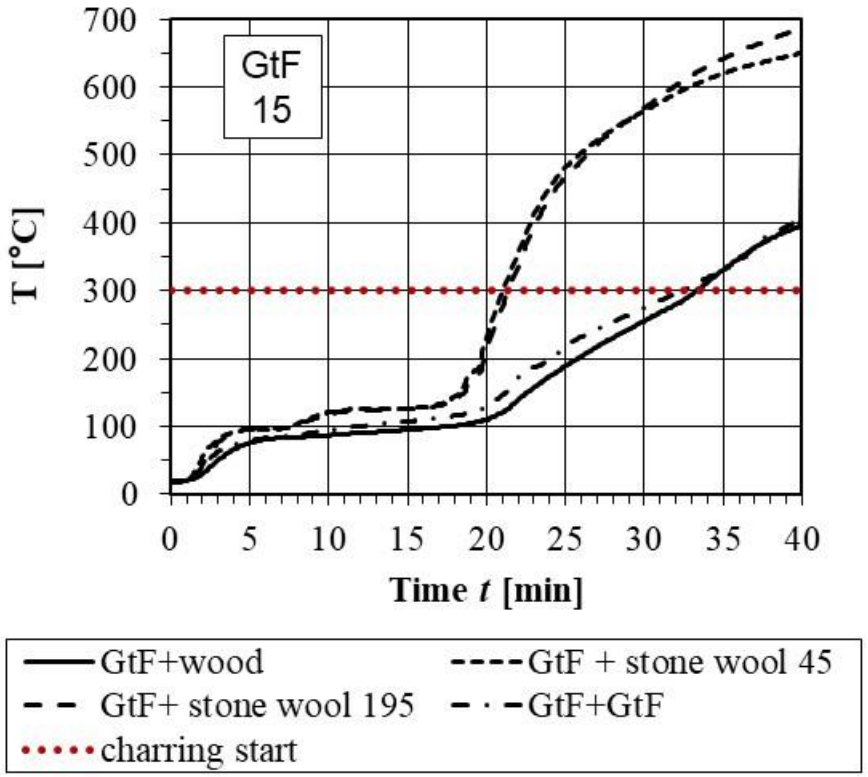
No	Material	Protection time $t_{prot,i}$	Sum of protection times
		min	min
1	Gypsum plaster-board type F (GtF)	30	30
2	Gypsum plaster-board type F (GtF)	11,3	41,3
3	Stone wool (SW)	28,7	**69,9**
4	CLT		

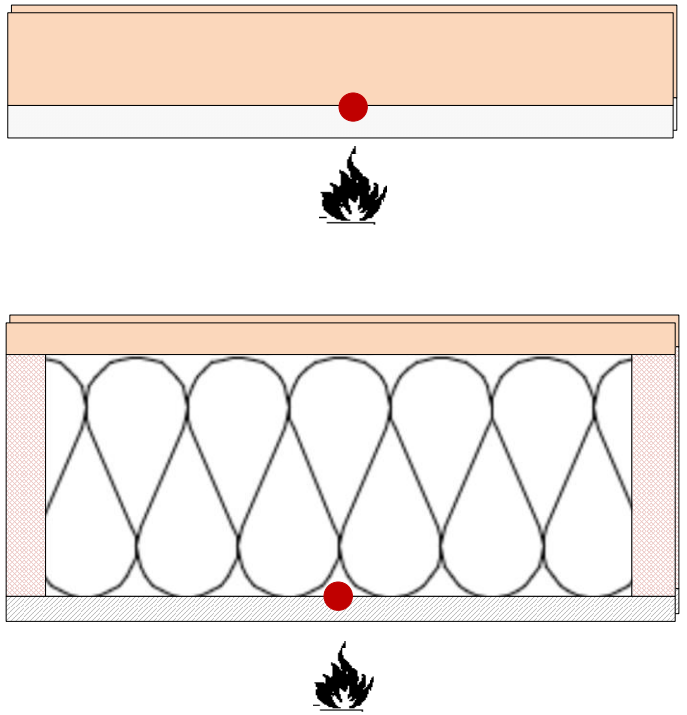
$$t_{ch} = \min \begin{cases} \sum t_{prot} \\ t_f \end{cases}$$

Separating Function Method

Start time of charring
Mineral wool vs wood substrate

$$t_{prot} = t_{prot,0} * k_{pos,unexp}$$





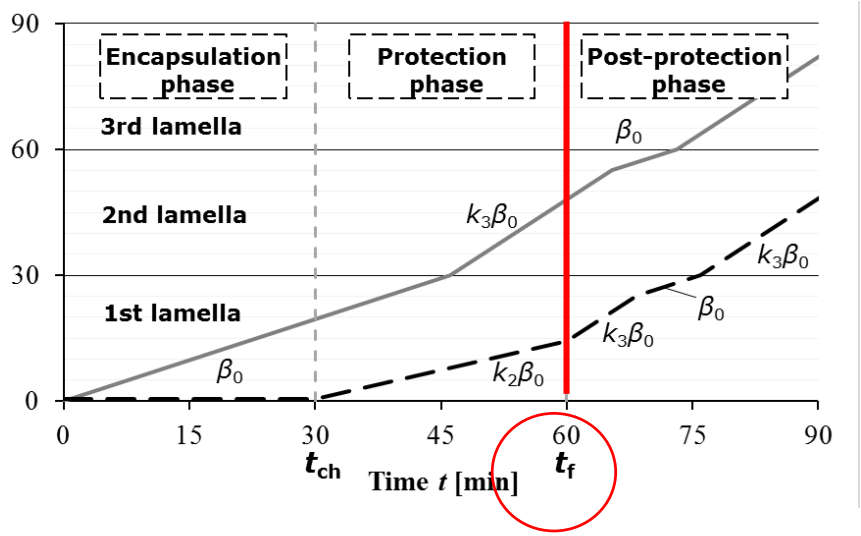
$k_{pos,unexp} = 1$

$k_{pos,unexp} < 1$

Failure of the cladding

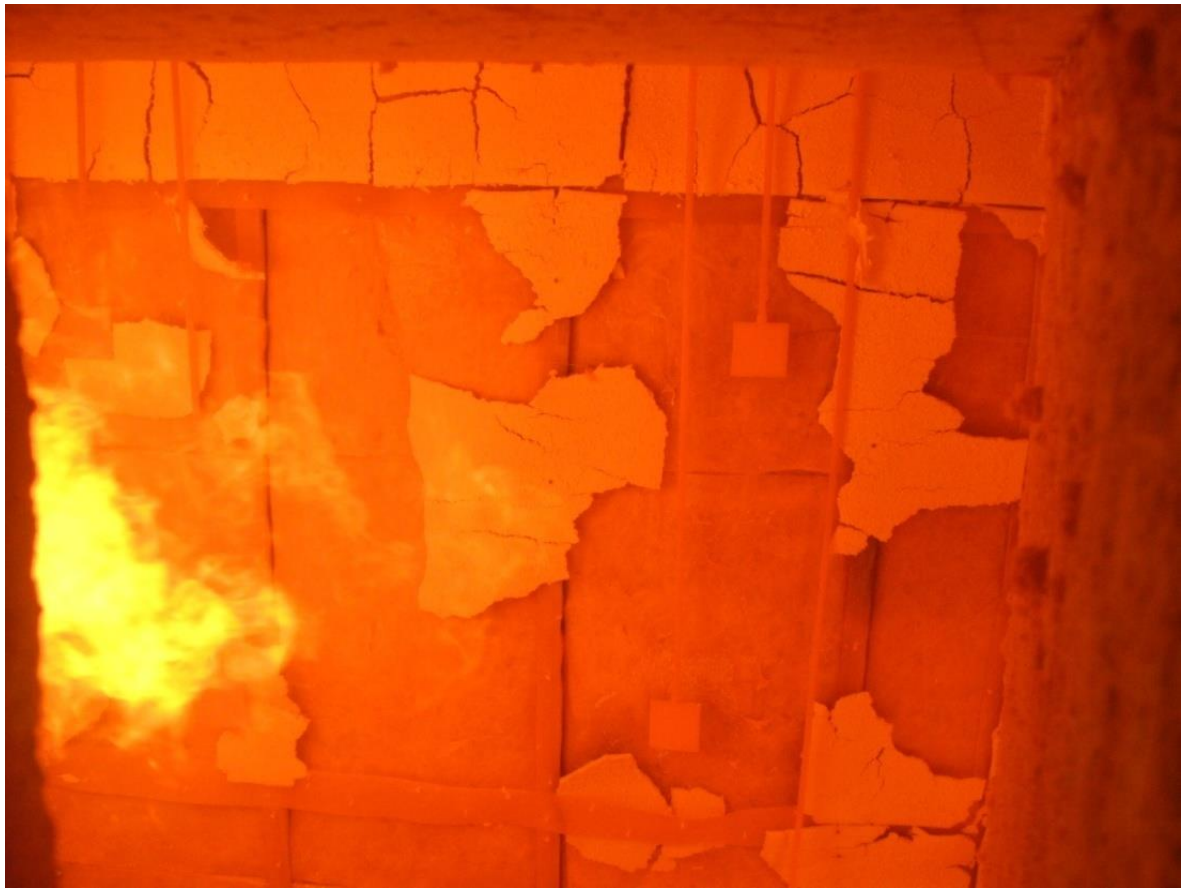
Mechanical degradation

Pull-out of fasteners



Failure time of fire protection system

t_f



Fall-off

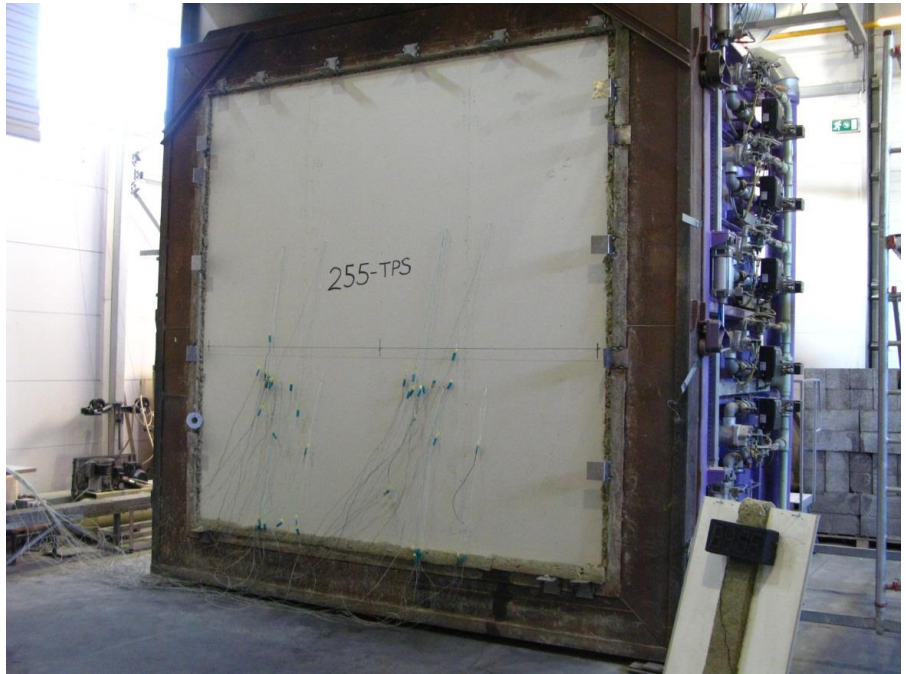
Heavy shrinkage

Failure time of fire protection system
t_f

- Tested values for specific products
  - **EN 13381-7:2019**
  - EN 1363, 1364, 1365 series

Controlled by TC-s

Visual observations



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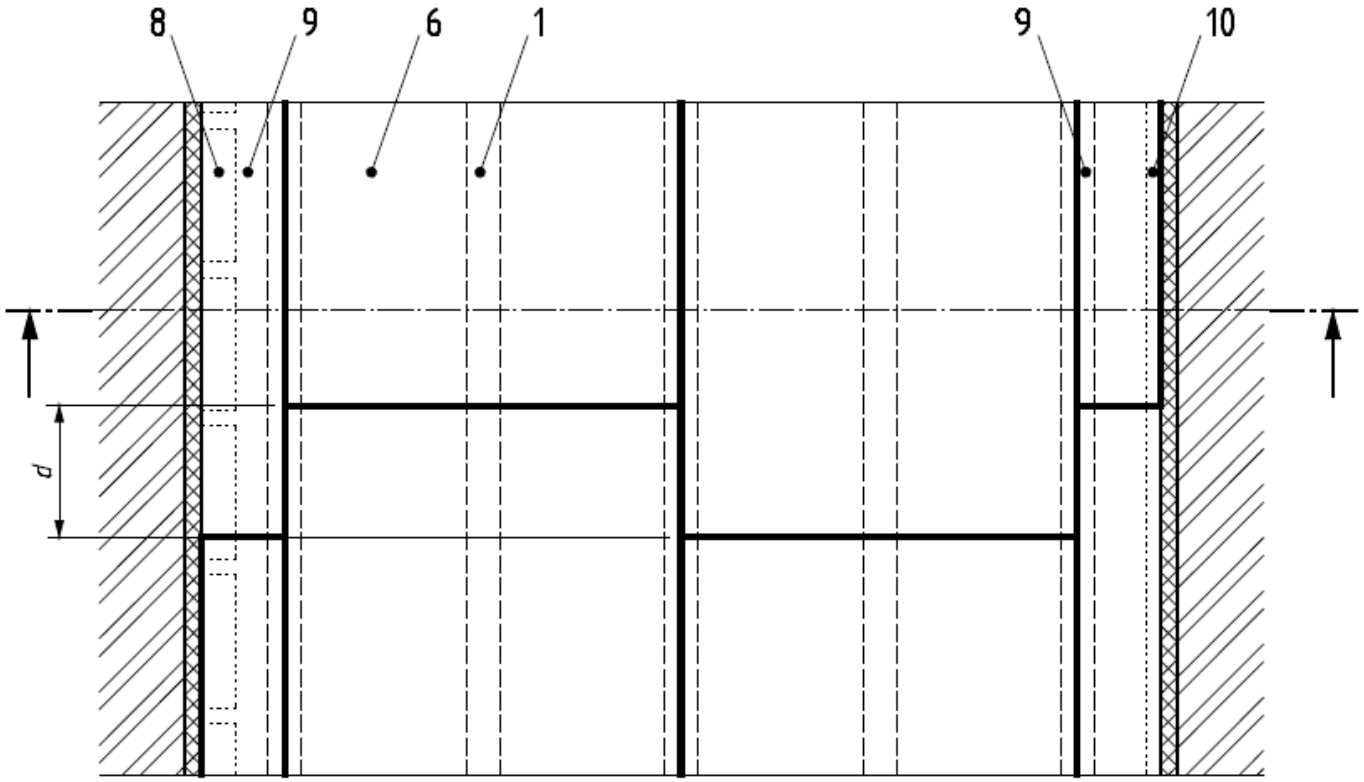
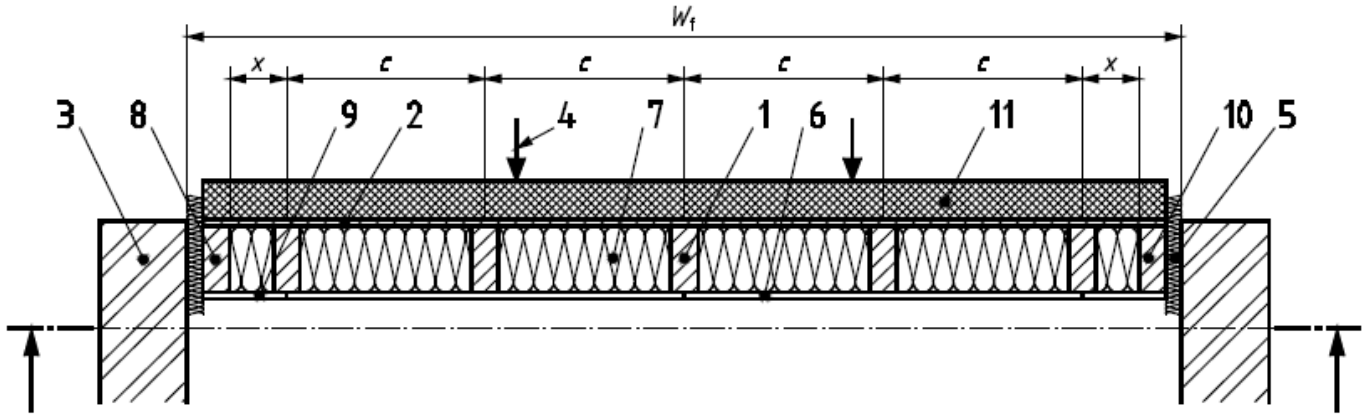
Full scale test of a floor



a) Top elevation



b) End elevation

Key

1	timber joist	7	cavity insulation
2	decking	8	outer joist (example: cut)
3	furnace	9	fire protection board (fitting part)
4	load	10	outer joist (example: half width)
5	insulation fitting part	11	spreader beam
6	fire protection board	*d*	board displacement

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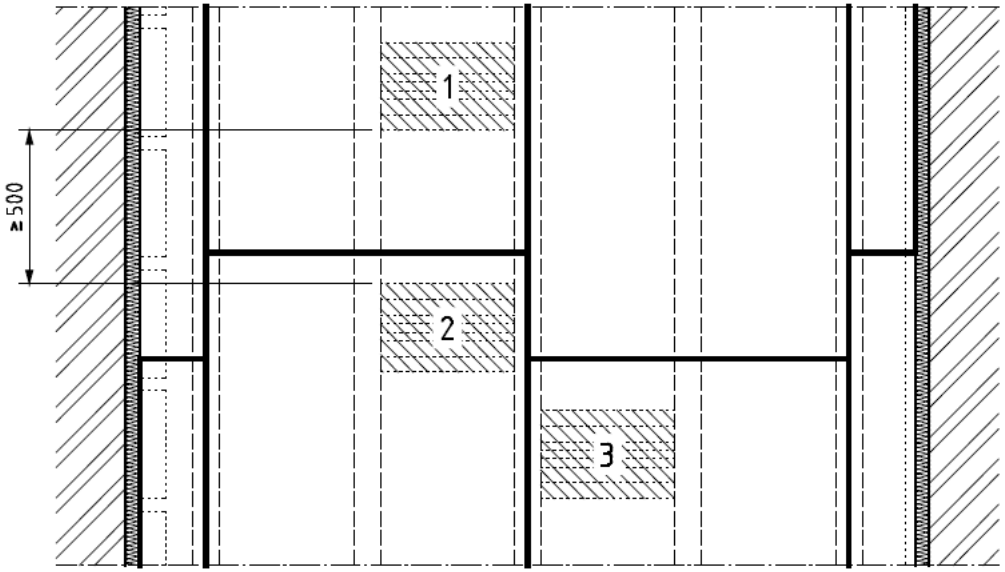
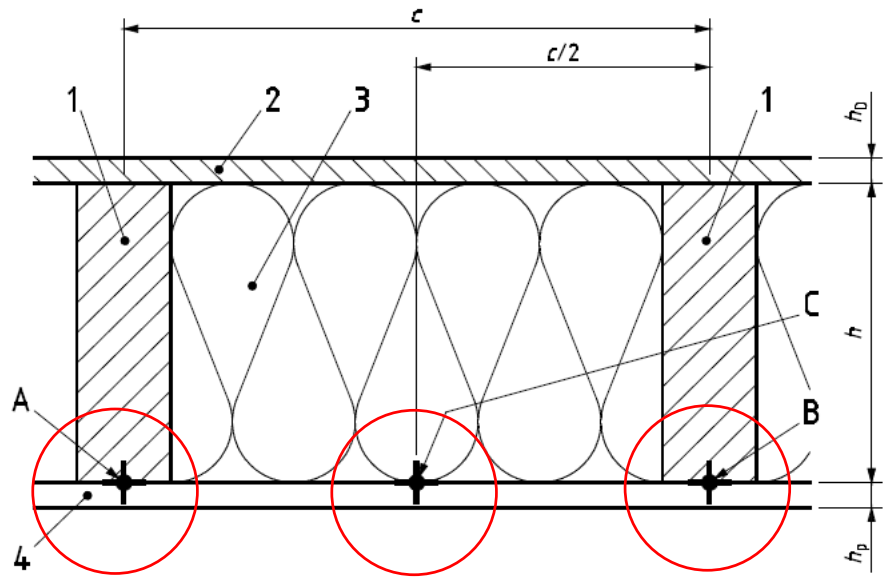
Temperature and charring measurements



Key

1 charring specimen I
2 charring specimen II
3 charring specimen III

Failure time of protection



End elevation

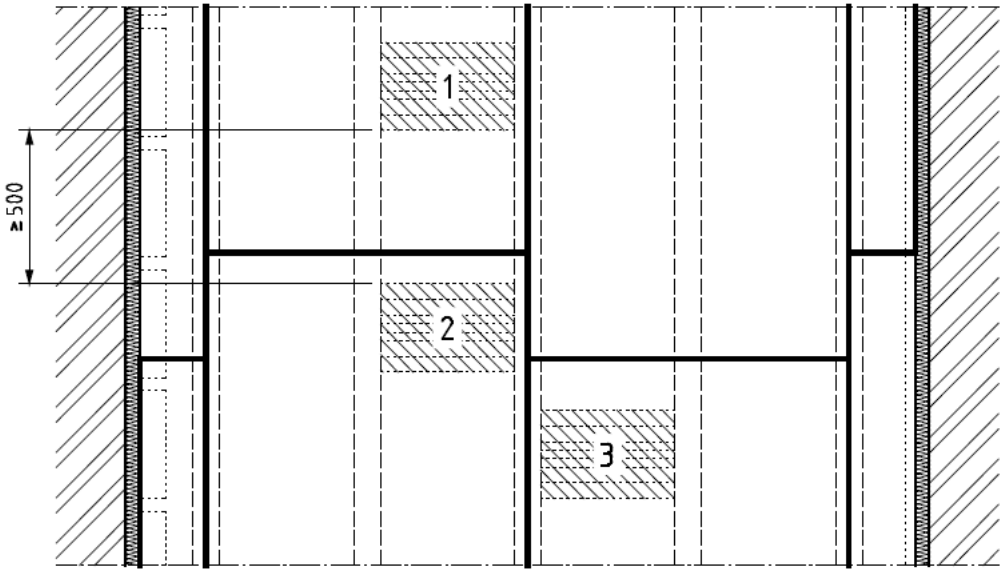
Key

1 loaded joist or stud
2 decking at the non-exposed side
3 cavity insulation (stone wool)
4 fire protection system including joints
c centre distance
h_p thickness of the fire protection system
h_D thickness of the Decking
A thermocouple group A: behind the fire protection system more than 200 mm away from any joint
B thermocouple group B: behind the fire protection system behind joints (for fire protection systems including joints)
C thermocouple group C: Centric between two loaded joists or studs

Centre distance of termocouples 300 mm

EN 13381-7:2019

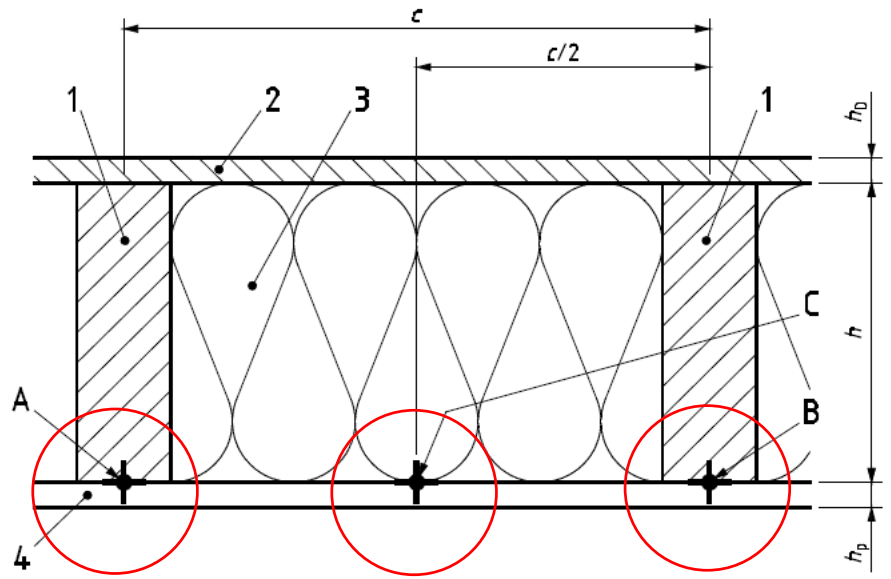
Temperature and charring measurements



Key

1 charring specimen I
2 charring specimen II
3 charring specimen III

Failure time of protection



The failure time:

- Maximum temperature at TC A and TC B; TC C **deviates less than 50K** from the mean furnace temperature
- Observations detect loss of stickability in total more than 0,25 m^2

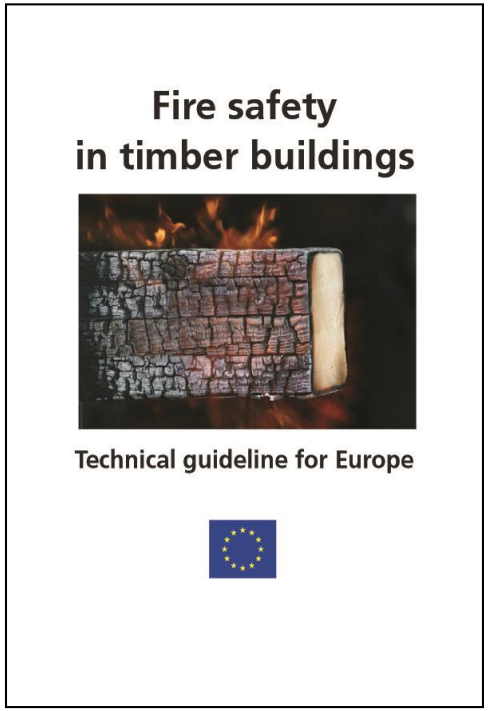
Failure time of fire protection system
t_f

- Tested values for specific products
  - EN 13381-7:2019 — Controlled by TC-s
  - EN 1363, 1364, 1365 series — Visual observations

- Generic values
  - Fire Safety in Timber Buildings – Technical Guideline for Europe (2010)
  - COST FP1404 documents (2018)
  - EN 1995-1-2:2022 (coming soon)

Just et al. (2018) Improved fire design models for Timber Frame Assemblies - Guidance document N 217-07

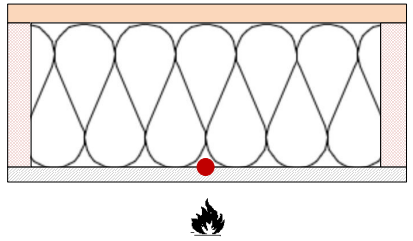
Östman et al. (2010) Fire Safety in Timber Buildings. Technical guideline for Europe.



https://costfp1404.ethz.ch/publications.html

EN 1995-1-2:20xx

Failure times of gypsum plasterboards



Draft EN 1995-1-2:2022

Table 5.9 – Failure time of the fire protection system due to mechanical degradation

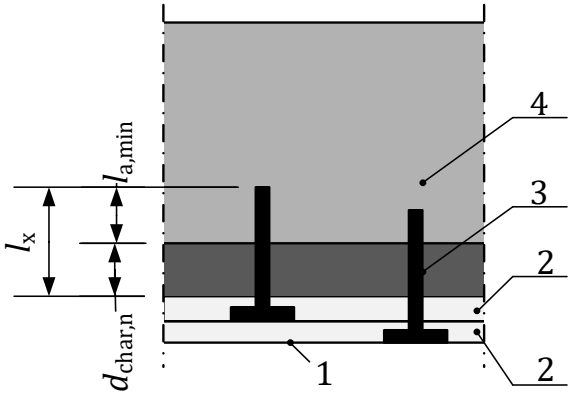
Panel(s)	Walls		Floors	
	t_f [min]	h_p [mm]	t_f [min]	h_p [mm]
Gypsum plasterboards Type F (EN 520), one layer	$4.9 \cdot h_p - 30$ (0.1)	$9 \le h_p \le 18$	$1.6 \cdot h_p + 3$ (0.2)	$12.5 \le h_p \le 16$
	58	$h_p > 18$	29	$h_p > 16$
Gypsum plasterboards Type F (EN 520), two layers	$1.6 \cdot h_p + 18$ (0.3)	$25 \le h_p \le 31$	$1.9 \cdot h_p - 1.5$ (0.4)	$25 \le h_p \le 31$
	68	$h_p > 31$	57	$h_p > 31$
Gypsum fibreboards (EN 15283-2)	*Values to be included in the second draft if available.*			
where:				
t_f	is the failure time of the fire protection system due to mechanical degradation, in min;			
h_p	is the thickness of the fire protection system; in mm.			

For gypsum plasterboards, Type A

$$t_f = t_{ch}$$

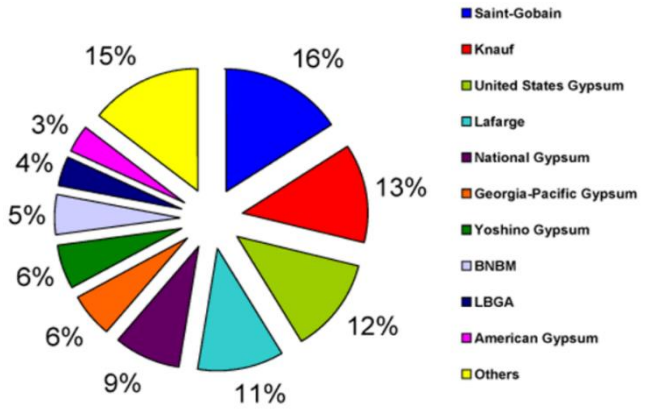
Failure time due to pull-out of fasteners

$$t_f = t_{ch} + \frac{l_x - l_{a,min}}{\beta_n}$$

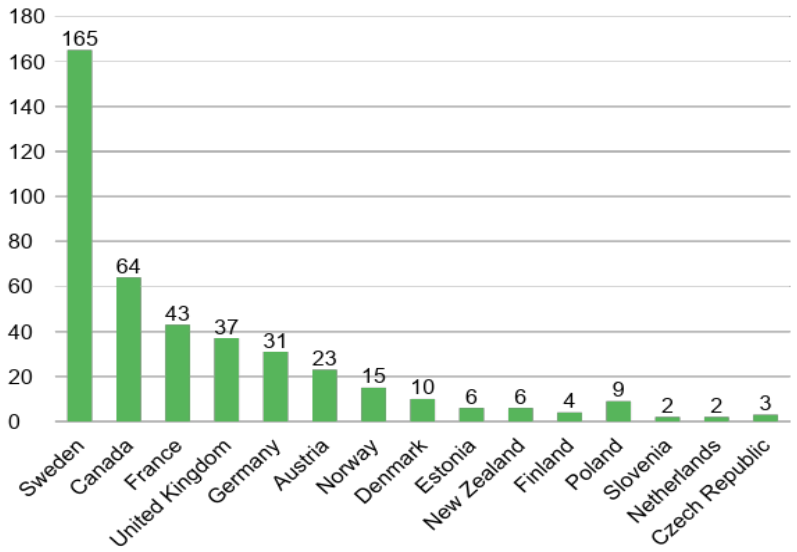


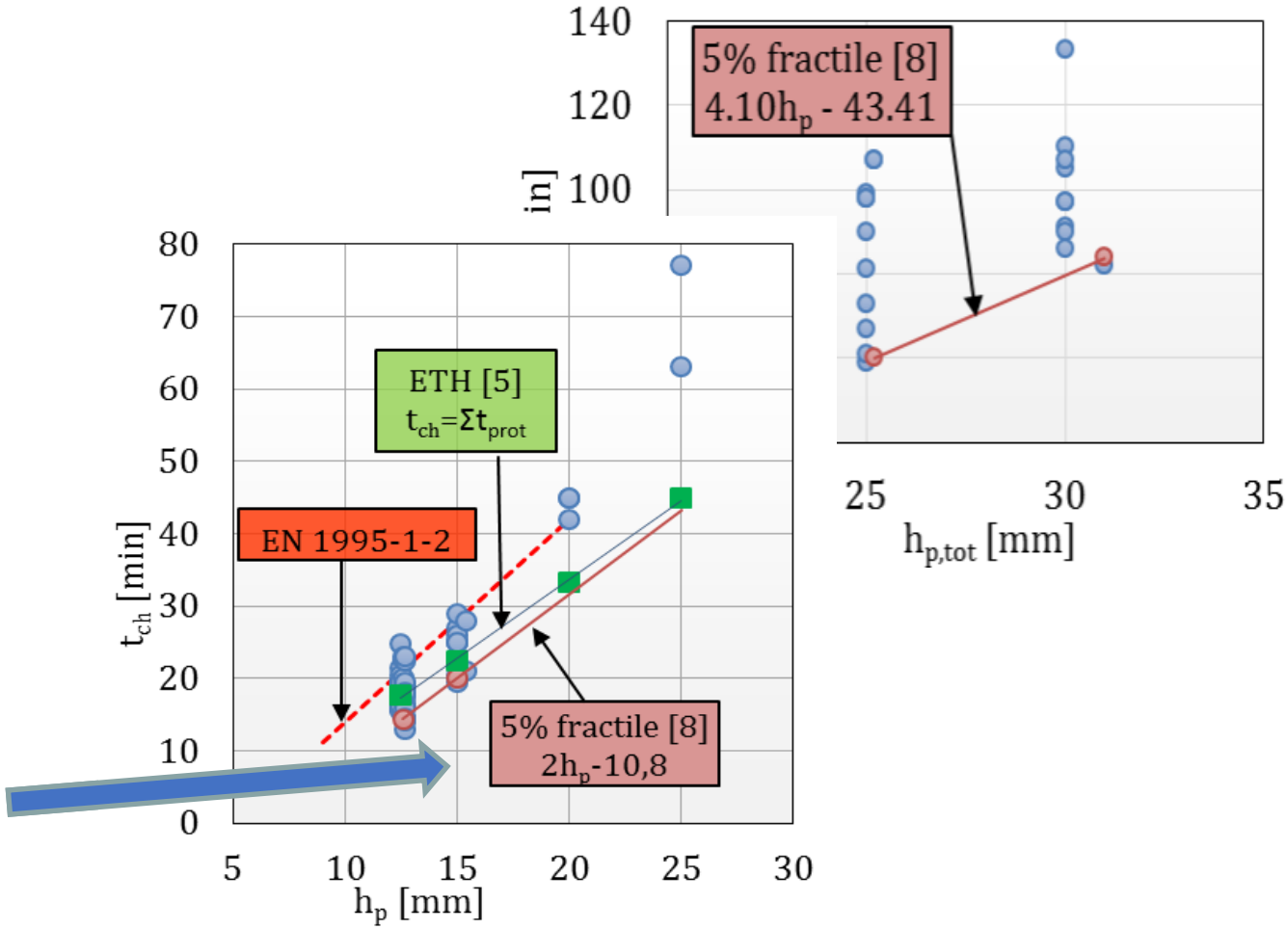
Analysis of the database

- Held at RISE Research Institutes of Sweden
- 470 full scale test reports



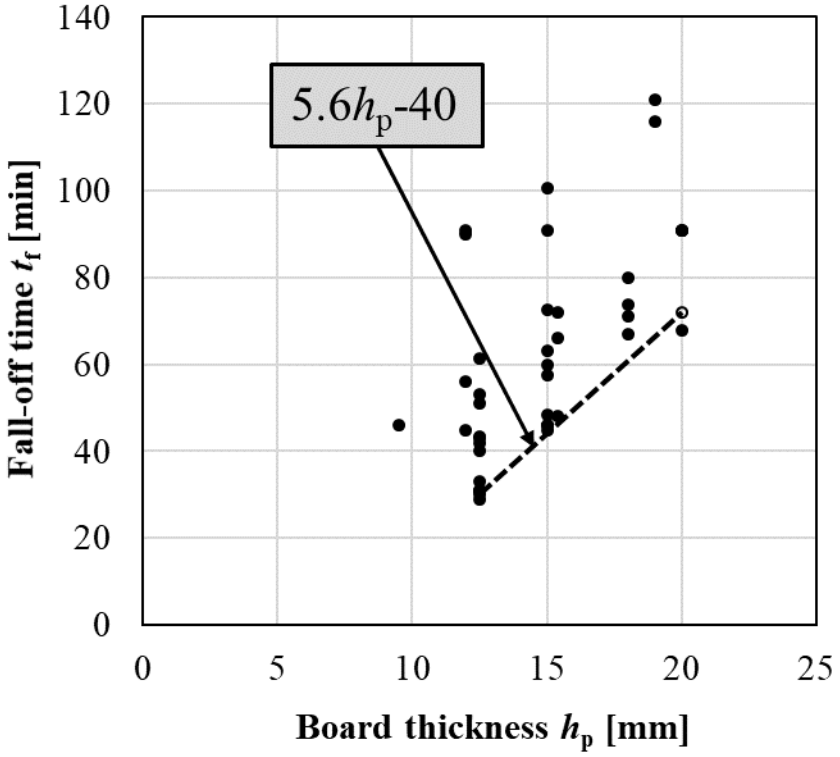
Full scale fire test reports



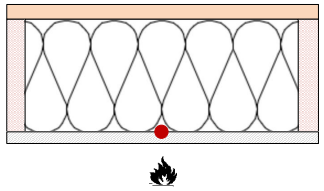


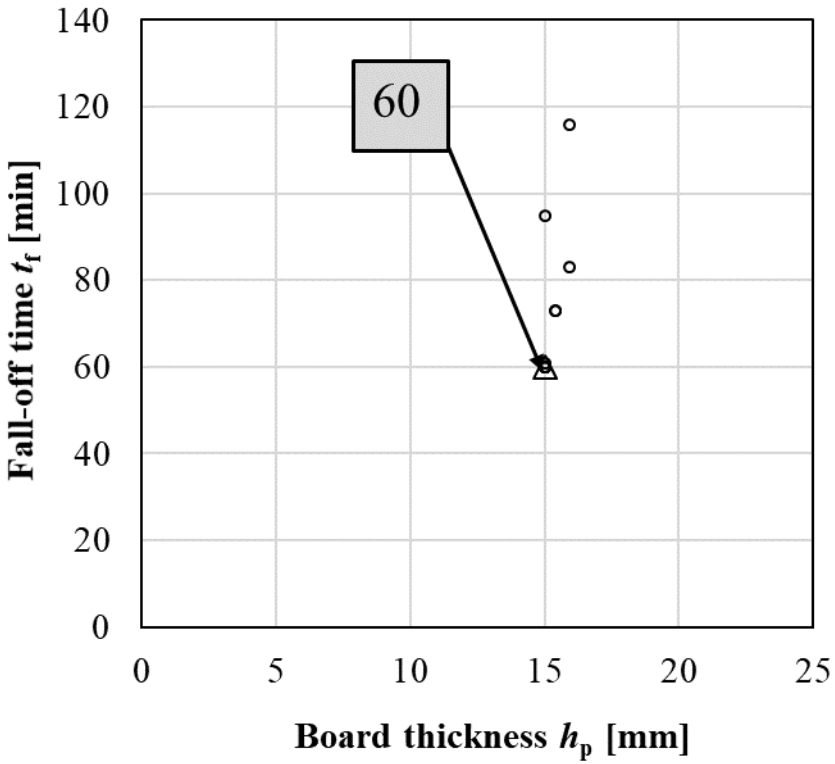
K.Kraudok. Master thesis at TUT
COST documents

Effect of substrate

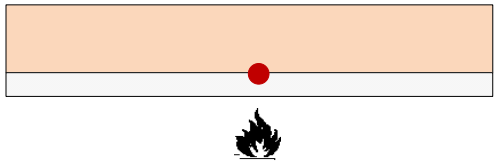


Gypsum plasterboards on **insulation**





Gypsum plasterboards on **CLT structures**



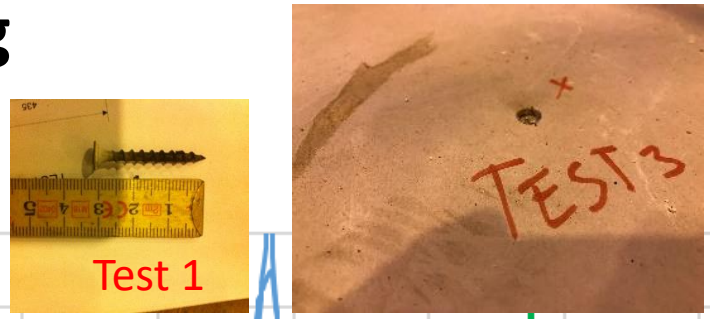
Effect of fastening on failure time

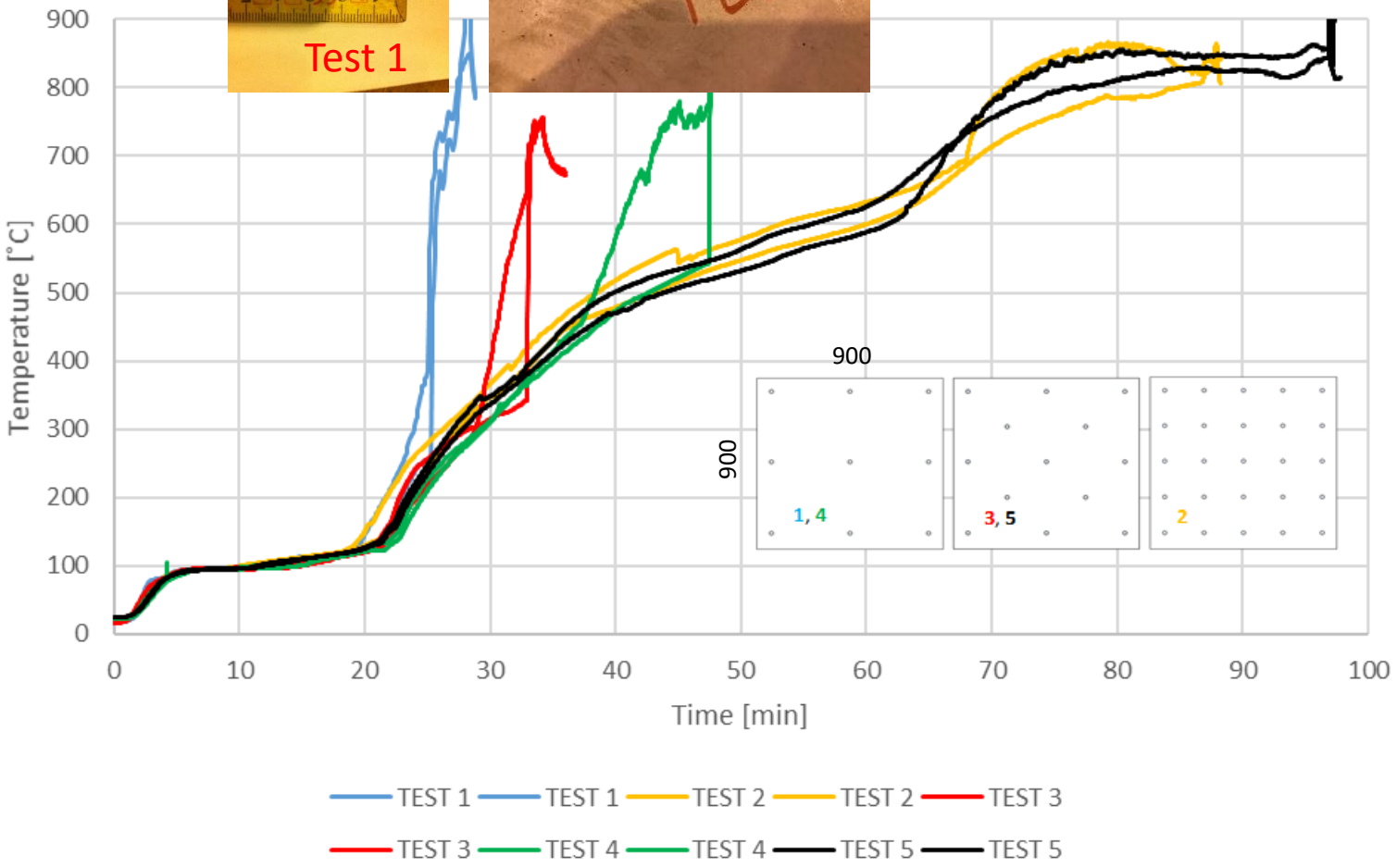
- Studs or beam spacing
- Spacing of fasteners
- Quality of mounting

120 min

Gypsum plasterboard,
Type F 15 mm

Effect of fastening





Model scale tests
GtF 15 on CLT

Summary

- Different charring phases for initially protected structures depending on properties of protection system.
- Substrate and fastening can influence start time of charring and failure time significantly.
- Start time of charring and failure time can be determined by EN 13381-7
- Generic values on start time of charring calculated according to Separating Function Method
- Generic values of failure times for gypsum boards in EN 1995-1-2:2022.

THANK YOU FOR YOUR ATTENTION!

Alar Just

Alar.just@taltech.ee

Alar.Just@ri.se