



# Fire regulations based on justified performance for multi-storey timber buildings

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# Background



- Combustibility of wood-based products
- Traditionally 1 – 2 storey buildings - fire risks are low
- Efforts in research and testing
- Design methods are available
- As a results in many countries fire regulations (prescriptive or performance based) allow multi-storey/high-rise buildings with wood



# Essential requirements in regulations

- The load-bearing capacity of the construction can be assumed for a specific period of time
  - Protective coverings and sprinklers can be utilized
- The generation and spread of fire and smoke within the construction works are limited
  - Compartmentation is essential independent of structural material
- The spread of fire to neighbouring construction works is limited
  - Distance, compartmentation, fire wall
- Occupants can leave the construction works or be rescued by other means
  - No fire load in exits; Movable fire load contributes to fire development before structural timber
- The safety of rescue teams is taken into consideration
  - Safe routes and proper means are essential in all buildings

# Key issues in regulations



## Safety of life

- Same principles independent of structural material
  - Early detection & alarm
  - Sprinklers (in higher buildings)
- Safe exits (no fire load)



Wood City, Helsinki, Finland. Photo: E. Mikkola



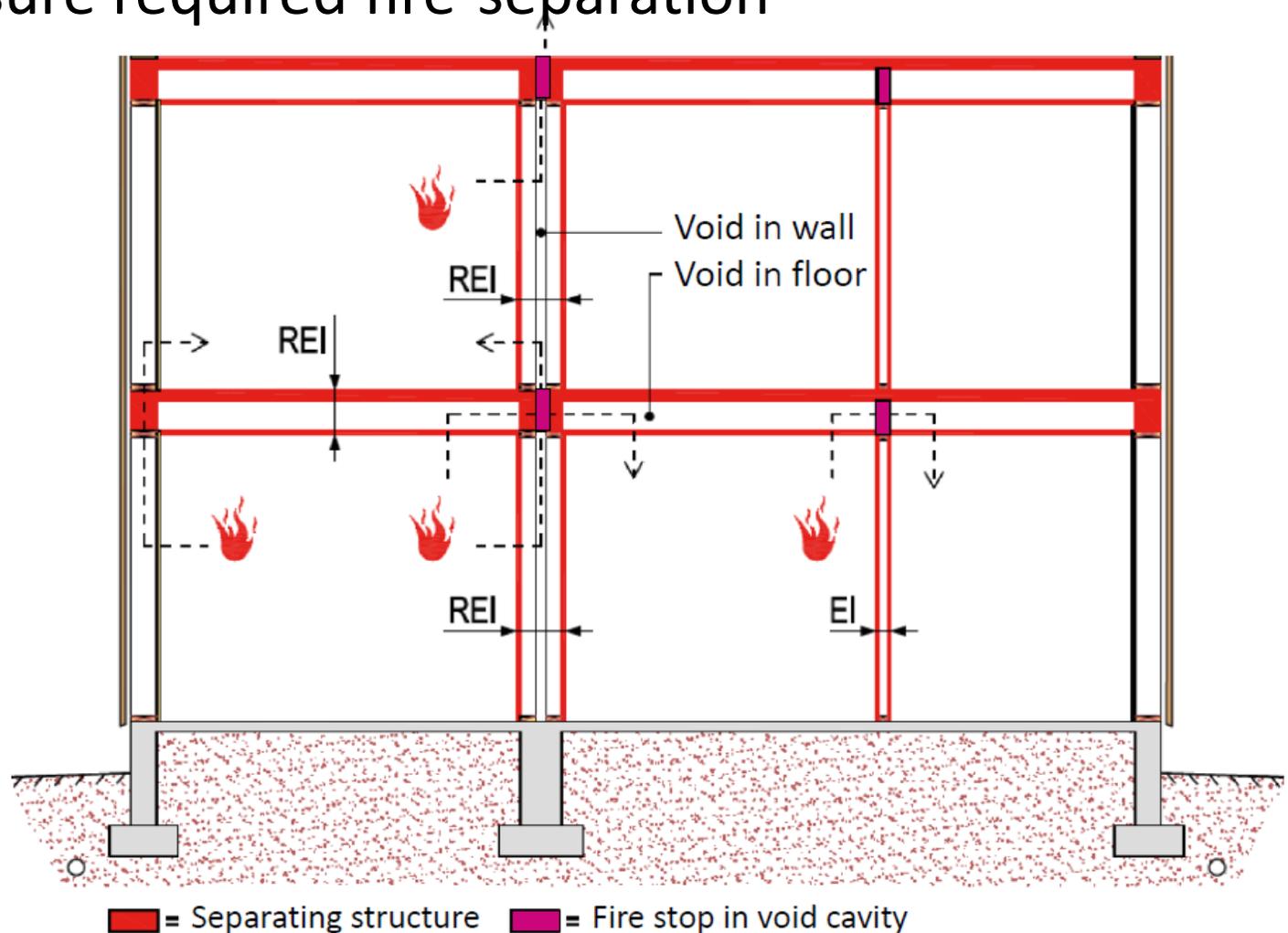
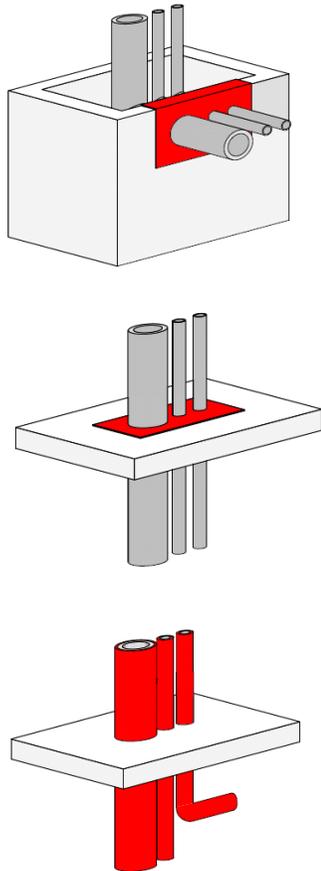
## Property protection

- Structures/timber elements protected when needed
- Compartmentation/fire walls
- R60 ... R120 for increased heights
- Sprinklers in higher buildings

# And detailing ... examples



Penetration seals and fire stops in voids ensure required fire-separation



Figures: Fire safety in timber buildings – Technical guideline for Europe. 2010. SP Report 2010:19.

■ = Separating structure   ■ = Fire stop in void cavity

# Study on fire performance of timber buildings<sup>1</sup>



- Fire safety engineering was used to justify different protective methods for timber structures
- The study included data on real fire loads and comparisons with statistical data
- As reference the requirements for max 8 floor building with non-combustible load bearing structures was used
  - Structures should withstand assumed fires (fire loads) with the same level of probability

<sup>1</sup>Mikkola, E. 2012. Performance based background for revision of Finnish fire regulations concerning timber framed buildings. Wood & Fire Safety, pp. 155-162. 7<sup>th</sup> International Scientific Conference, Strbske Pleso, Slovakia.

- No fire brigade intervention - fire protection based only on passive means and/or automatic extinguishing
- Protective means:
  - Coverings: K<sub>2</sub>30 or K<sub>2</sub>60 of non-combustible material
  - Sprinklers

## Results

- Two possibilities (for apartment buildings and buildings with similar fire loads):
  - Non-combustible K<sub>2</sub>60 covering, or
  - Non-combustible K<sub>2</sub>30 covering + sprinklers

# Relative probability (compared to reference) of local collapse for different protective methods



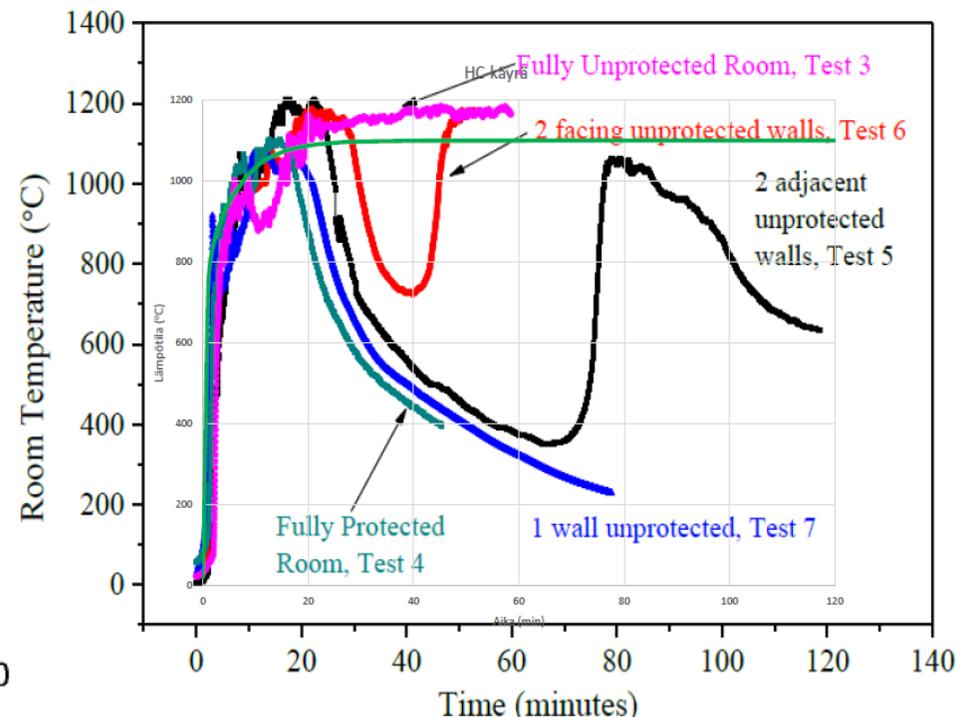
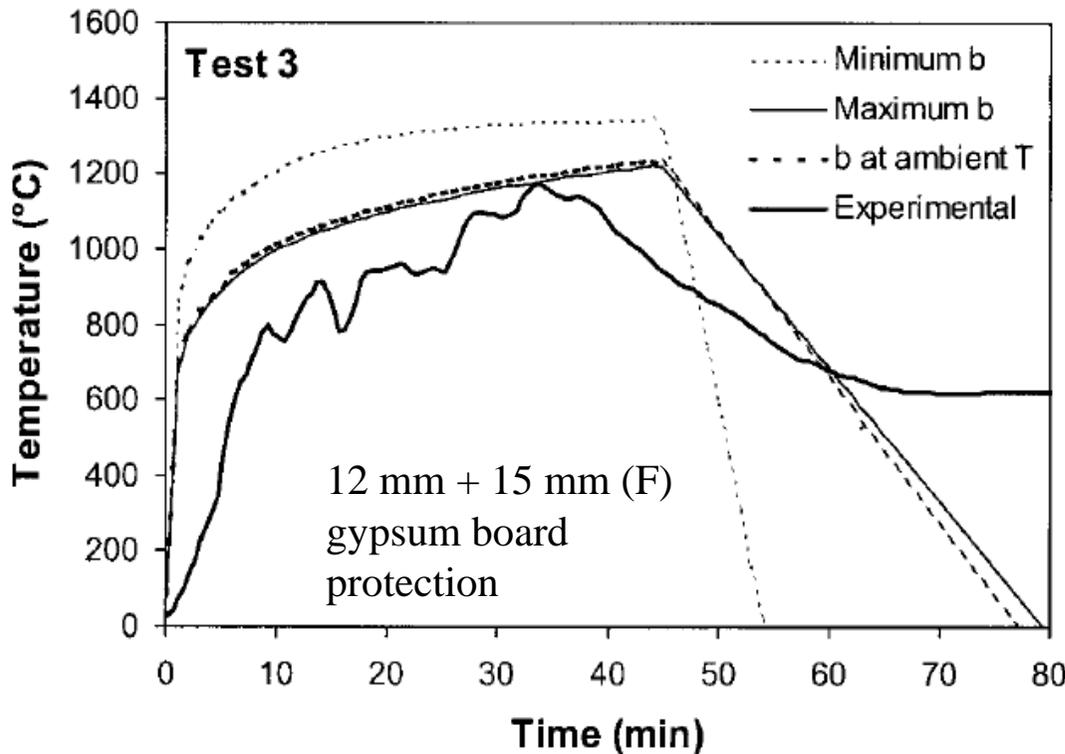
## Apartment buildings up to 8 storeys

| Fire resistance | Structure/surface             | Sprinklers | Covering | Probability of local structural failure |
|-----------------|-------------------------------|------------|----------|---|
| R60             | <b>Steel/Gypsum Reference</b> | No         | -        | 1.0                                     |
| R60             | Wood/Gypsum                   | No         | 30 min   | 5.0                                     |
| R60             | Wood/Gypsum                   | No         | 60 min   | 1.0                                     |
| R60             | Wood/All wood                 | Yes        | -        | 1.2                                     |
| R60             | Wood/Gypsum                   | Yes        | 30 min   | 0.63                                    |

# Visible timber surfaces<sup>2</sup>



- Fire exposure at different conditions: standard fire testing/ parametric fire curves/natural fire curves
- Charring rates for different conditions – resulting requirements for load-bearing structures



Hakkarainen, Tuula. Post-Flashover Fires in Light and Heavy Timber Construction. Journal of Fire Sciences 2002. Vol. 20. Pp. 133 – 175.

Xiao Li, Cameron McGregor, Alejandro Medina, Xiaoqian Sun, David Barber, George Hadjisophocleous. Real-scale fire tests on timber constructions. WCTE 2016, Vienna, Austria.

<sup>2</sup>Mikkola, E., Rinne, T. and Granström, M. Extended use of massive wood structures without coverings – Arguments for revision of fire safety regulations. KK-Palokonsultti Oy. 2017.

# Charring depths - Standard fire



Predictable behaviour (2 hours and more) – time for fire brigade

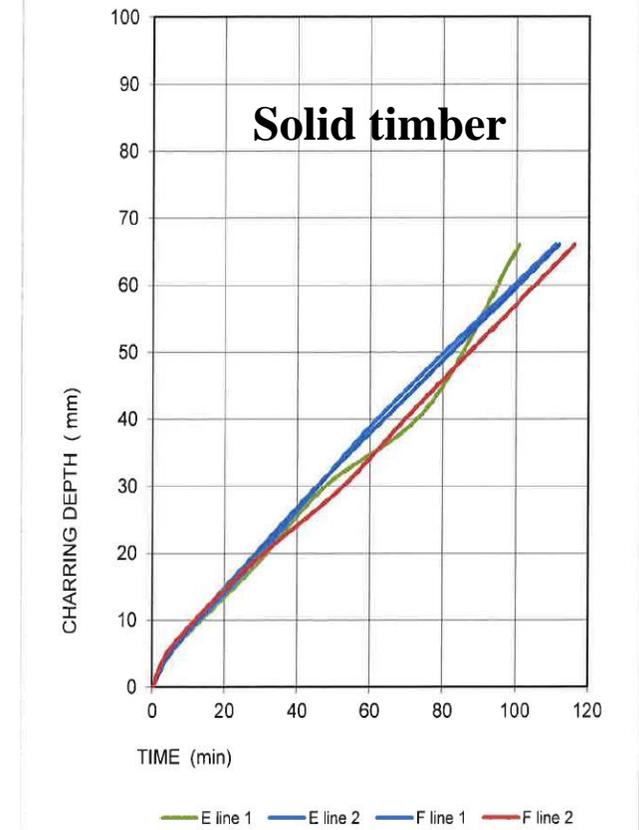
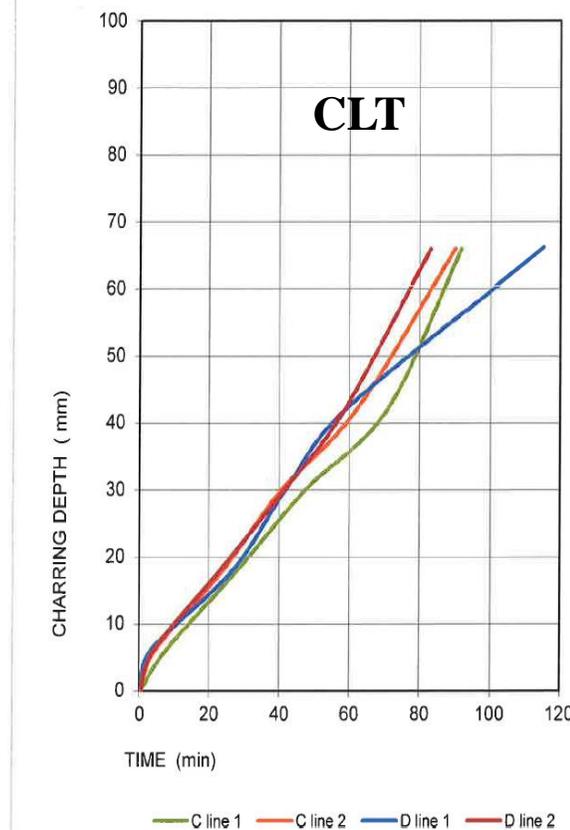
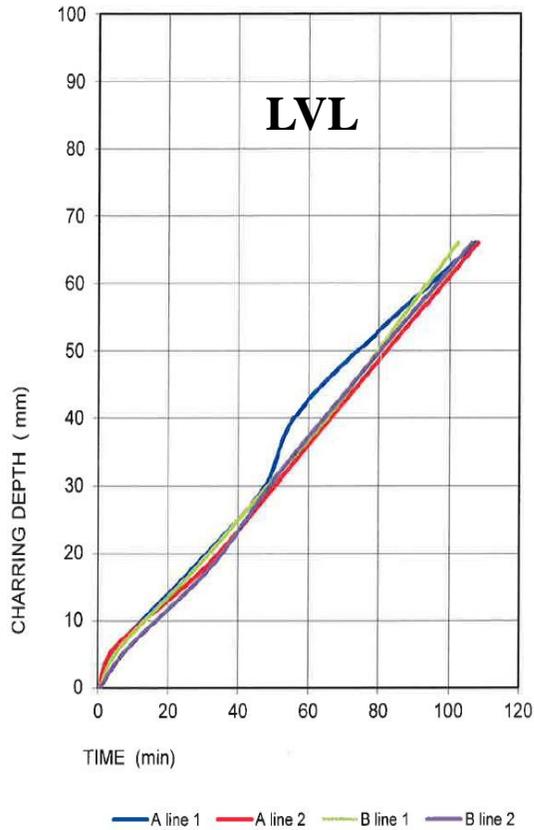


Figure 1. Test 1, charring depth in function of time for Kerto Q specimen A and B (specimen A fire exposure perpendicular to laminations (boards) and B in direction of laminations (joists)).

Figure 2. Test 1, charring depth in function of time for CLT specimen C and D (specimen C fire exposure perpendicular to laminations (boards) and D in direction of laminations (joists)).

Figure 3. Test 1, charring depth in function of time for specimen E, solid timber and specimen F, glued laminated timber.

One-dimensional charring of solid timber, glued-laminated timber, LVL and CLT. Test report No. VTT-S-04746-16. November 25, 2016. VTT Expert Services Ltd.

# Charring depths – predictable also for extreme HC fire exposure

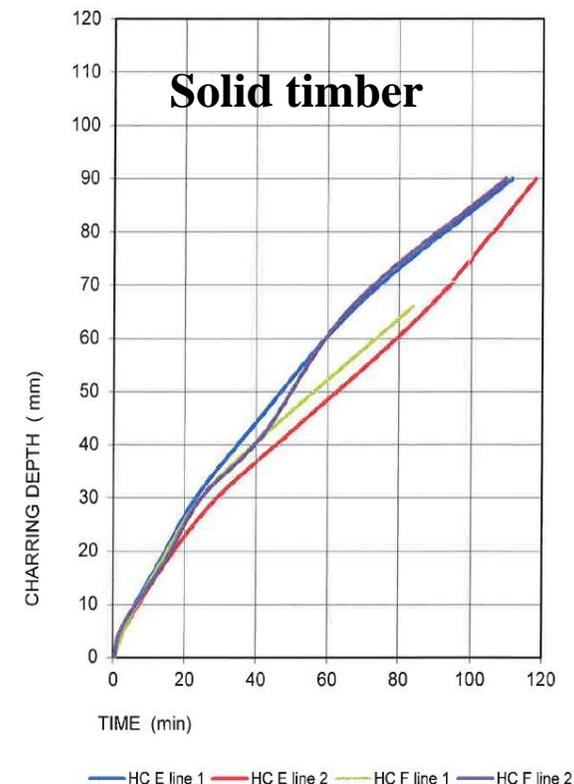
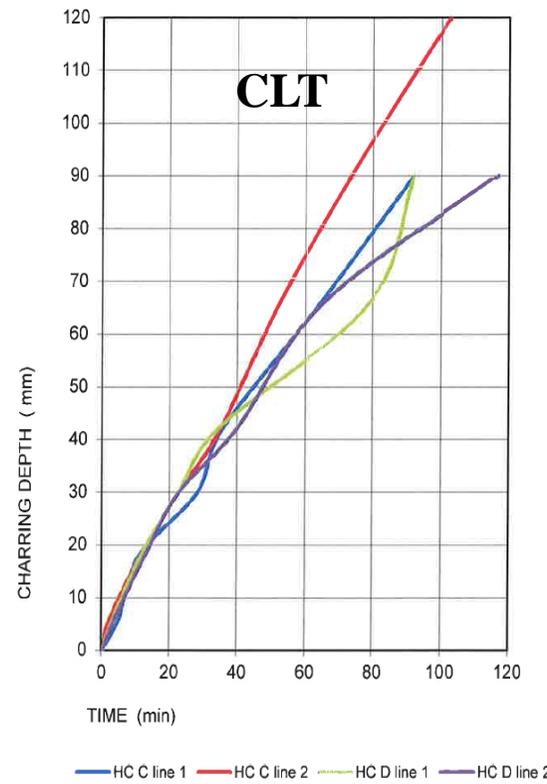
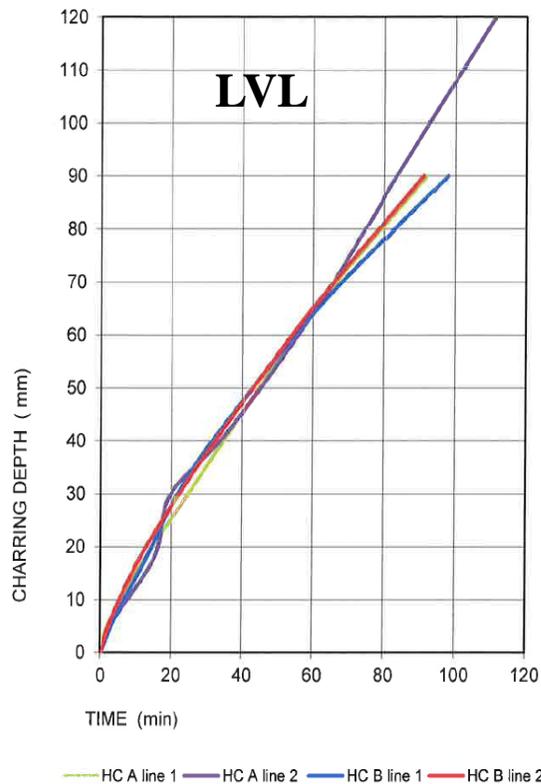


Figure 4. Test 2, charring depth in function of time for Kerto Q specimen A and B (specimen A fire exposure perpendicular to laminations (boards) and B in direction of laminations (joists)).

Figure 5. Test 2, charring depth in function of time for CLT specimen C and D (specimen C fire exposure perpendicular to laminations (boards) and D in direction of laminations (joists)).

Figure 6. Test 2, charring depth in function of time for specimen E, solid timber and specimen F, glued laminated timber.

One-dimensional charring of solid timber, glued-laminated timber, LVL and CLT. Test report No. VTT-S-04746-16. November 25, 2016. VTT Expert Services Ltd.

# How to take into account large visible wood surfaces in fire safety design

## Example:

Fire resistance requirements, when the basic requirement is R60 (= 60 min fire rating):

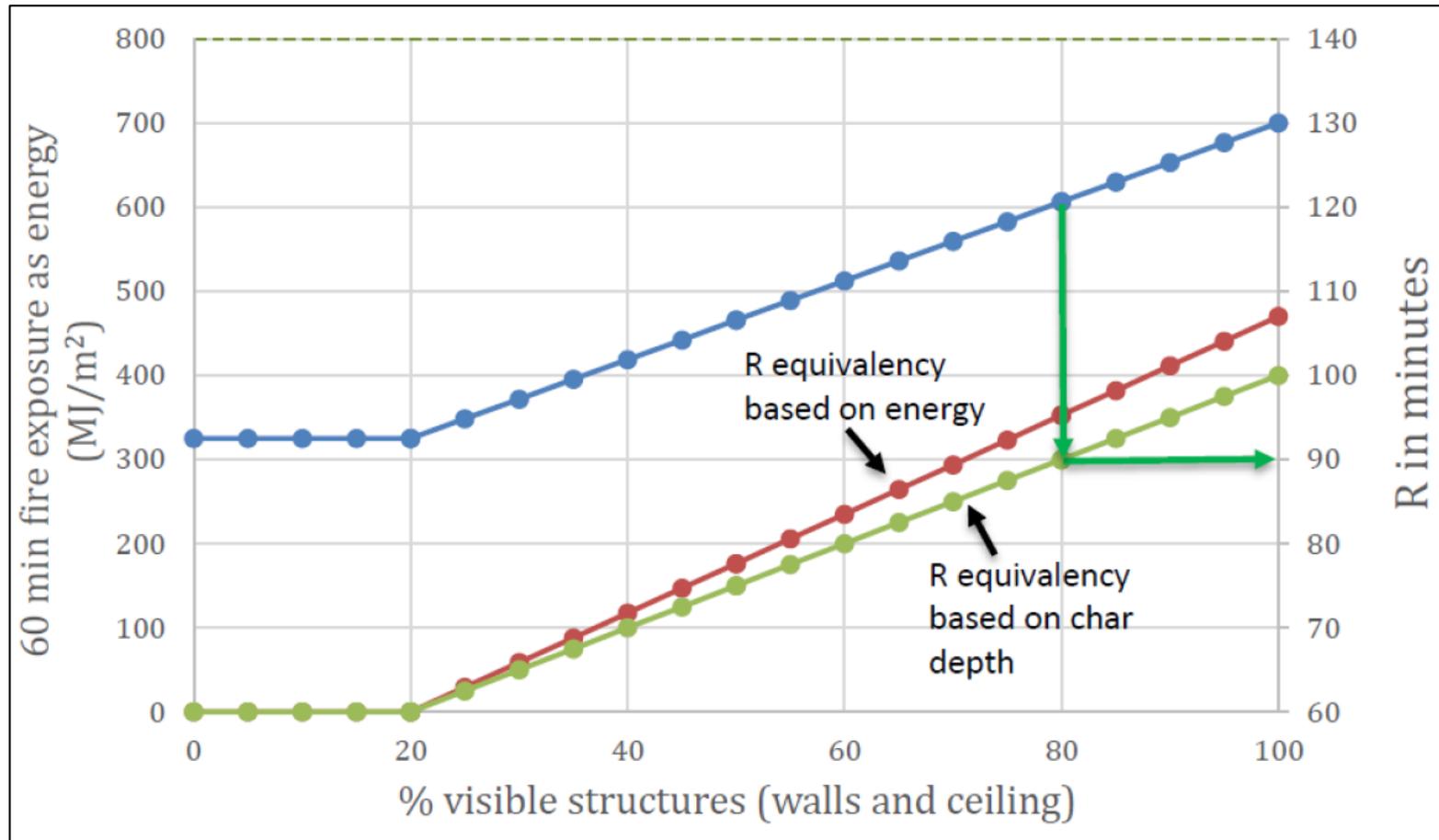
- R60, if maximum 20 % visible wood as linings
- R90, if 20 – 80 % visible wood
- R120, if more than 80 % visible wood

Eurocode 5 charring rate values are used in calculations + product specific guidance

# Larger visible wood surfaces - increased fire resistance times



Exposed timber surfaces can be taken into account in R requirement as shown in the figure below. Eurocode 5 charring rates can be used in calculations.



*Fire exposure as total energy and corresponding R equivalency values based on total energies and char depths as a function of percentage of area of visible structural elements.*

# Fire accidents and regulations



- It is important to analyse carefully the reasons of fire accidents
- Main concerns:
  - Products/materials/compartments used are not those planned/according to fire regulations
  - Quality of workmanship/missing control on-site
- Why to change regulations in the above mentioned cases ?
- Why not emphasis in overall quality control and on-site control by authority/third party

# Change of building heights in Europe



## Fire safety in timber buildings Technical guideline for Europe

1990



2000



- ≥ 5 storeys
- ▨ 3-4 storeys
- ▧ ≤ 2 storeys (incl. 0)
- No information

2019

| Country     | Prescribed/<br>Performance based |
|-------------|----------------------------------|
| Austria     | 6/No limit                       |
| Finland     | 8/No limit                       |
| France      | No limit/No limit                |
| Germany     | 5-6/No limit                     |
| Norway      | 4/No limit                       |
| Sweden      | No limit/No limit                |
| Switzerland | 30 m/No limit                    |
| UK          | No limit/No limit                |

Number of  
storeys or height  
in meters

**Thank you for your attention**