COST Action TU0904
Integrated Fire Engineering and Response



# The Behaviour of Protected and Unprotected Wooden Members under the Fire

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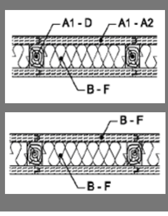
## Contents

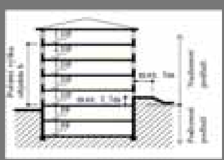




## Fire Safety of Timber Structures – Czech Republic

- EN 13501-1 – reaction to fire: D, E and F
- Component : DP2, DP3
- Structural system: combustible
- Multi-Storey Wood Based Buildings –12 m

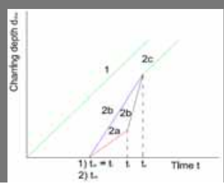


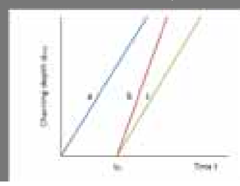





## Introduction

- The behaviour of protected and unprotected wooden members under the fire.
- For the elements which are protected by the fire claddings, the beginning of charring is moved till the $t_{ch}$ (surface temperature of the timber structure is 300 °C).
- The charring of the timber element can occur before the deformation of the fire protection but with lower speed than specified in EN 1995-1-2.
- After the time called $t_f$, which means failure time of protection, the charring rate starts to increase.
- The contribution to the fire resistance of timber structures $t_{pr}$

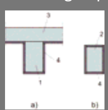




## The behaviour of wooden members under the fire protective claddings under the fire

Simply computational methods to determine time of start of charring of protected members or failure time of protection.




$t_{ch} = \frac{h_p}{\beta_0}$ wood-based panels or wood panelling $t_f = \frac{h_p}{\beta_0} - 4$

$t_{ch} = 2{,}8\, h_p - 14$ gypsum plasterboard $t_f = 2{,}8\, h_p - 14$

$t_f = t_{ch}$ In either event computational methods suppose that $t_{ch}$ equal $t_f$. $t_{ch} = t_f$

$\beta_n = k_3 \beta_0$ Then occur almost double of charring rate. $\beta_n = k_s k_2 k_n \beta_0$

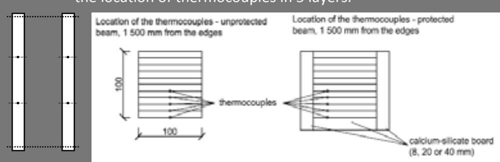




## Fire tests

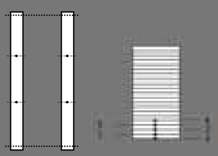
The fire test of wooden beams (100 x 100 x 4500 mm) was performed to determine the contribution of wooden constructions to fire resistance using calcium-silicate boards

- the protected and unprotected members were tested;
- the calcium silicate boards were tested in 2 types and both of them in 2 thicknesses (type 1 – 8 and 20 mm, type 2 – 20 and 40 mm);
- the location of thermocouples in 5 layers.



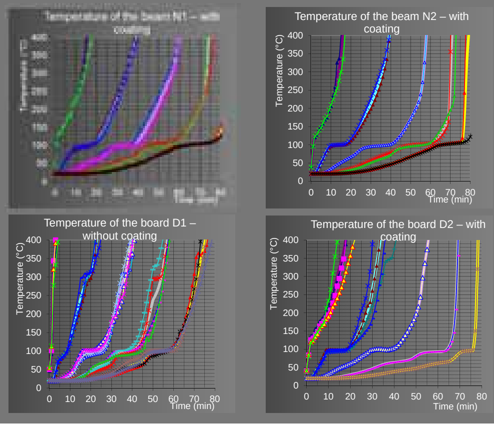
## Fire tests

- Fire test of wooden beams (100 x 200 x 4500 mm) and boards (2000 x 1200 x 100 mm) for determination the contribution to the fire resistance using intumescent painting.
  - the protected and unprotected members were tested;
  - the location of thermocouples in 5 layers.





## Fire tests






## Fire tests

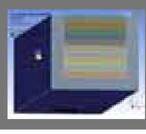
- Charring rate of the protected β´´ and the unprotected β´ members changing in the time

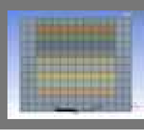

| t | β´´ | β´ |
|---|---|---|
| (min) | (mm/min) | (mm/min) |
| 10 | 0,51 | 0,63 |
| 15 | 0,53 | 0,62 |
| 20 | 0,54 | 0,61 |
| 25 | 0,55 | 0,6 |
| 30 | 0,55 | 0,6 |
| 35 | 0,56 | 0,6 |
| 40 | 0,56 | 0,6 |
| 45 | 0,56 | 0,59 |
| 50 | 0,56 | 0,59 |
| 55 | 0,57 | 0,59 |
| 60 | 0,57 | 0,59 |
| 65 | 0,57 | 0,59 |
| 70 | 0,57 | 0,59 |
| 75 | 0,57 | 0,59 |
| 80 | 0,57 | 0,59 |
| 85 | 0,57 | 0,59 |



## Numerical modelling – 1st fire test

- 3D model was performed using the ANSYS Workbench programme, solved in thermal analysis (Transient thermal) using a fire of 60 minutes.
- Material properties dependent on temperature (*λ*, *c*, *ρ*):
  - they were supplied by the manufacturer based on testing for the calcium-silicate board;
  - for wood at elevated temperatures were taken from the Eurocode (EN 1995-1-2), because it corresponded the best to the reality.
- The heat transfer was calculated by using values dependent on the temperature according to EN 1991-1-2 ($\varepsilon_m$=0,8, $\alpha_{c,exp}$=25 W/m²K, $\alpha_{c,unexp}$=4 W/m²K).



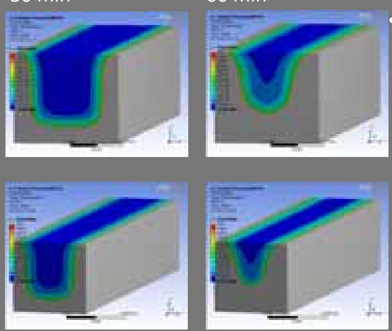




## Numerical modelling – 1st fire test

30 min 60 min

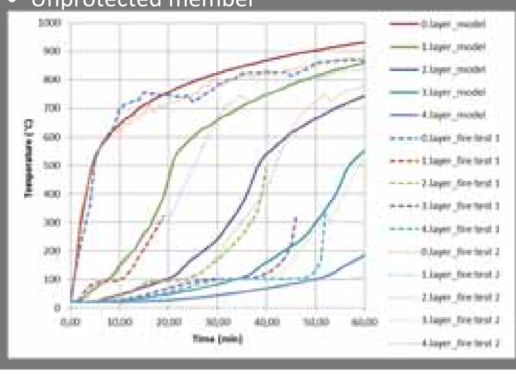
- 20 mm
- 8 mm





## The comparison of the numerical model with the fire test results

- Unprotected member

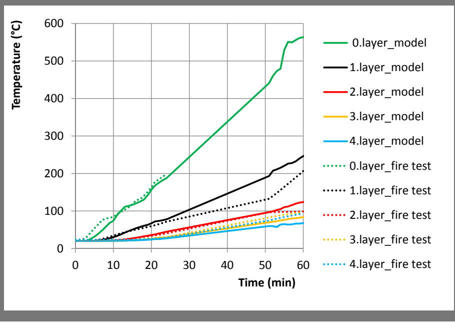


Fire safety in Czech Republic
Introduction
Fire tests
Numerical modelling
**Comparison of the numerical modelling with the fire tests**
Conclusion

## The comparison of the numerical model with the fire test results

- Protected member

  Calcium-silicate board: type 1, thickness 20 mm



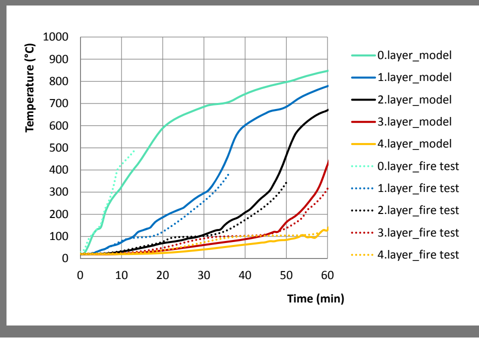



Fire safety in Czech Republic
Introduction
Fire tests
Numerical modelling
**Comparison of the numerical modelling with the fire tests**
Conclusion

## The comparison of the numerical model with the fire test results

- Protected member

  Calcium-silicate board: type 2, thickness 8 mm






Fire safety in Czech Republic
Introduction
Fire tests
Numerical modelling
Comparison of the numerical modelling with the fire tests
**Conclusion**

## Conclusion

- The behaviour of wood under the fire is a very predictable phenomenon.
- In many cases, according to Eurocode 5 (part 1-2), it is very difficult or nearly impossible to determine the starting time of charring of the timber element of the fire protection and the failure time of the cladding. In this area, there are still some deficiencies and it is necessary to perform fire tests in order to increase the level of knowledge and to be able to further develop more precise computational methods.
- On the basis of my numerical analysis (direction perpendicular to the grains), the following was determined:
  - with higher density there is a lower growth in temperature;
  - with higher specific heat there is a lower growth in temperature;
  - with higher heat conductivity there is a higher growth in temperature.



Fire safety in Czech Republic
Introduction
Fire tests
Numerical modelling
Comparison of the numerical modelling with the fire tests
**Conclusion**

## Goals

- Determine the time of the contribution to the fire resistance $t_{pr}$ for some type of fire claddings;
- established the charring rate of protected member by a coefficient determined on the basis of the ratio between the charring rate of protected and unprotected members.



# Thank you for your attantion

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