Restrained Behaviour of steel Beams Exposed to Fire

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Introduction

Background of the Study

The study presented here has been performed as part of a European project called **COMPFIRE.**

During the project fire tests were conducted on:

- Connection Components
- Isolated Joints
- Sub-frames
- Full scale buildings

State of the art

Steel Structures in Fire

- Loss of Strength and Stiffness
- Thermal expansions
- Excessive deformations

Engineering approach (design codes)

- All Structural components i.e. connections, beams and columns are designed as isolated components in Fire
- For a beam the flexural resistance determines the design resistance in the absence of any interaction with surrounding structure

State of the art

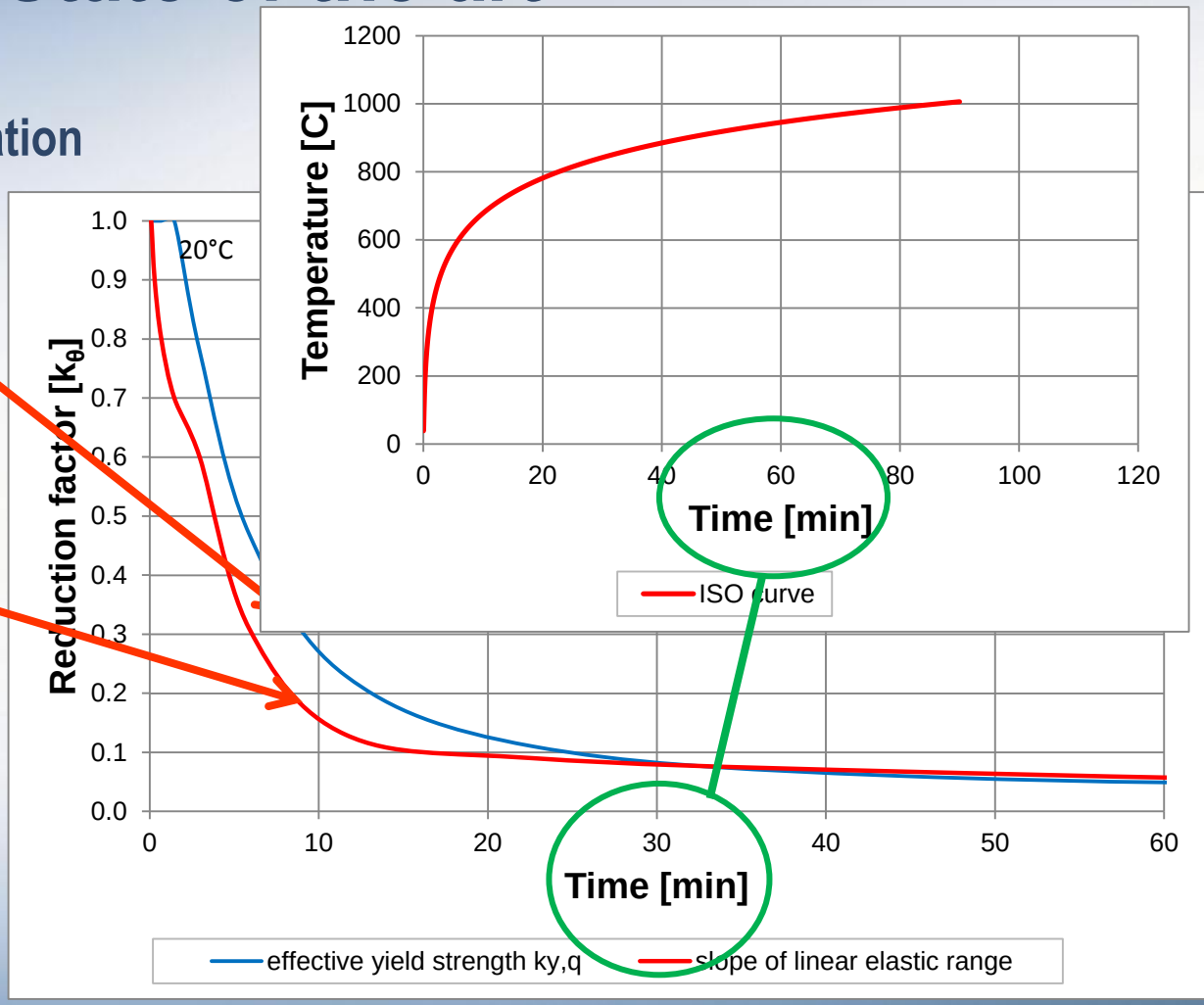
Material properties degradation

- Yield Strength

$$f_{y,\theta} = k_{y,\theta} f_y$$

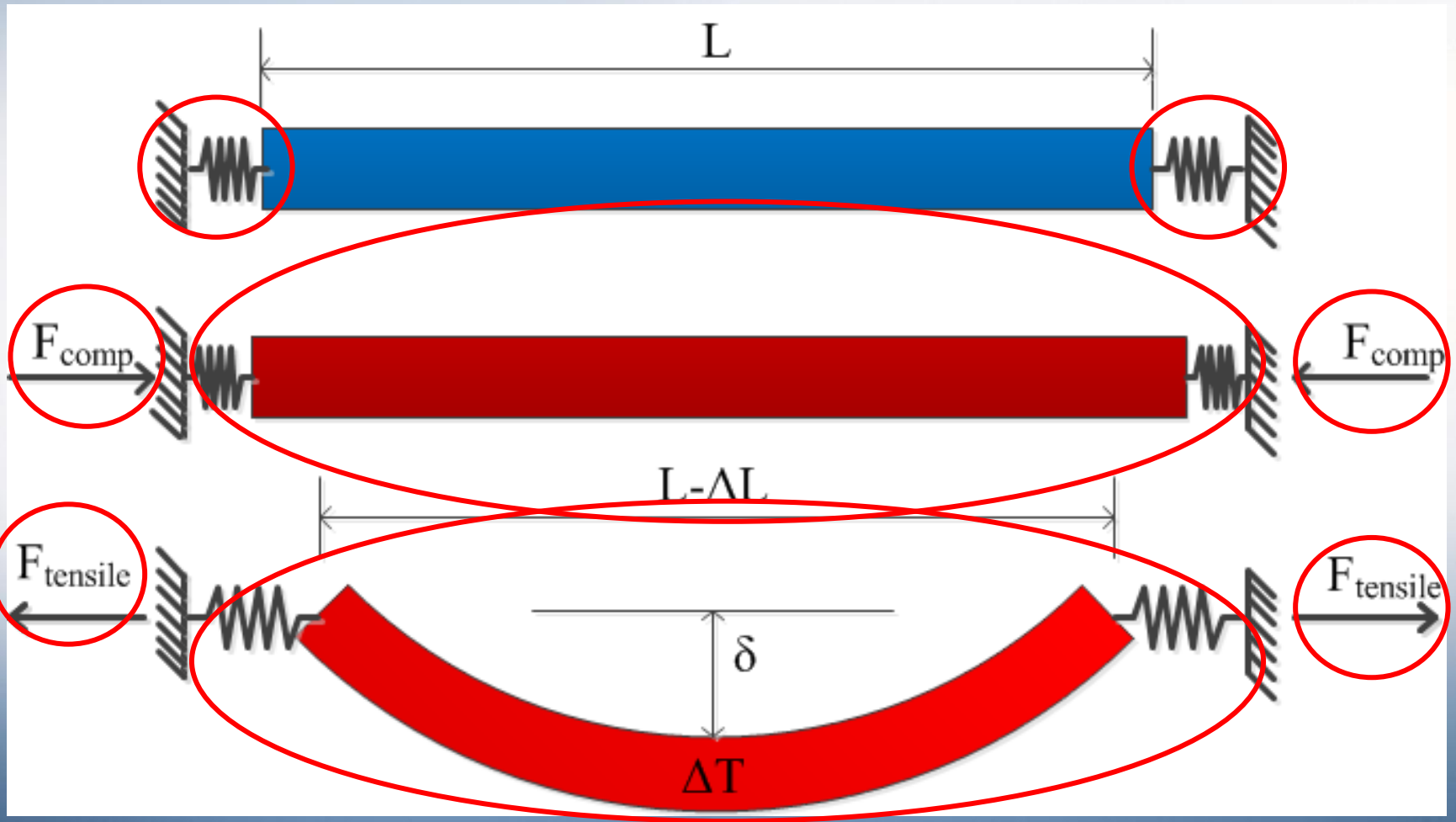
- Modulus of Elasticity

$$E_\theta = k_{E,\theta} E$$



State of the art

Restrained Beam

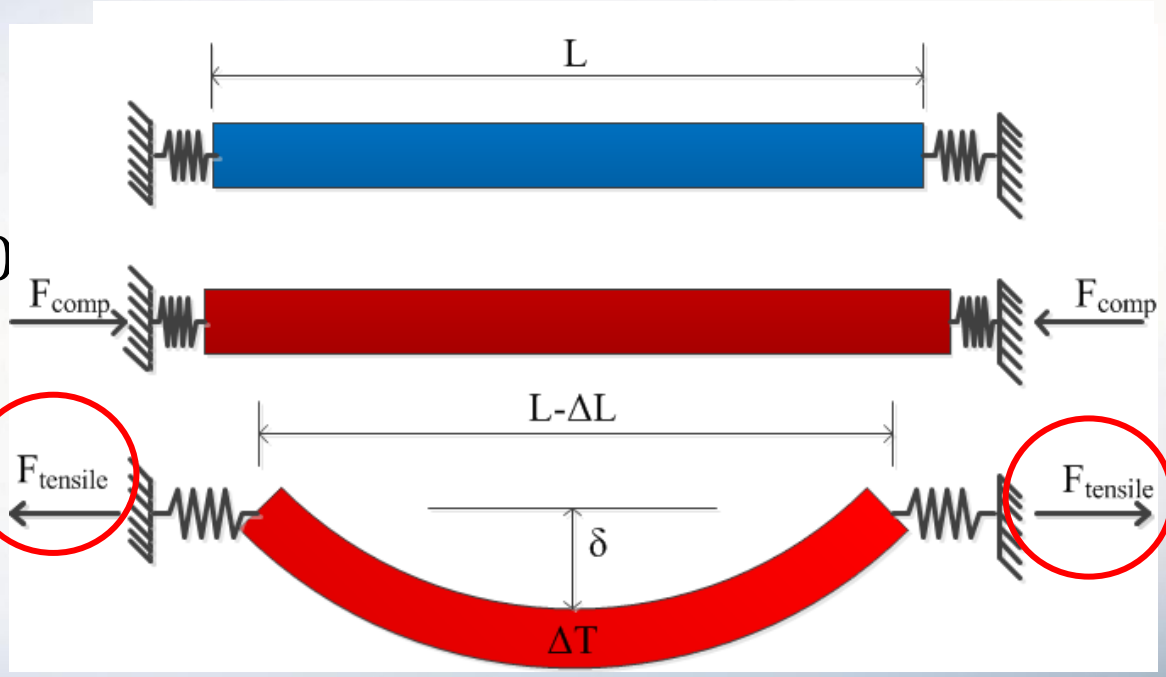


State of the art

Equilibrium at elevated temperature

- **Isolated beam**

$$M_{Ed,fi} + M_{fi,Rd,t} = 0$$

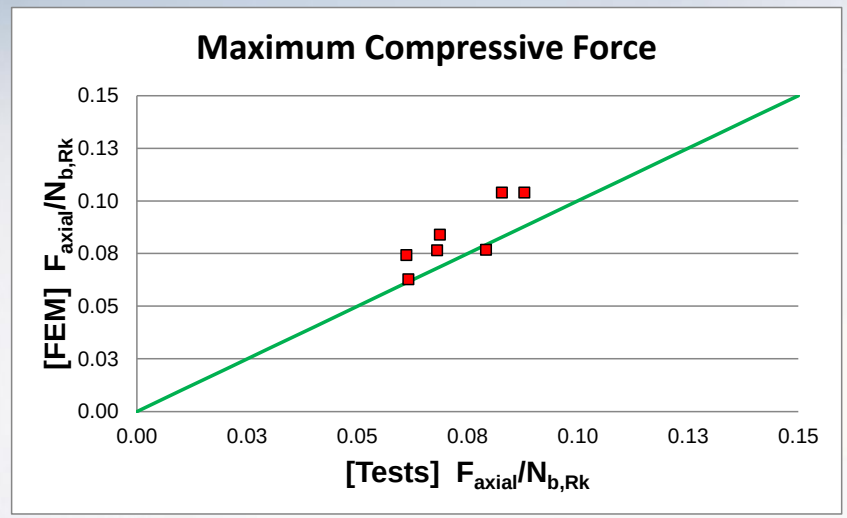


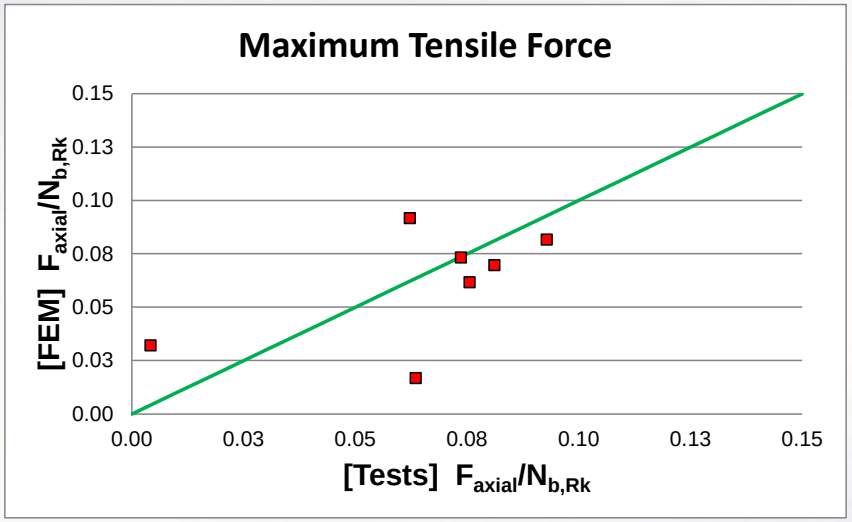
- **Restrained Beam**

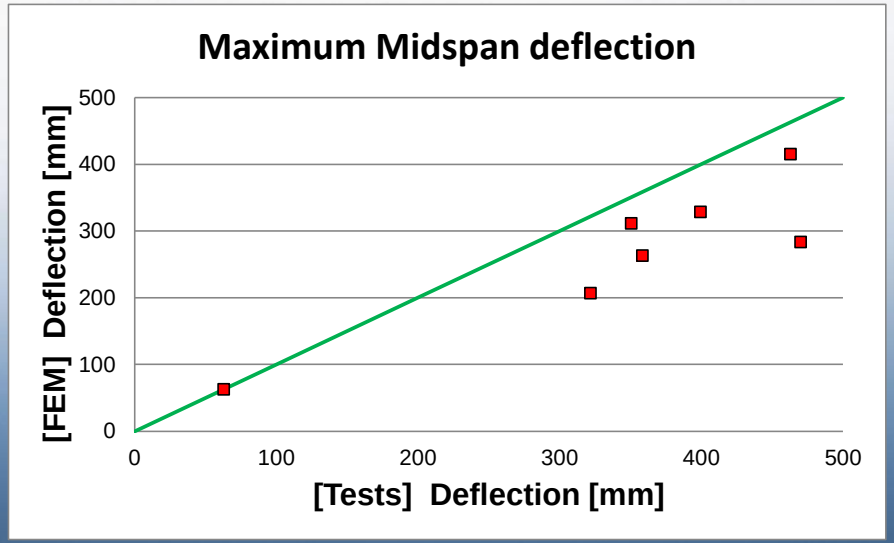
$$M_{Ed,fi} + M_{fi,Rd,t} + F_{axial} \times \delta = 0$$

Benchmarking of FE-Models

Results:



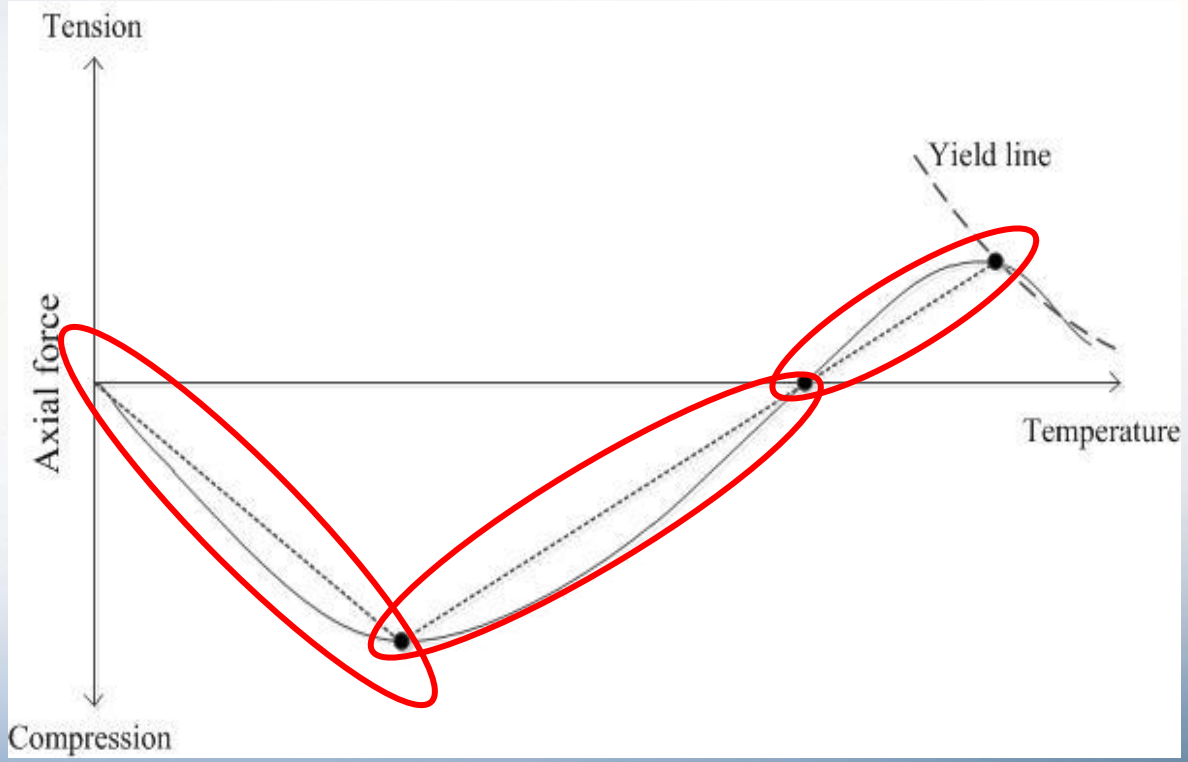




Hand Calculation Method

Variation of Axial force with temperature (Wangs Method*)

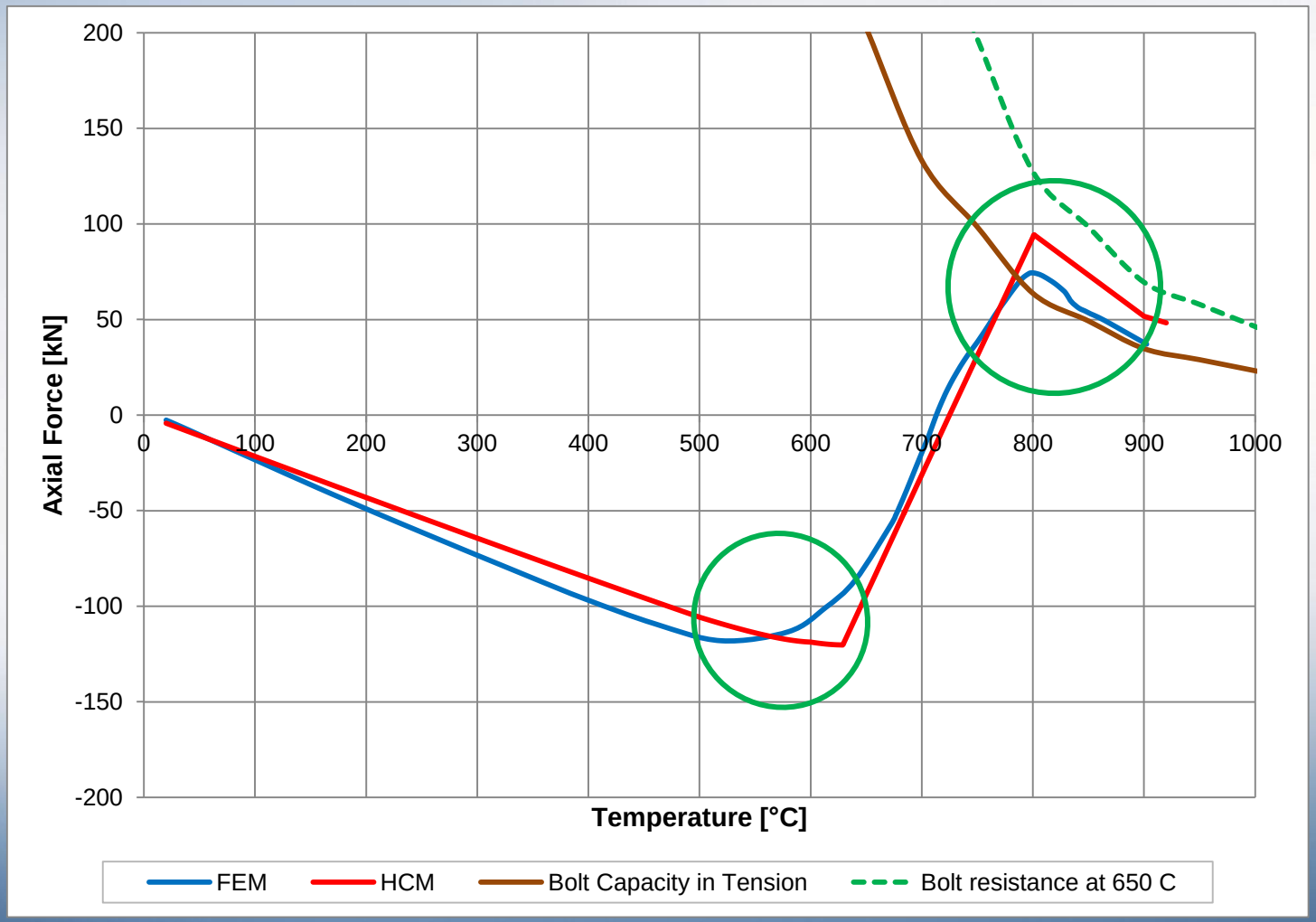
- Elastic stage
- Non-linear stage
- Catenary stage



*Wang, Y., Burgess, I., Wald, F., Gillie, M., "Performance-Based Fire Engineering of Structures", CRC Press, 2013

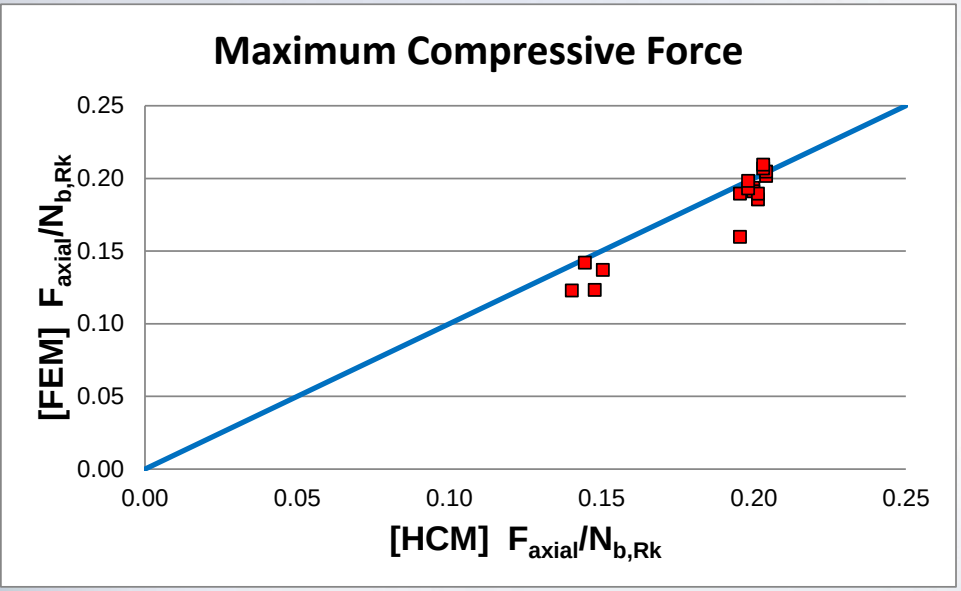
Comparison between HCM and FEM

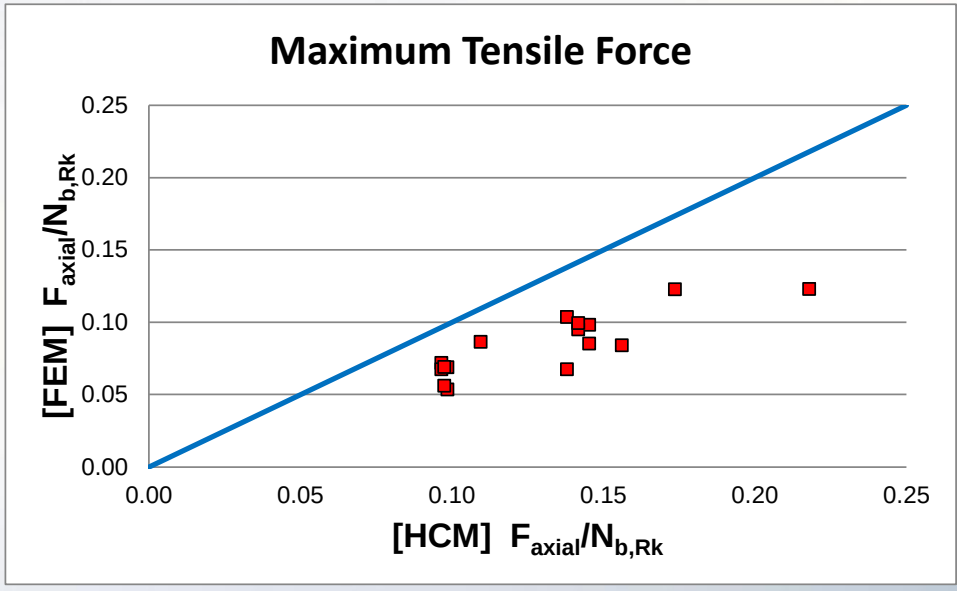
Results: Uniform temperature



Comparison between HCM and FEM

Results





Conclusions

- Catenary action in restrained beam provides additional resistance approx. 100°C beyond the conventional limiting temperature

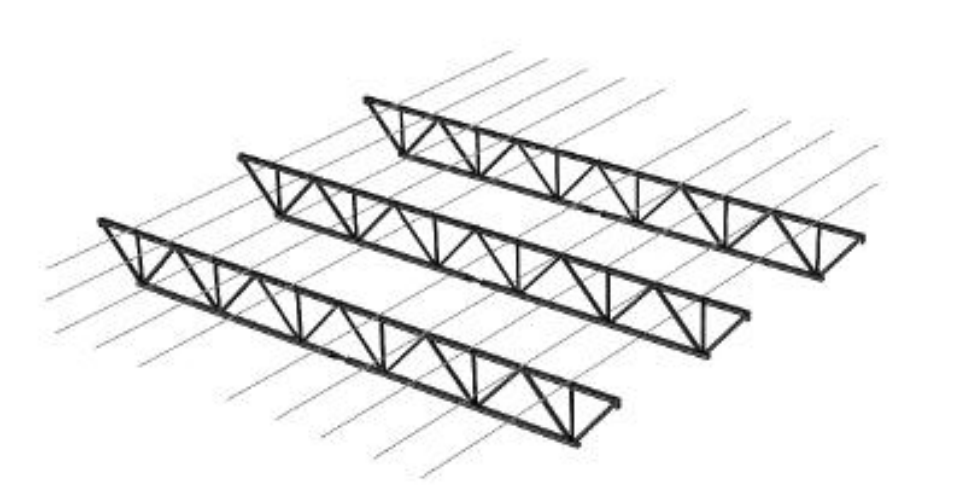
- Very high midspan deflections approx. 500 mm could be observed in the restrained beam but still be below the limit state.

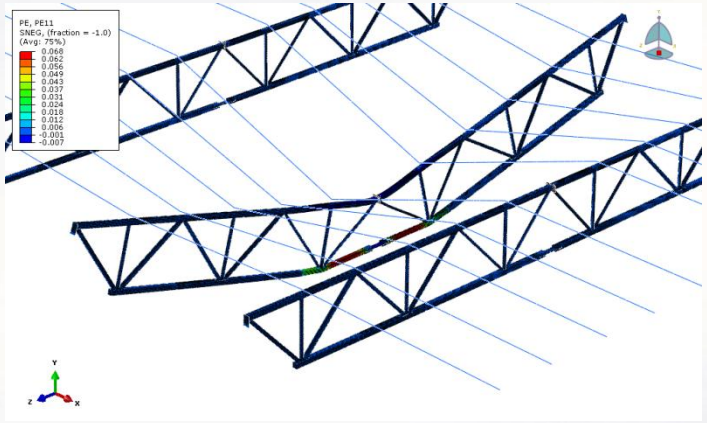
- The FE-models accurately depict the axial stiffness and the maximum compression force measured in the tests, about 10% maximum difference.

- FE-Modelling provides a reliable tool for comparison to the Hand calculation procedure, in particular as the models have been validated against tests results.

Future work

- Application of the same method to trusses in industrial halls





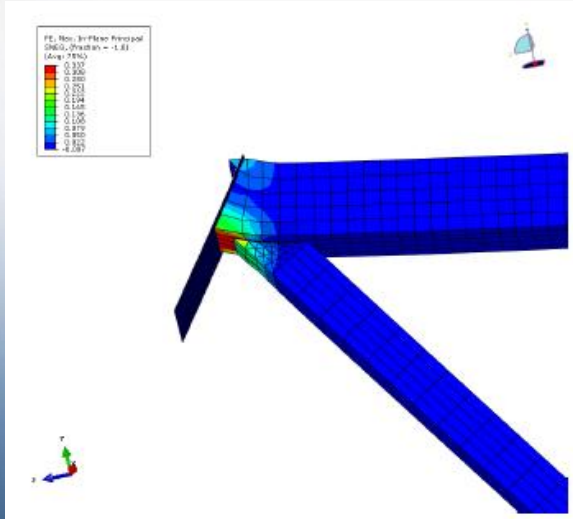


Figure 65 Deformed shape, support

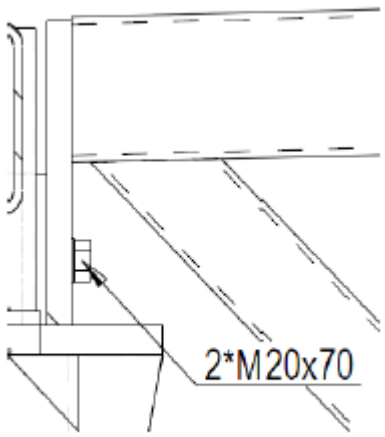
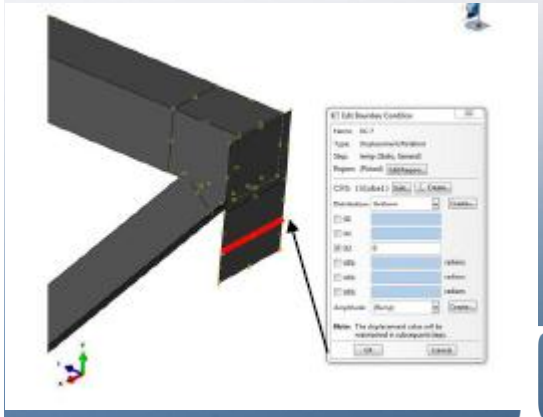


Figure 19 Support according to the drawing



Future work

- As seen above the connection can prove the weak link in terms of resisting the applied loading if the membrane forces are large enough
- Fire testing and subsequent FEmodelling of the connection detail with bolts
- Study different connection details to see how much additional fire resistance time is added by increasing the connection resistance
- Cost comparison to other passive fire protection measure