Design of composite columns under high temperatures with special consideration of imperfections

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STAHLBAU

Outlining

- Introduction
- Thermal Analysis
- Mechanical Analysis
- Imperfections
- Conclusion

Advantages of composite columns

- Small dimensions at high load level
- Uniform dimension in multi-storey building
- High fire resistance because of the insulation properties of concrete
- No additional fire proofing

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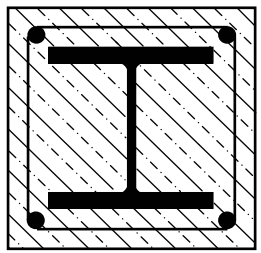
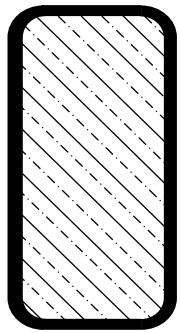
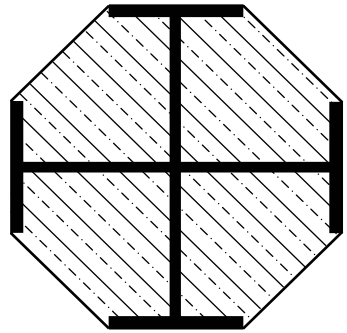
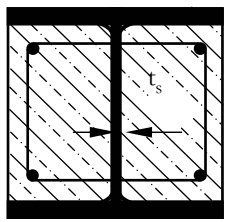
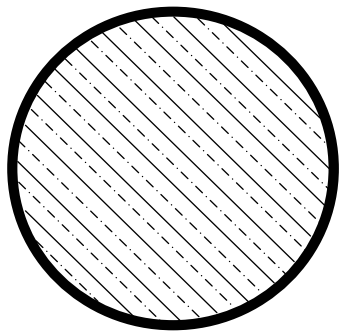
Types of composite columns

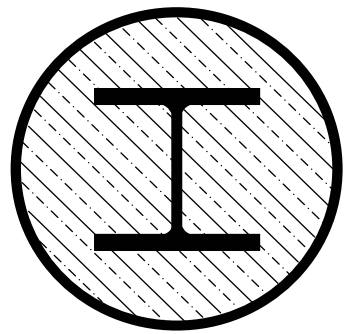






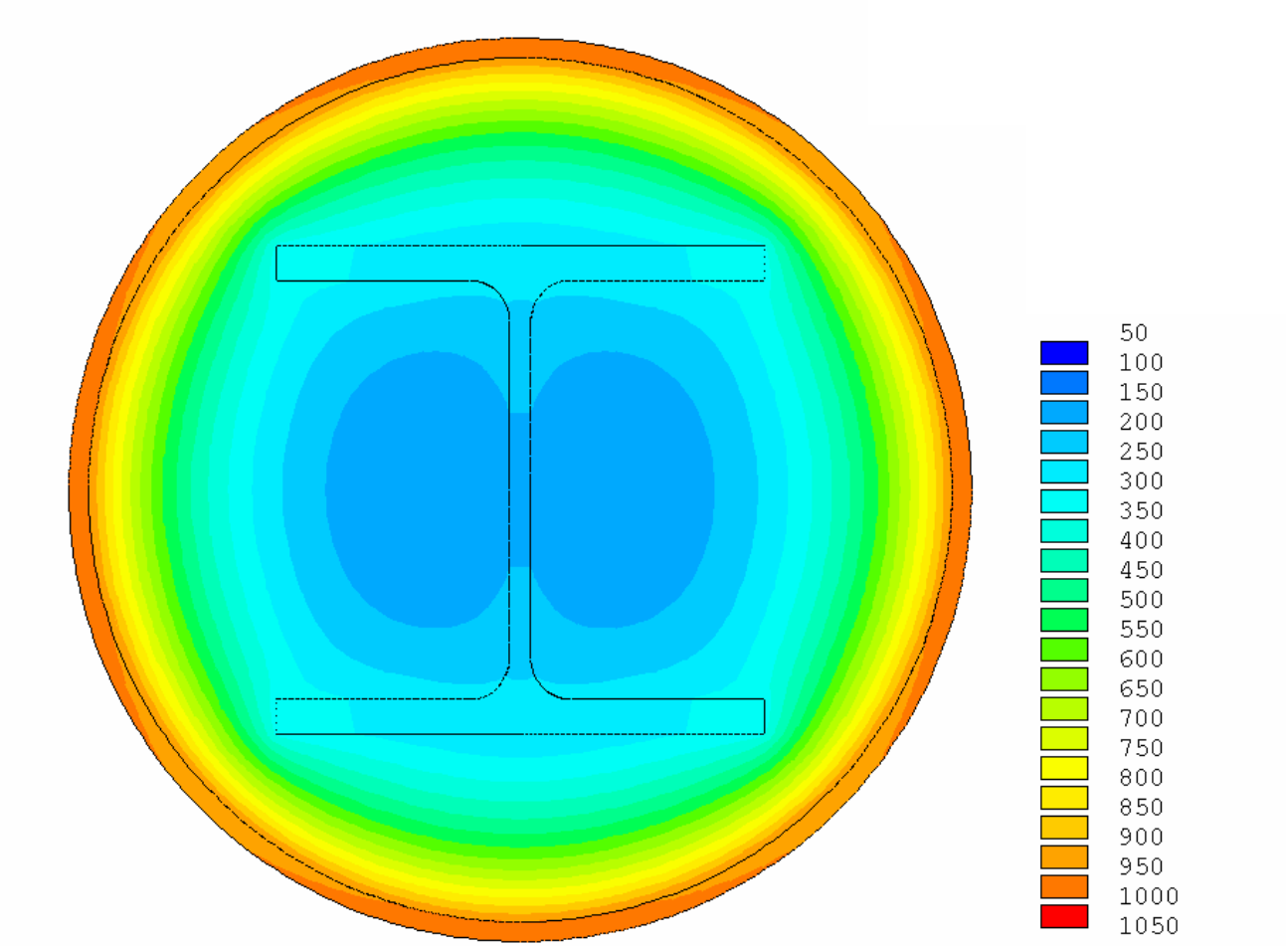






Heating and load behaviour

- Temperature distribution after 90 minutes of standard fire exposure



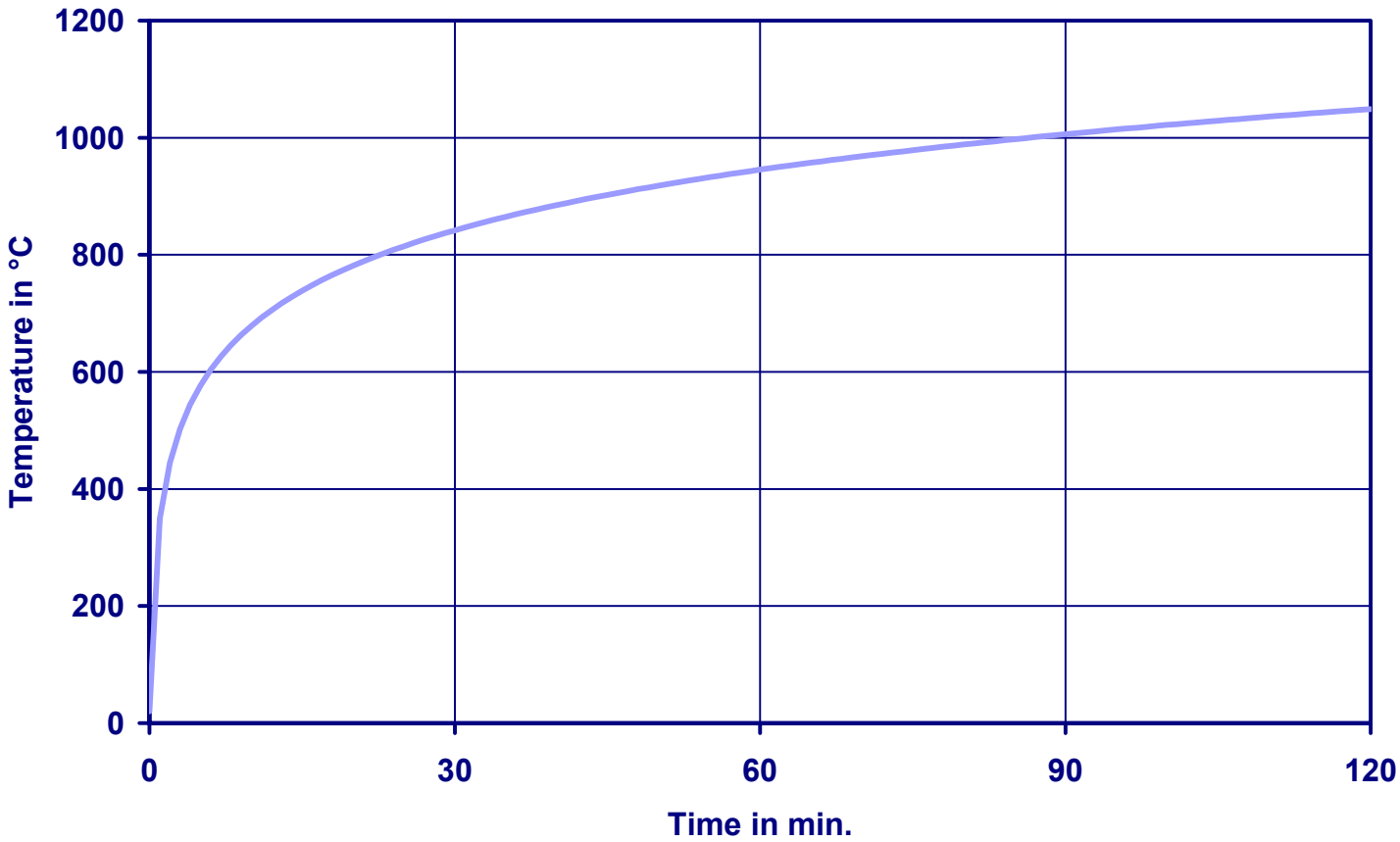
Calculation of fire resistance

- Divided in two independent steps
- Thermal analysis
  - Calculation of the temperature distribution over the cross section
- Mechanical analysis
  - Calculation of the axial buckling load
  - Considering thermally induced stresses
  - Including geometrical Imperfection

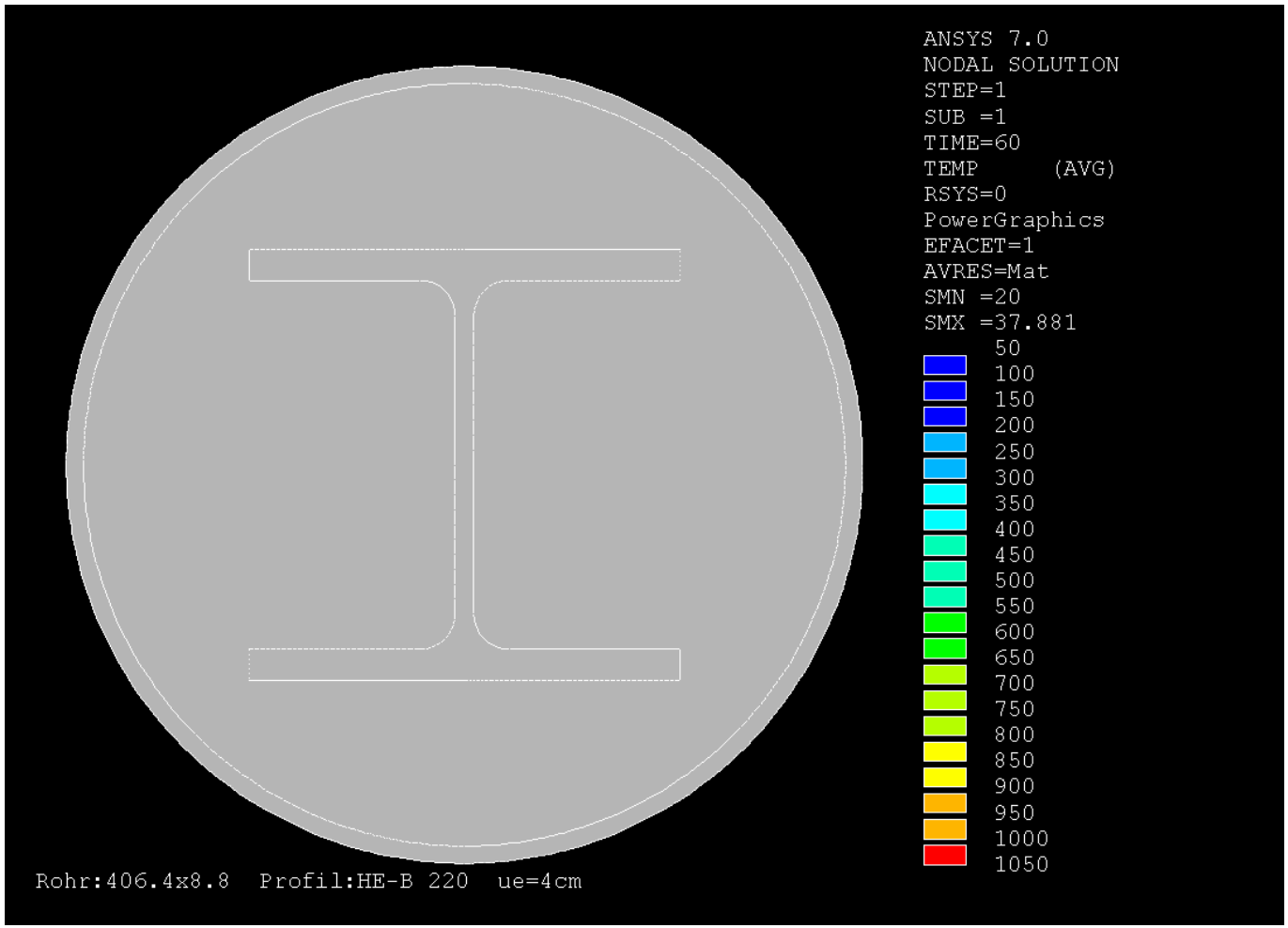
Thermal properties

	steel	concrete
Thermal conductivity λ (20°C)	53 W/m K	2 W/m K
Heat capacity c (20°C)	440 J/kg K	900 J/kg K
Convection coefficient α_c	25 W/m² K	25 W/m² K
Emissivity coefficient ε_{res}	0,56	0,56

Standard fire ISO-834



Temperature distribution under standard fire exposure (90 min.)



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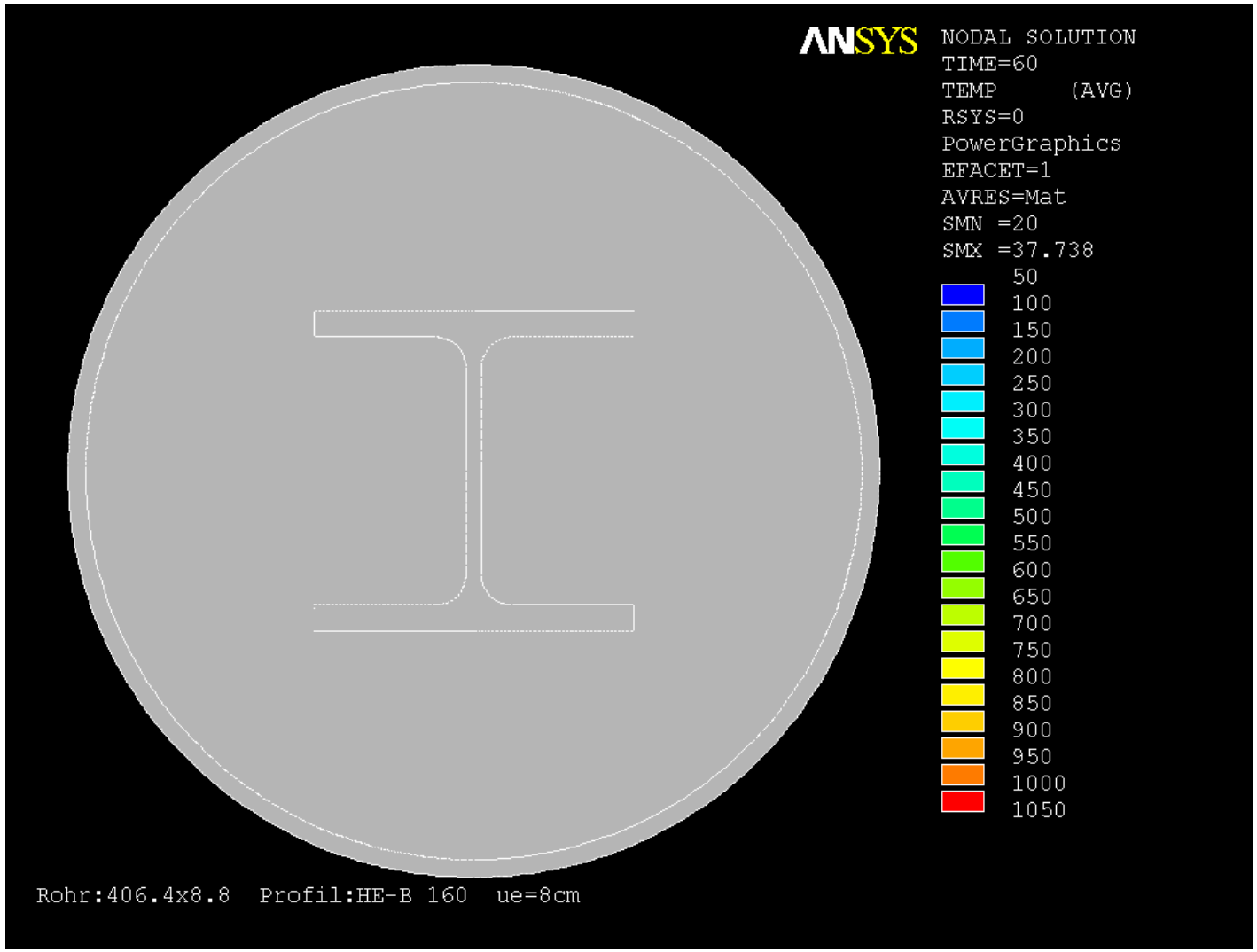
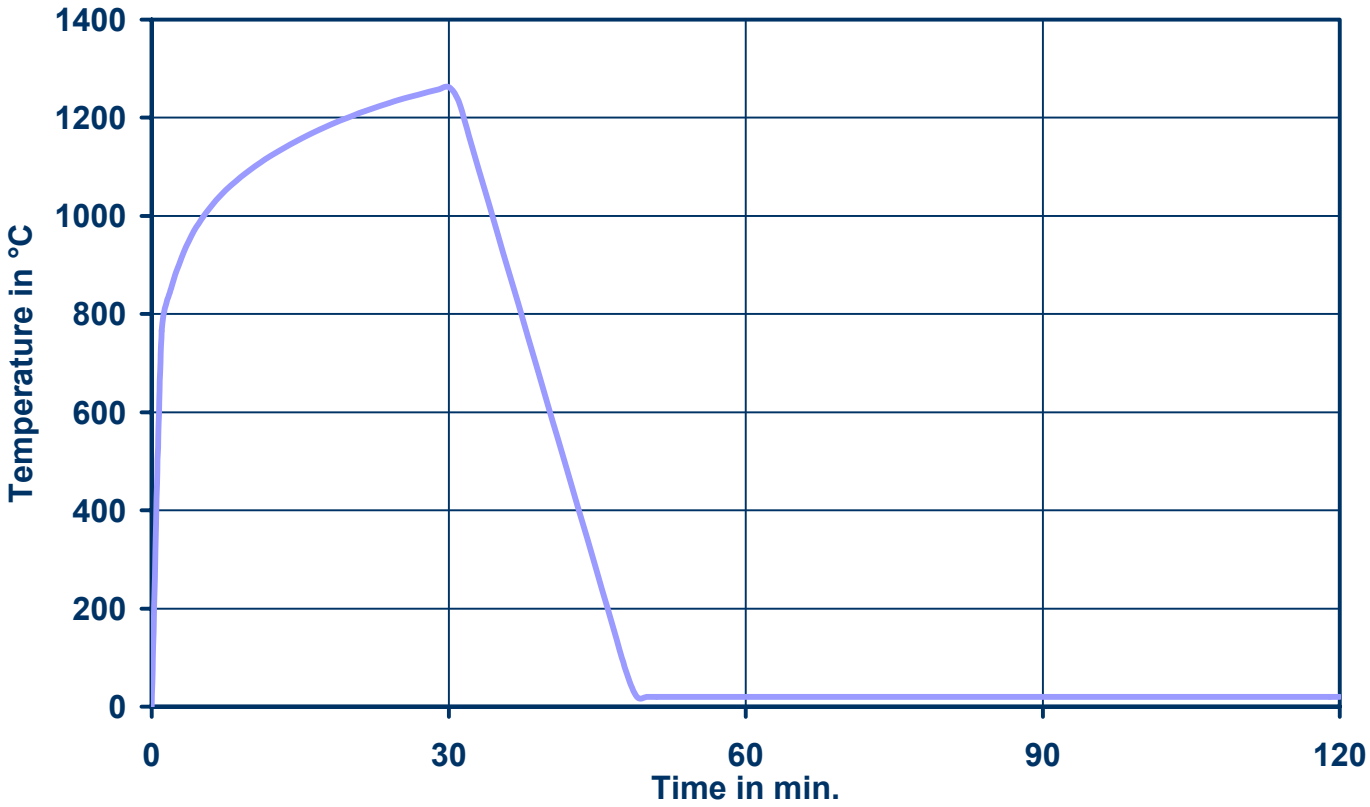


Natural fire exposure

Fire load: q_{fid} = 1700 MJ/m²; opening factor: O = 0.14 $m^{0.5}$



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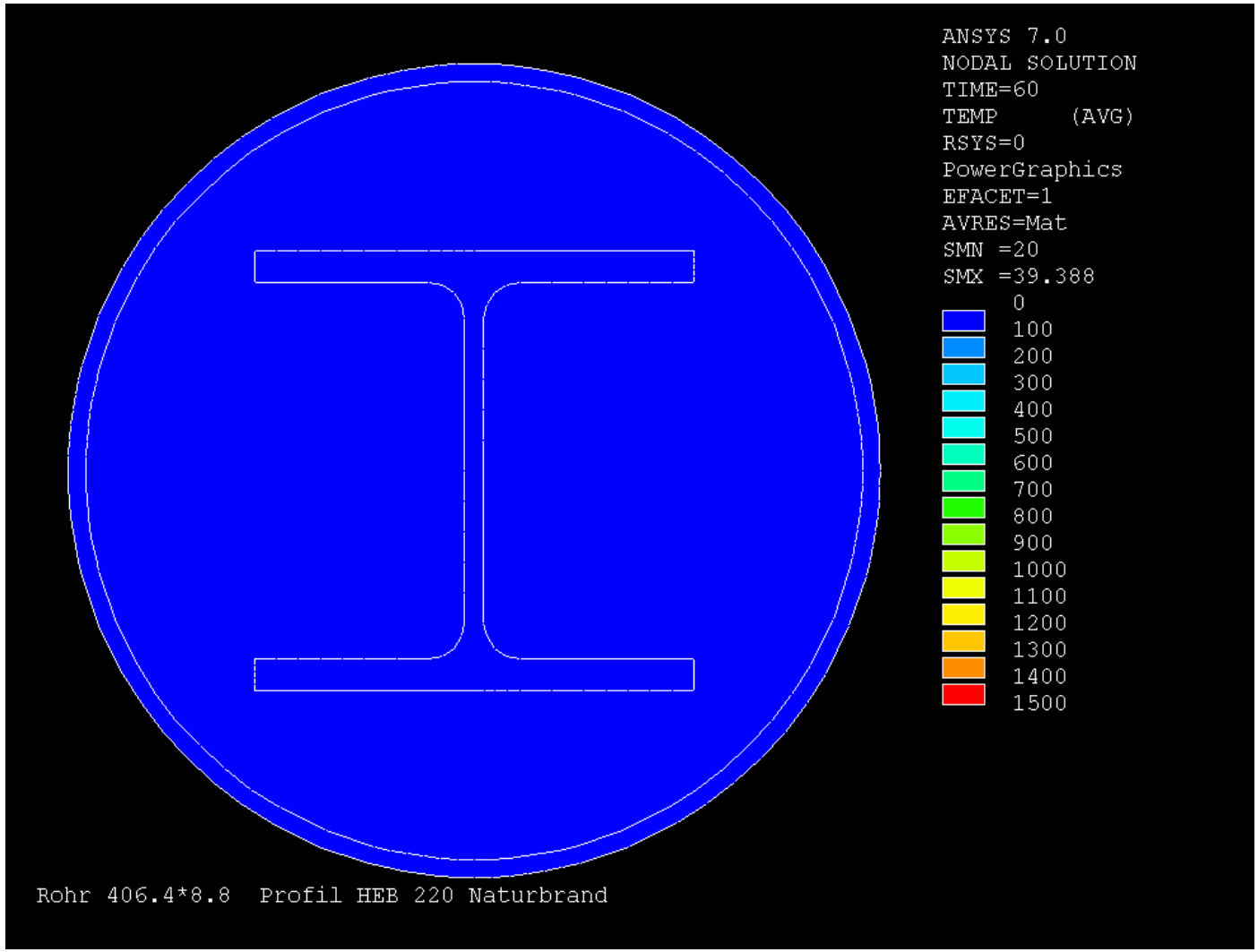
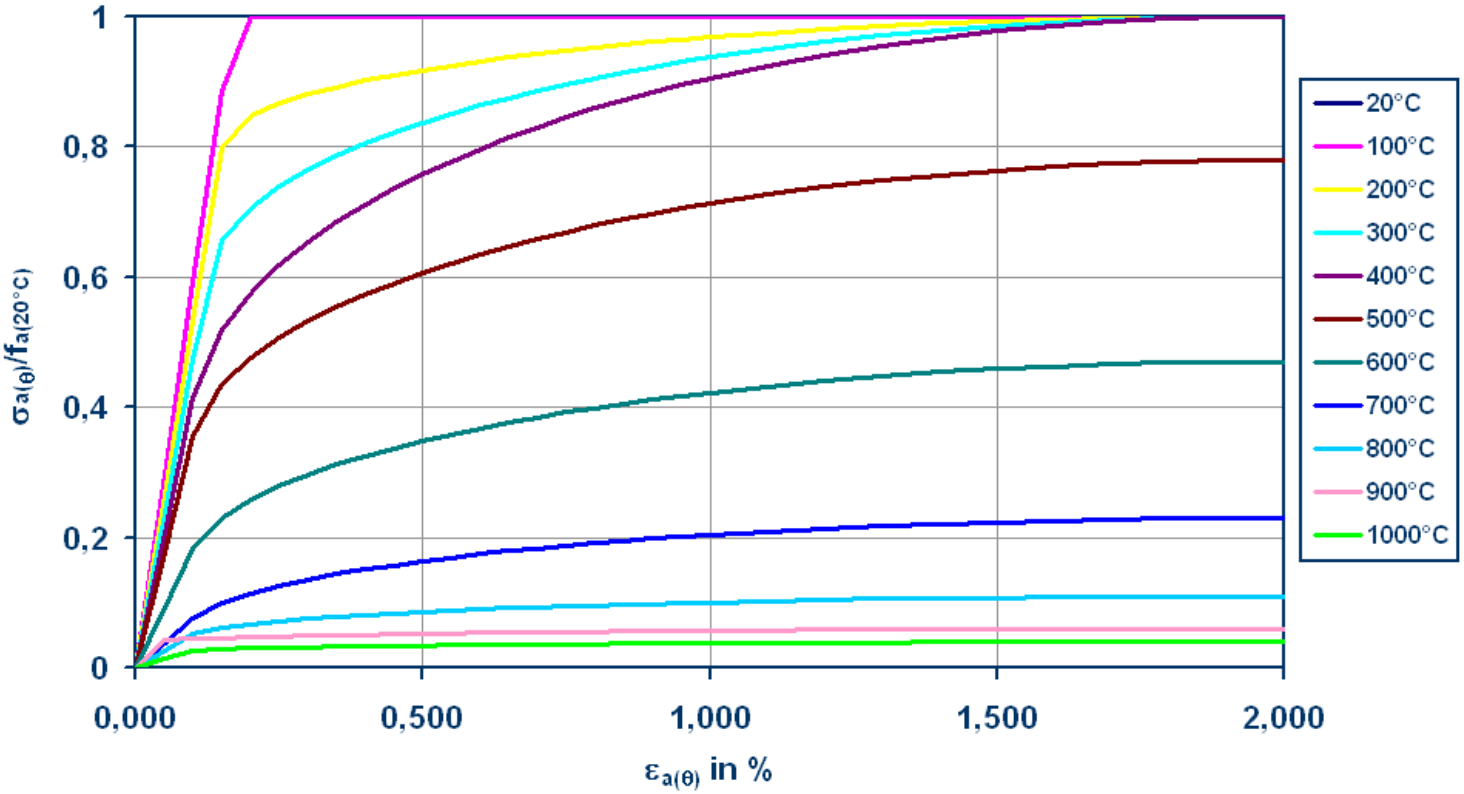
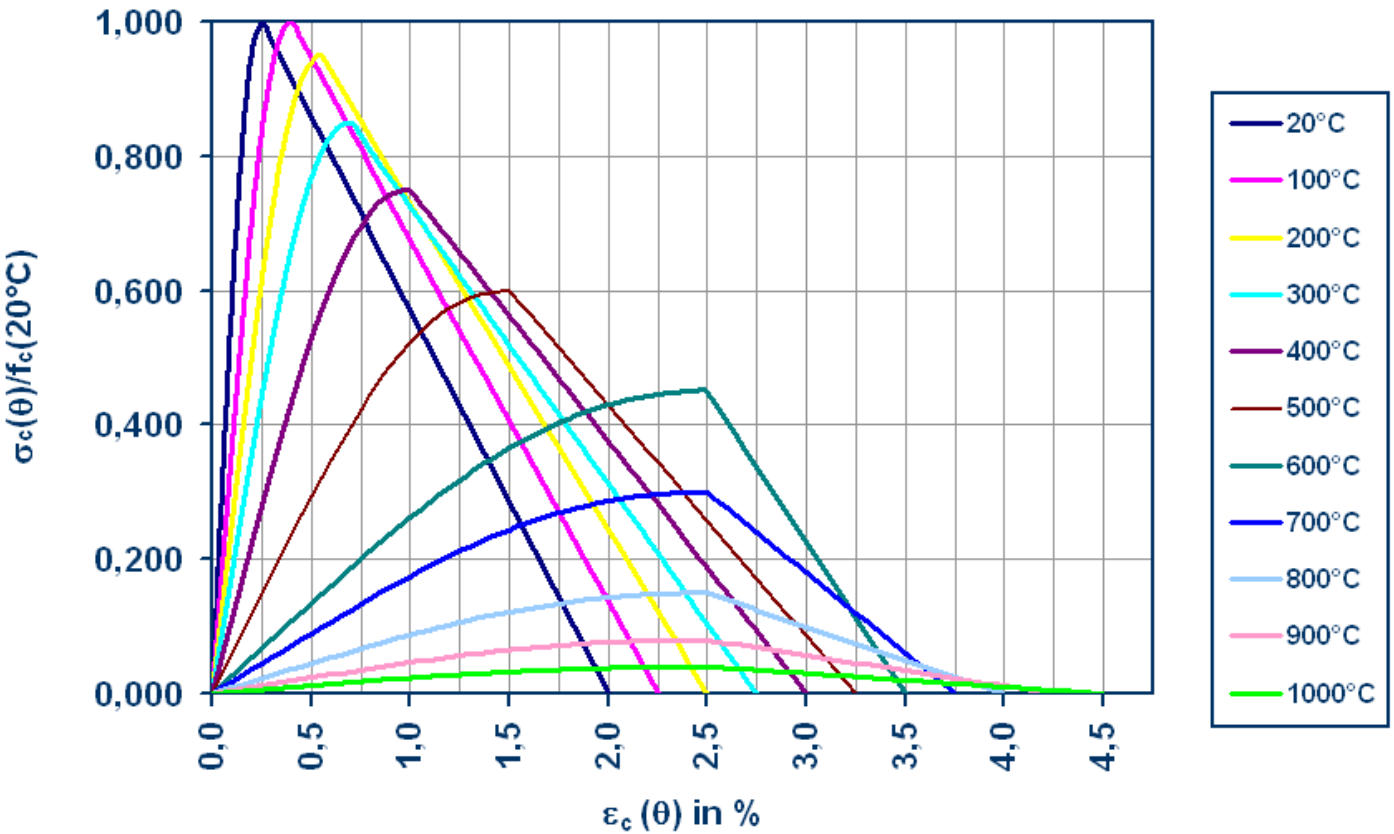
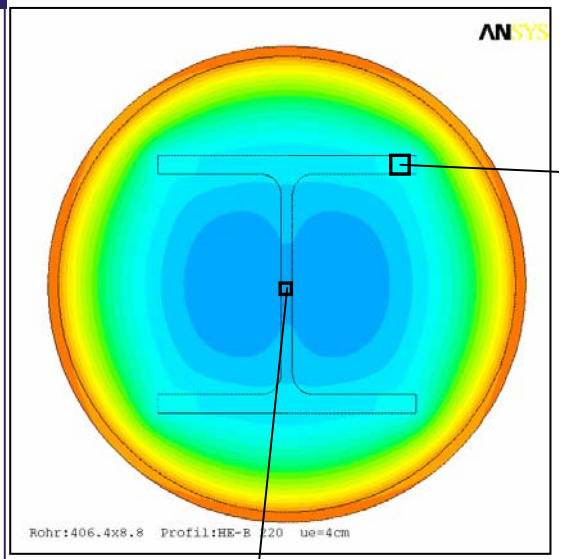


Stress-strain relationship for steel at elevated temperatures



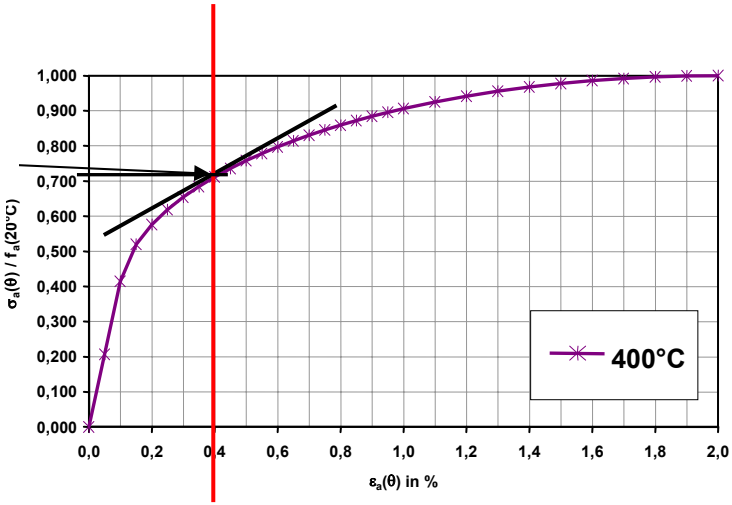
Stress-strain relationship for concrete at elevated temperatures





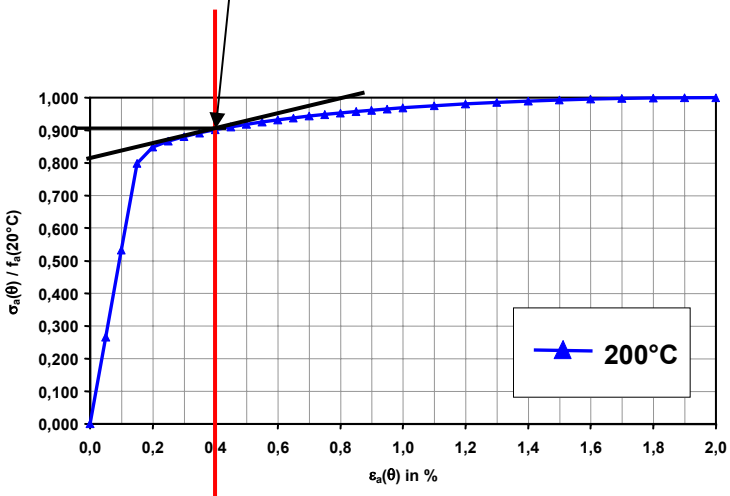
θ = 400°C

ε = 0,004



θ = 200°C

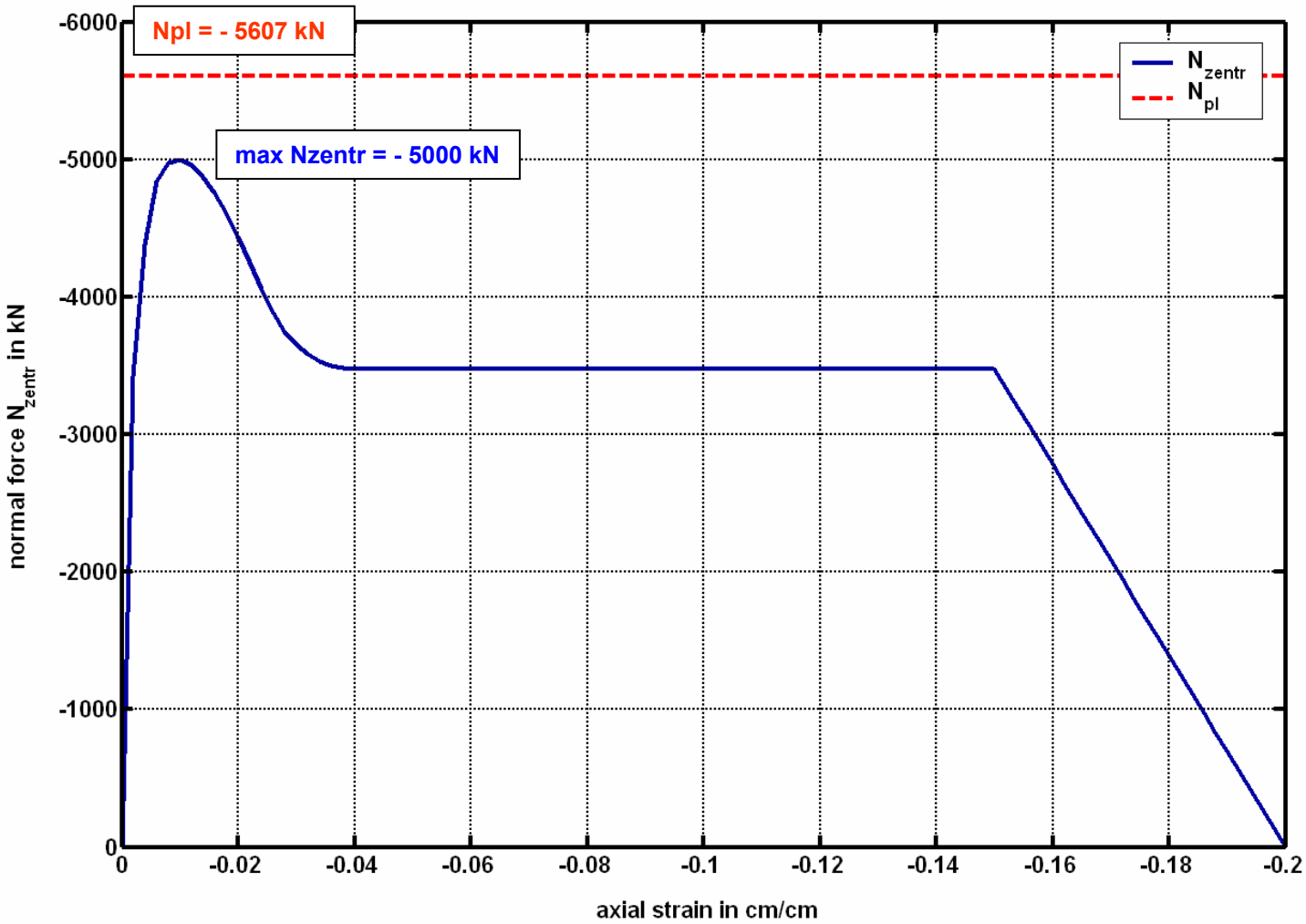
ε = 0,004



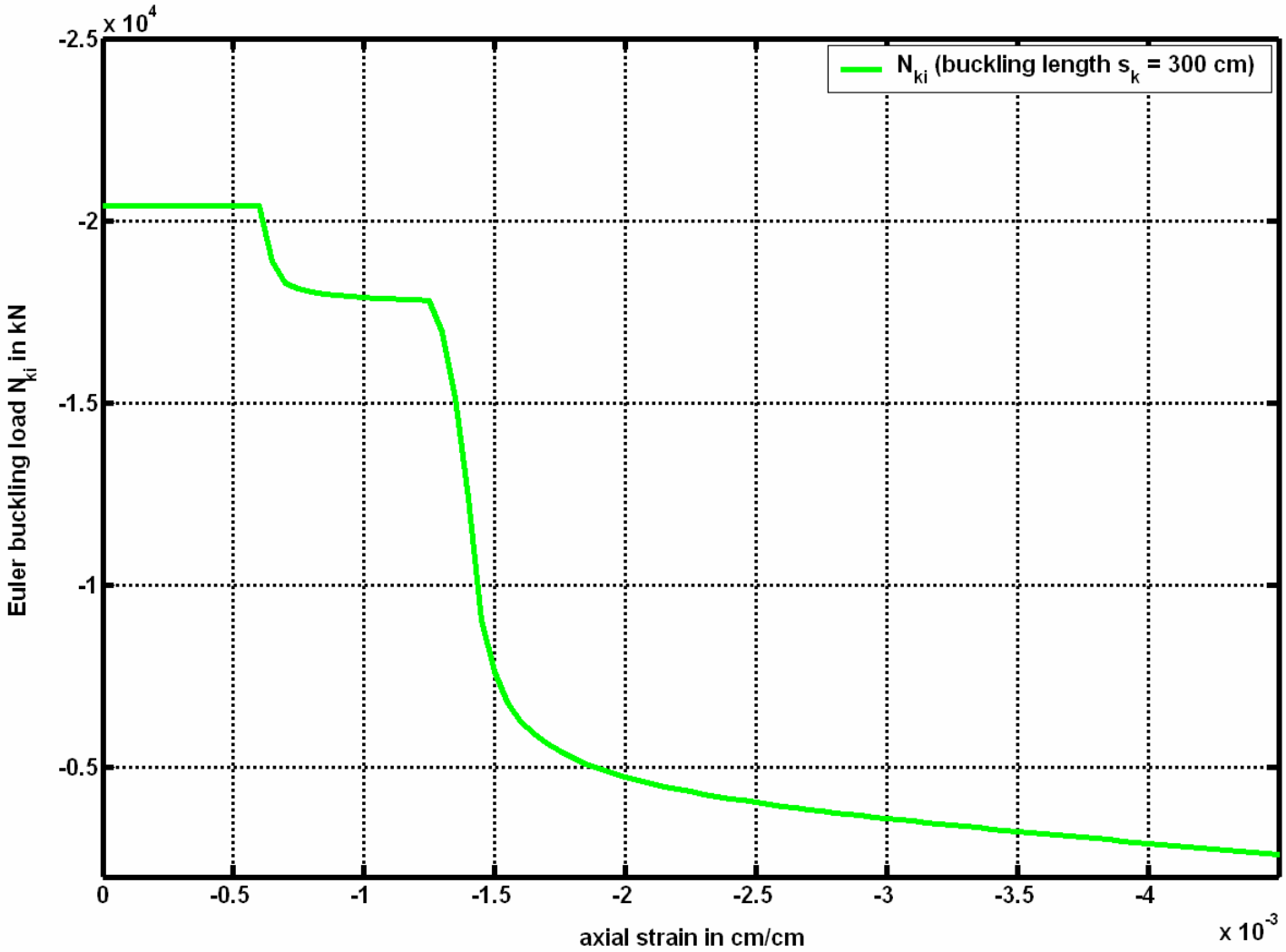
$$N_{zentr} = \Sigma(\sigma_{ai,\theta,\varepsilon} A_{ai} + \sigma_{ci,\theta,\varepsilon} A_{ci})$$

$$N_{ki} = \frac{\pi^2 \Sigma(E_{ai,\theta,\varepsilon} I_{ai} + E_{ci,\theta,\varepsilon} I_{ci})}{s_k^2}$$

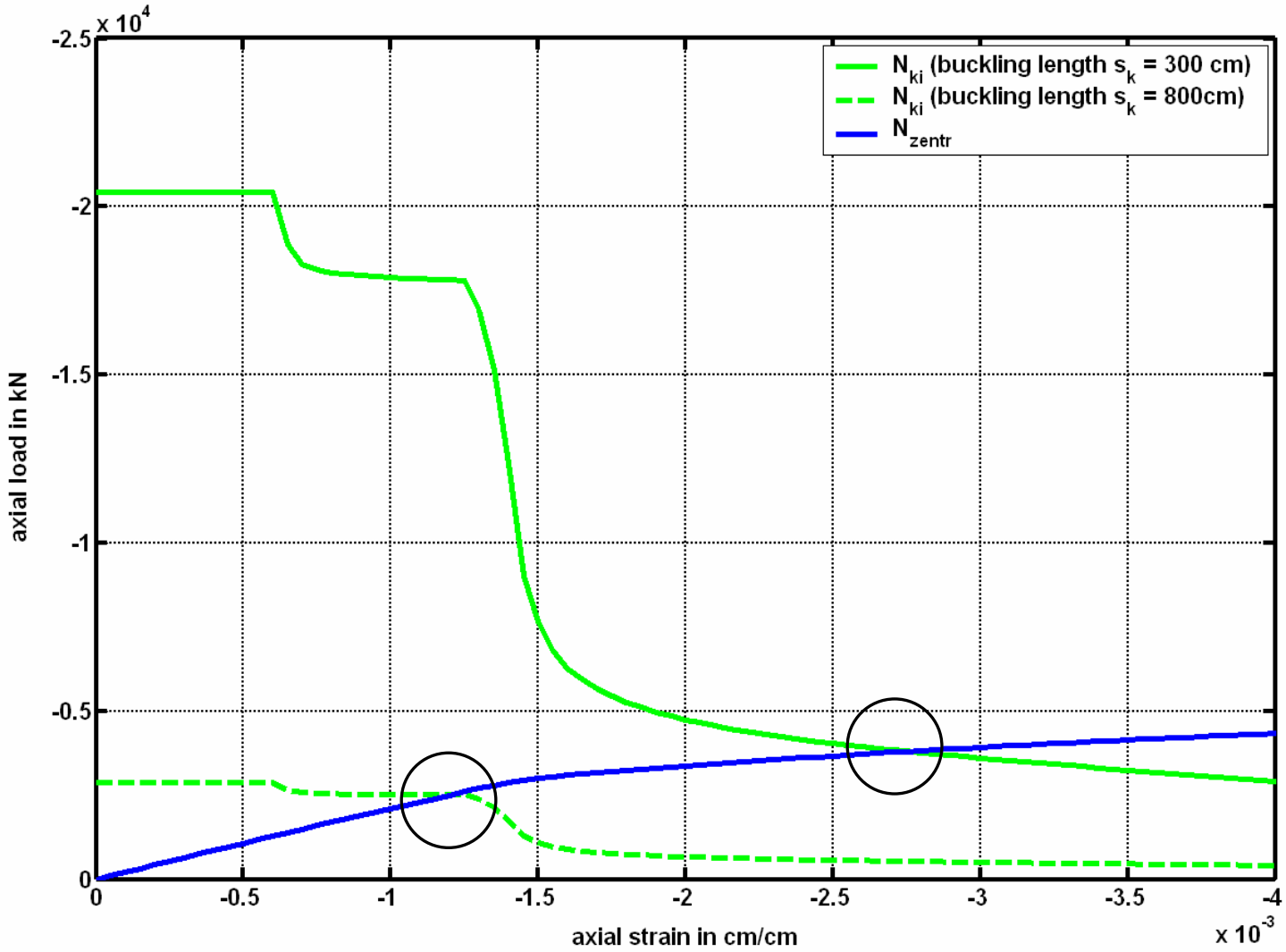
Resistance of the cross-section as a function of axial strain



Euler buckling load as a function of axial strain

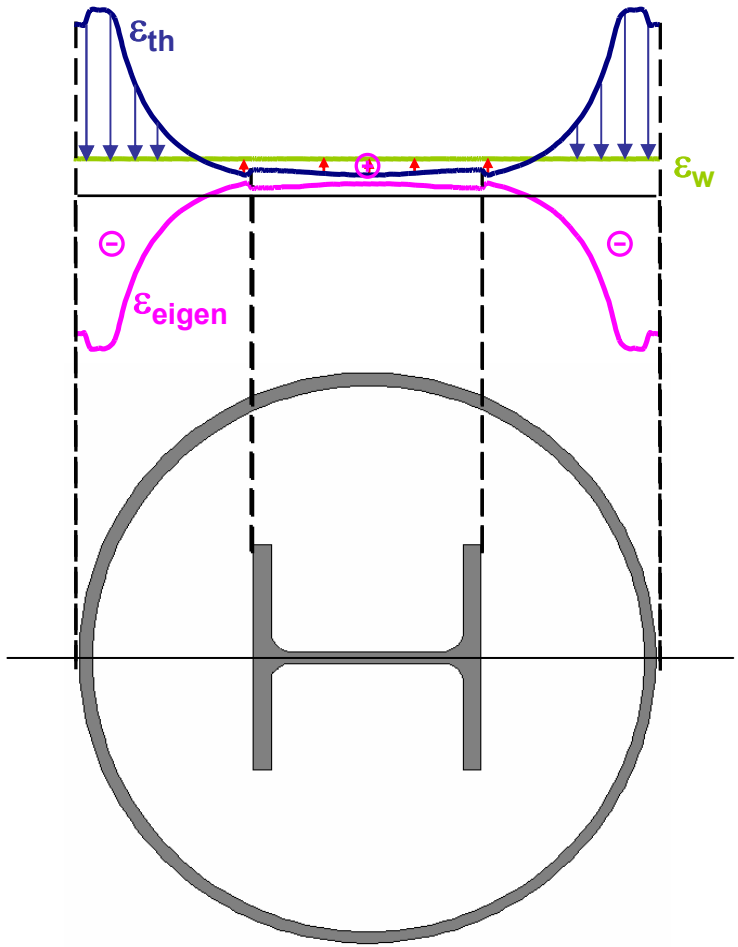


Determination of the axial buckling load



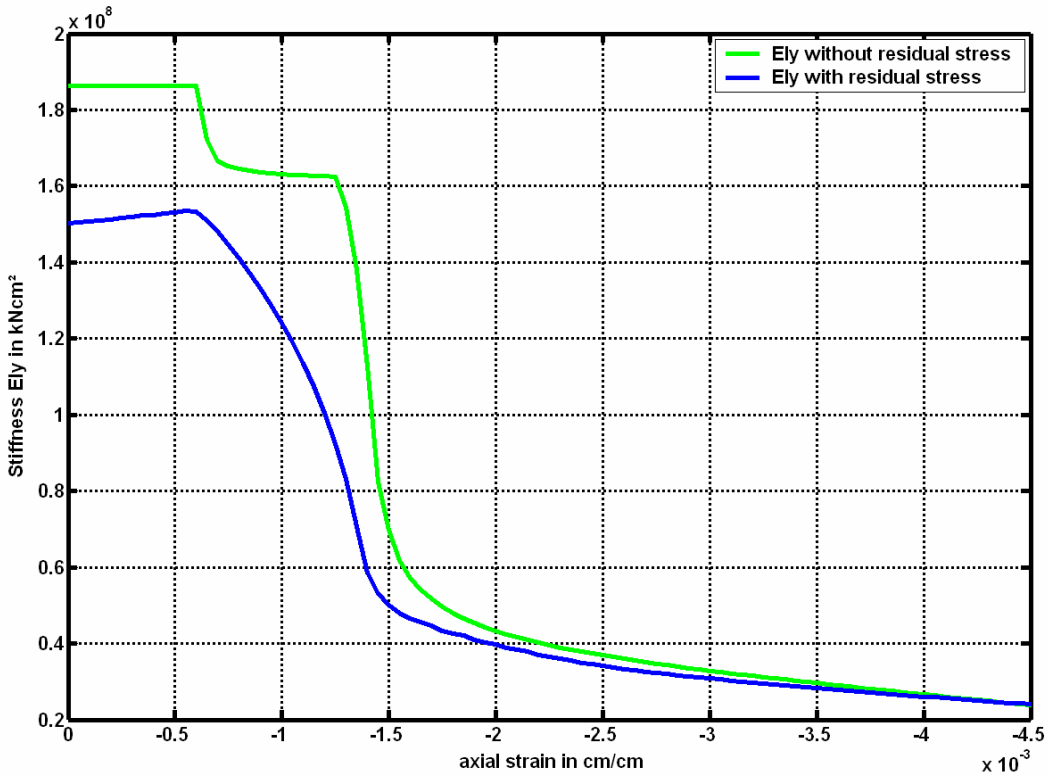
Thermally induced stress

- Residual stresses are a function of ε_{th} in cross section
  - outside: compression ⟺ inside: tension

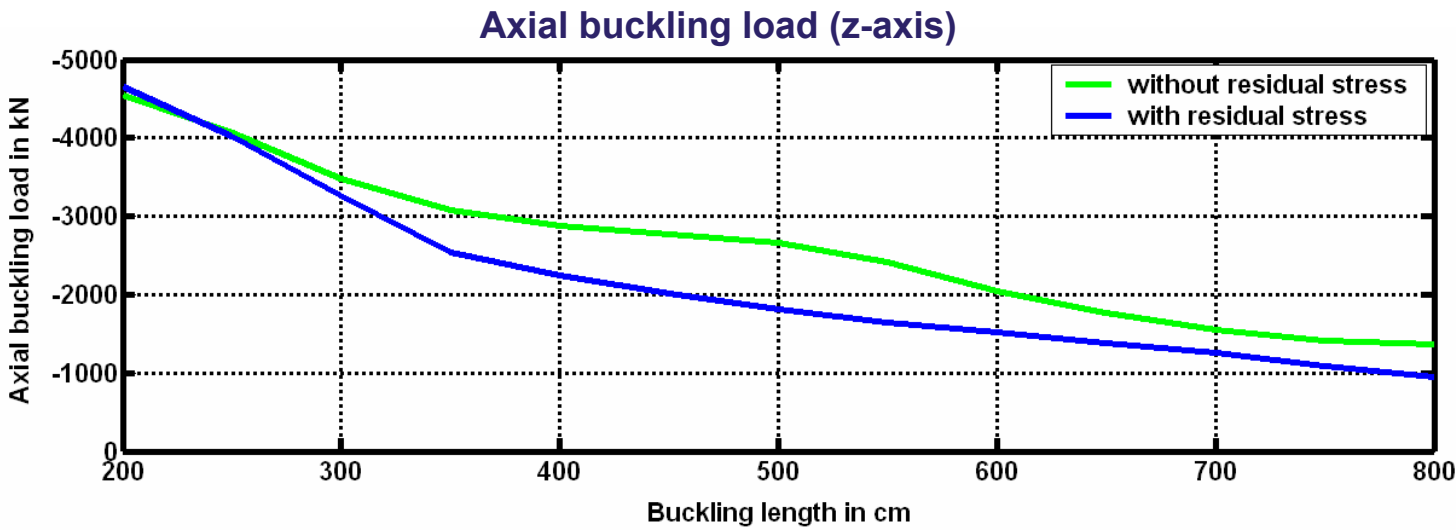


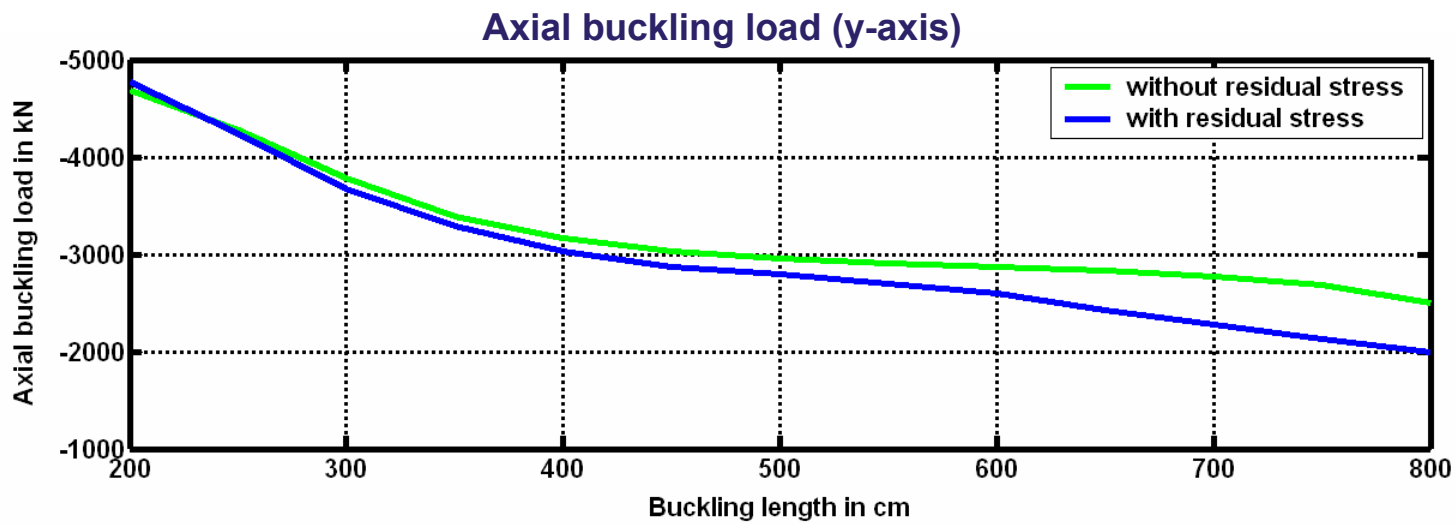
Effect of residual stresses on the axial buckling load

- Additional compressive stress at the outer range of the cross-section
- Decrease of stiffness



Axial buckling load as a function of the buckling length





Geometrical imperfection and eccentric loading

- Determination of the moment-curvature relationship
- Consideration of the unequal distribution of the stiffness along the column
  - Stiffness is dependent upon load
- Second-order analysis including geometrical imperfection

Conclusion

- The calculation of fire resistance of composite columns is divided in two steps
- Thermal analysis calculates the temperature distribution over the cross section
- Mechanical analysis with temperature dependent material laws
- Thermal stress decreases the axial buckling load

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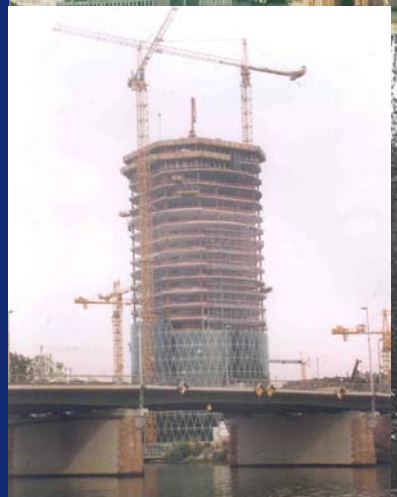



Thank you for your attention