Integrated Fire Engineering and Response

COST action network number TU0904 in domain Transport and Urban Development

March12-15 2014, Lulea

Thermo-mechanical analysis of steel columns using different constitutive laws

Di.St. – Department of Structures for Engineering and Architecture
University of Naples "Federico II"
ITALY

Department of Civil and Structural Engineering
University of Sheffield
ENGLAND

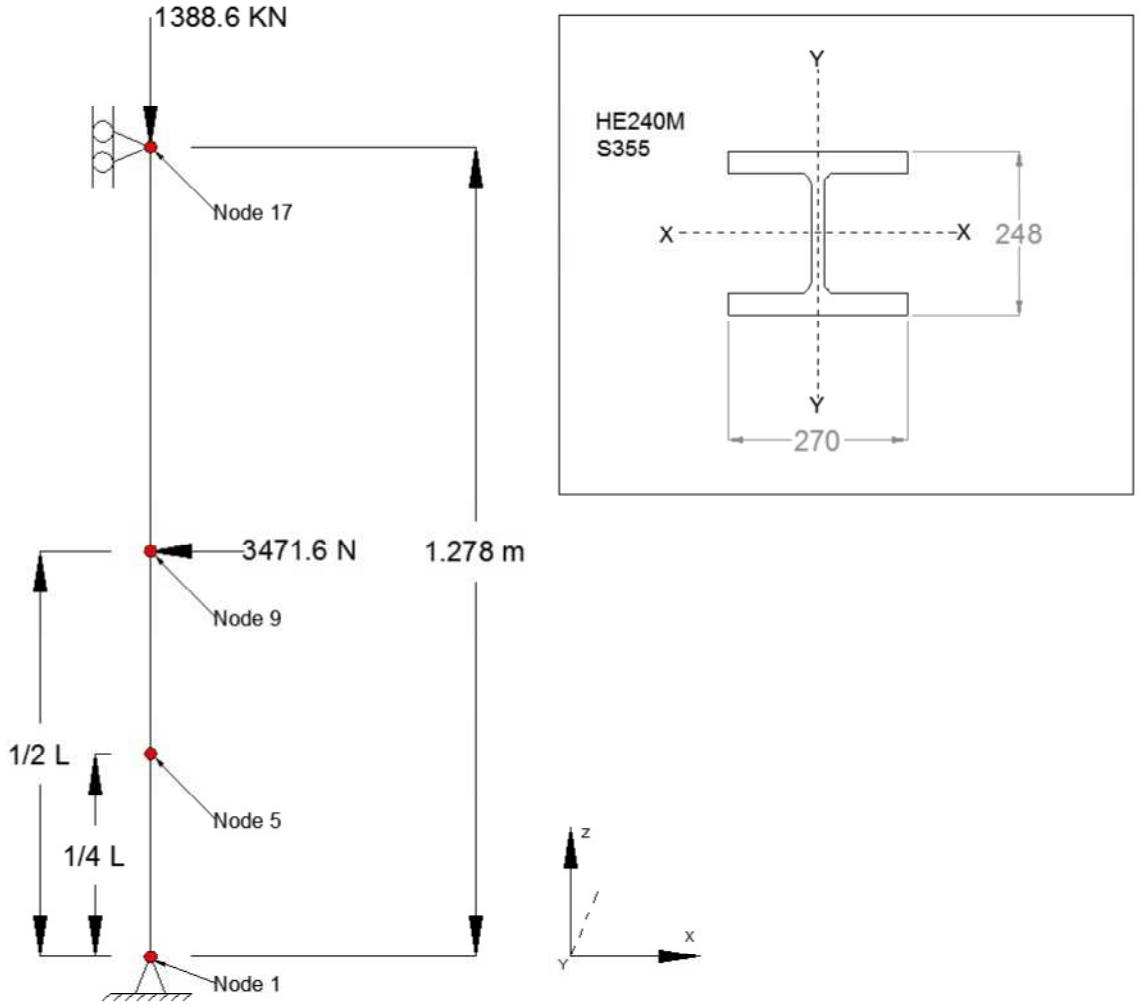
D. Sannino
WG3 - I. Burgess
WG1 - E. Nigro
M. Alexandreu

Summary

- Application of advanced calculation models in fire analyses requires special attention by the designer to the modeling details and the type of finite element adopted for the structural model. The assumptions made in modeling of the thermo-mechanical properties influence the analytical results.

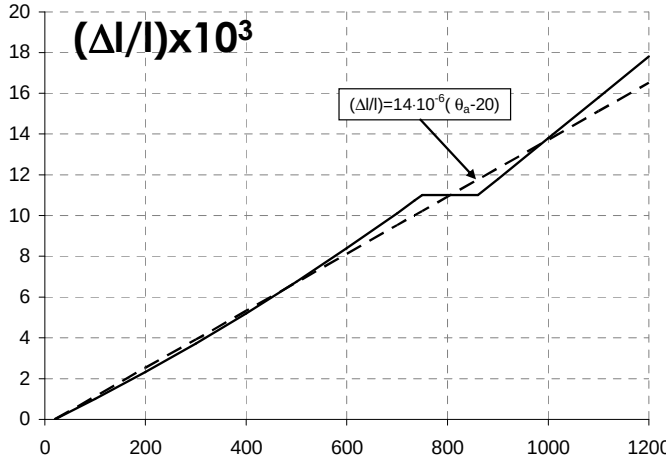
- The use of a simplified constitutive law does not significantly affect the results in terms of time of collapse when the structures or substructures analyzed are characterized by collapse due to the attainment of limiting tensile stress in the material.

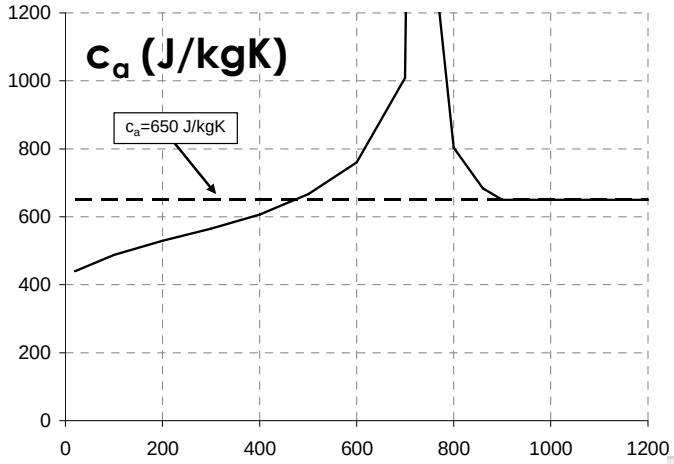
- For analyses in which buckling phenomena cause the dominant collapse mode, this simplified constitutive law can significantly affect the results, both in terms of time to collapse and displacement behavior.

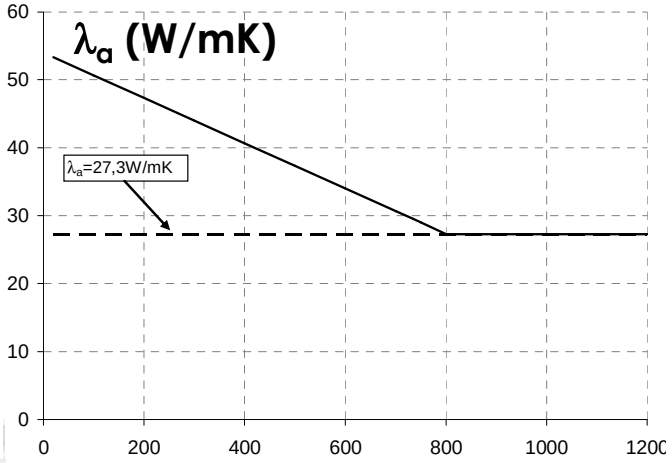


Comparison between thermo-mechanical properties

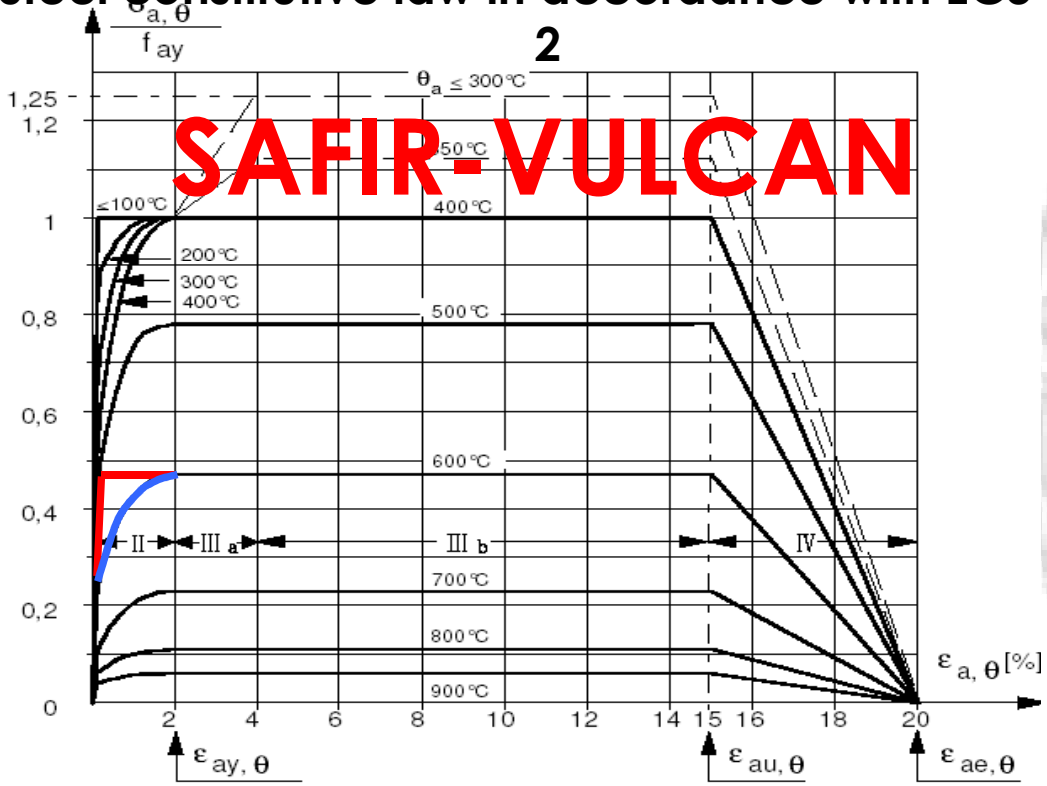
Steel thermal properties in accordance with EN1993-1-2



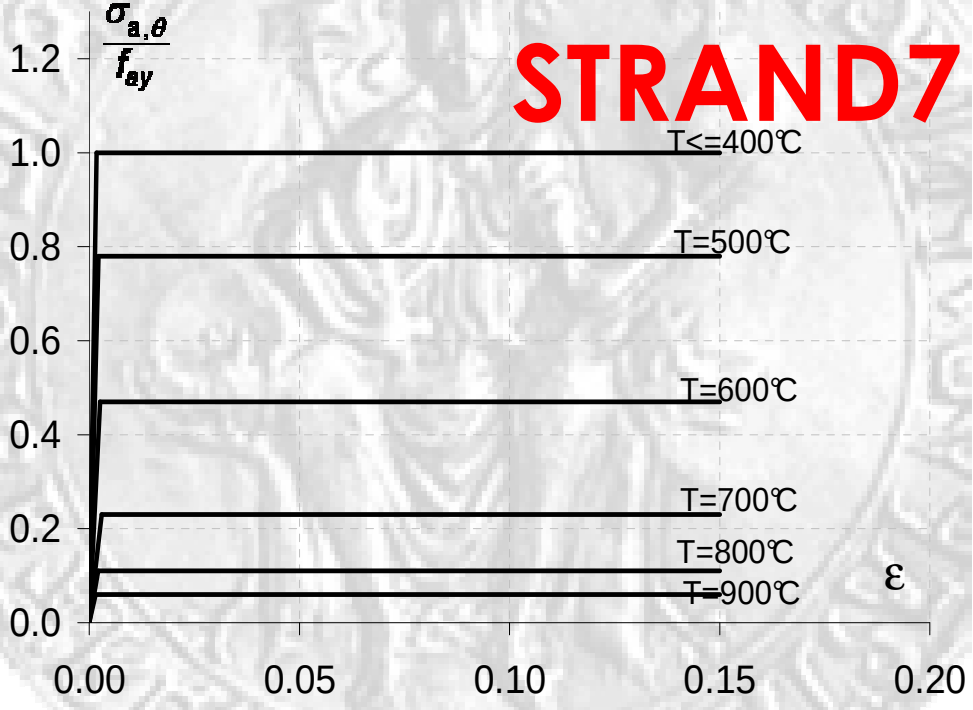




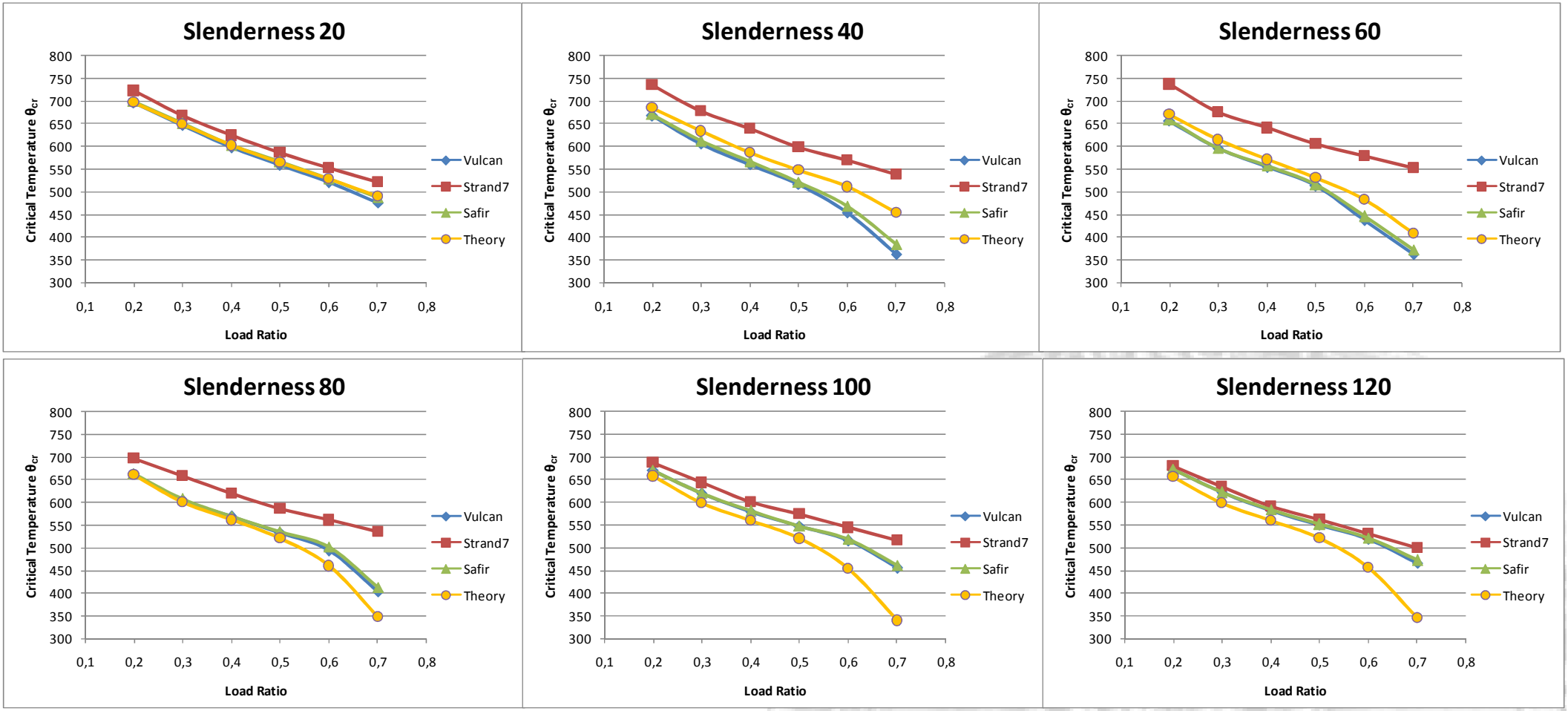
Steel constitutive law in accordance with EC3-1-2



Simplified (elastic-plastic) constitutive law for steel at high temperatures

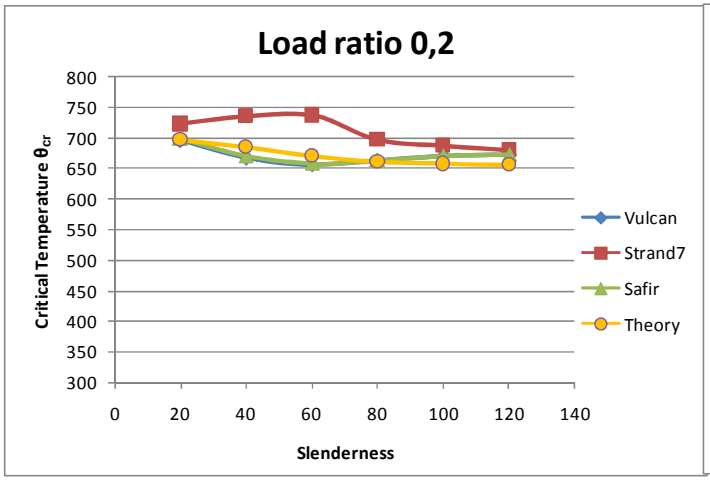


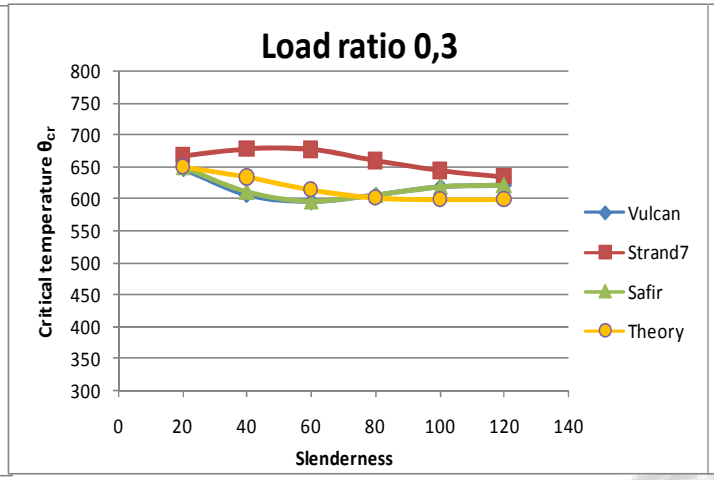
Comparison between software varying Load Ratio

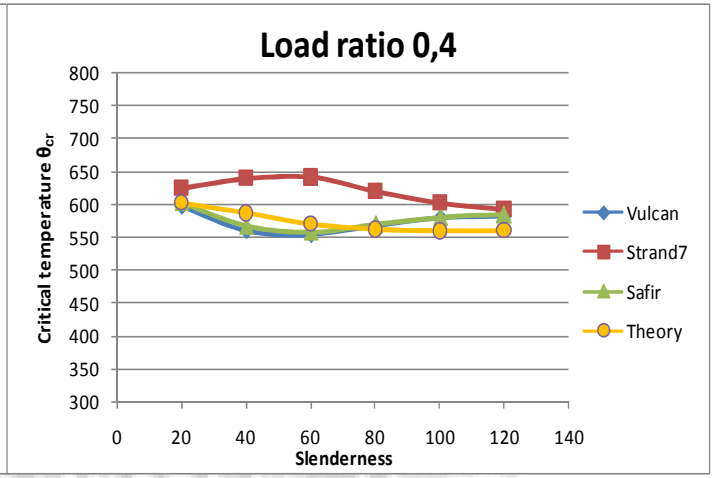


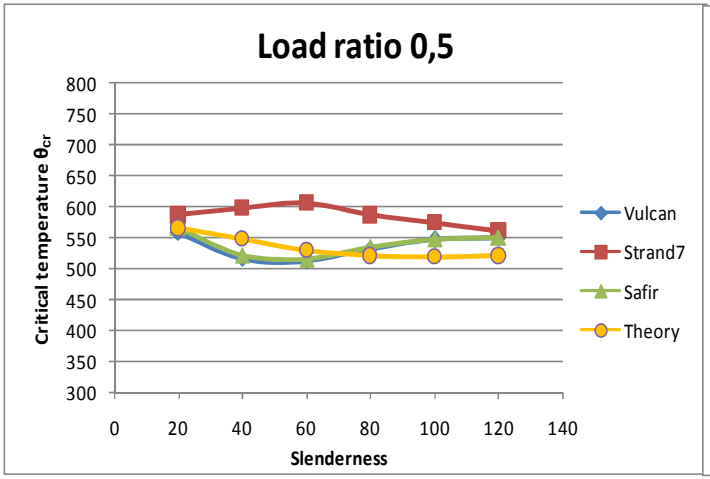
- SAFIR and VULCAN models are almost perfectly in agreement.
- The STRAND7 results differ from the other because of the constitutive law simplification.
- Differences from SAFIR and VULCAN in respect to EN1993-1-2 are due to geometric imperfections, defined by a horizontal force applied in the SAFIR and VULCAN models, so a slightly smaller value of critical temperature can be expected than when using the perfect theoretical formula, especially for higher slenderness values.

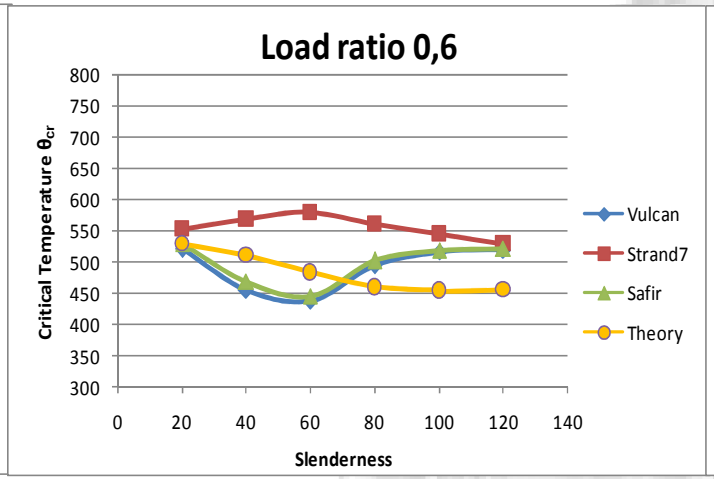
Comparison varying Slenderness







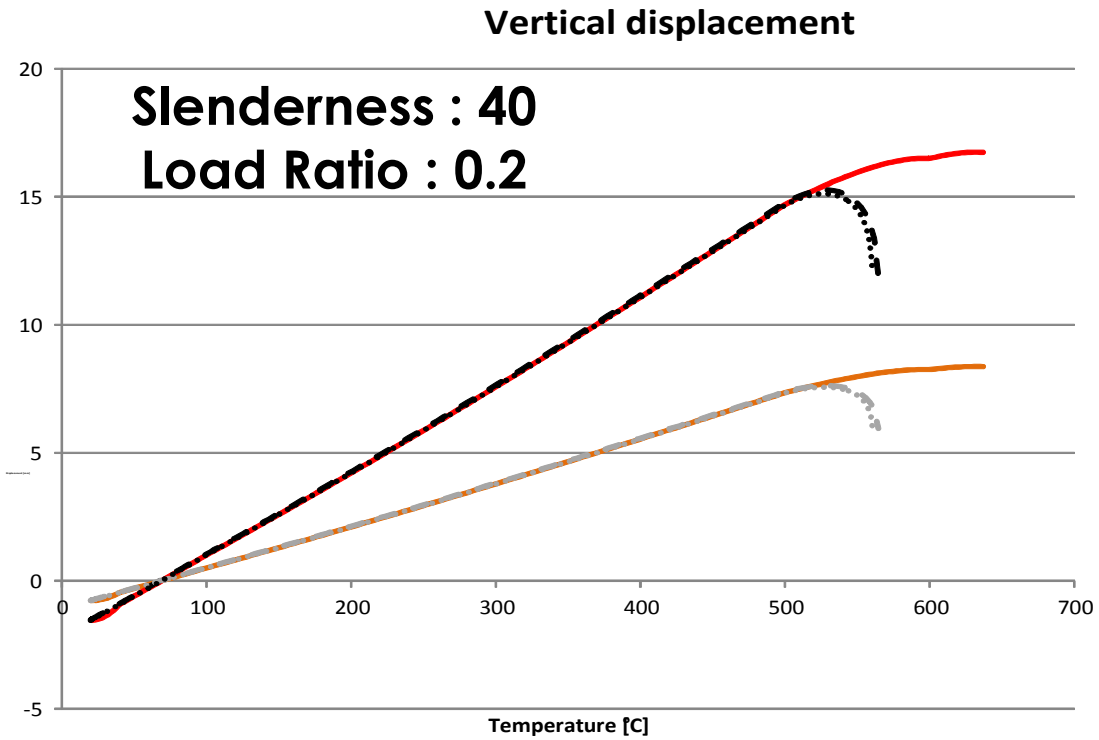




- **The STRAND7's differences increase with the load ratio.**
- **The results obtained by varying the slenderness show that the theoretical curves cross the analytical curves for values of slenderness in the region of 75.**
  This is comparable to the value of transition slenderness evaluated as:

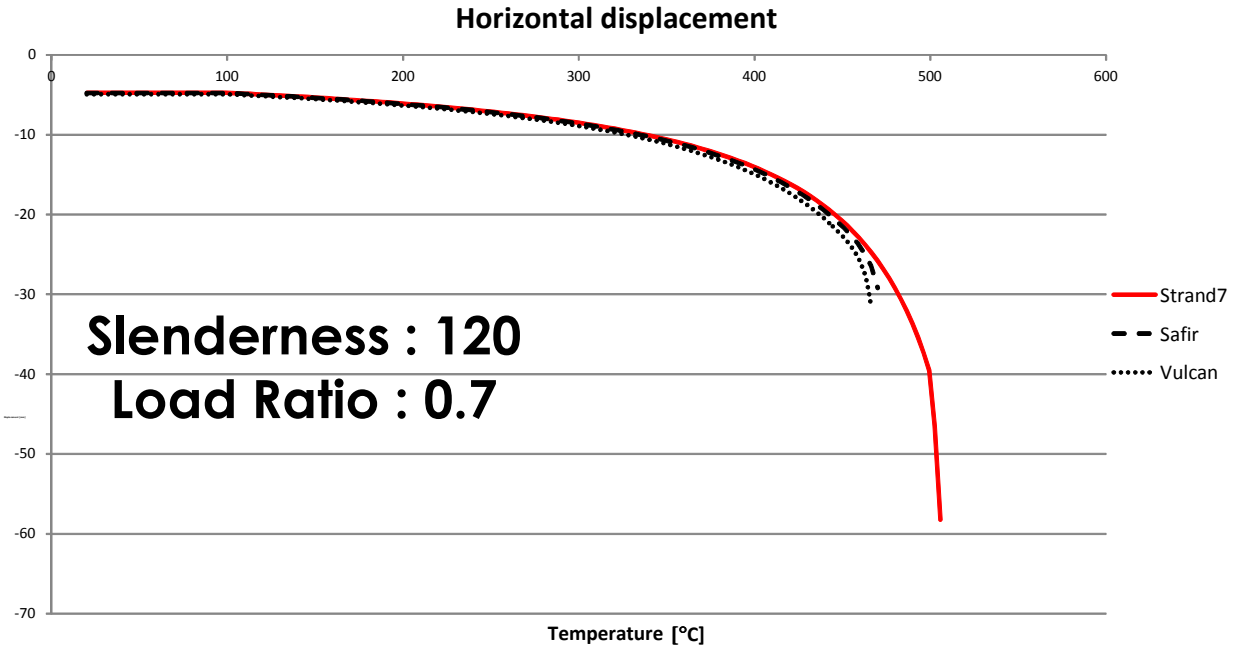
$$\lambda_1 = \pi \sqrt{\frac{E}{f_y}} = 76{,}37$$

Comparison in terms of displacements



The two nodes considered are at the top (Node 17) and at the middle (Node 9) of the column

The curves from STRAND7 are more rigid than the others. The point at which the former curves diverge from the others coincides with the point at which the proportionality limit is passed by the steel in the column elements.



Conclusions

- ✓ The analyses carried out show that the use of a simplified constitutive law for steel at high temperature, especially in analyses characterized by buckling phenomena, can significantly influence the results.

- ✓ The analyses were carried out using three different software codes, SAFIR, VULCAN and STRAND7. The first two of these use the constitutive law for steel at high temperature according to EN1993-1-2, while STRAND7 only allows a simplified constitutive law.

- ✓ SAFIR and VULCAN analyses are almost completely in agreement. The differences between these two software and the analytical results can be justified by the way in which geometric imperfections were defined.

- ✓ Considering the STRAND7 results the influence of the simplified constitutive law on the results is clear, especially for high load ratios and for slenderness between 40 and 100. The buckling phenomenon is controlled most sensitively by the tangent modulus of the force-displacement curve and therefore depends on the shape of the stress-strain curve. For this reason the results from STRAND7 differ from those from the other software. The largest differences are evident for the values of load ratio.

Thanks for your attention