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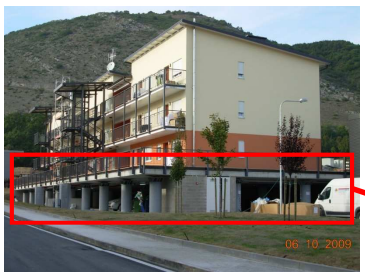
Thermo-mechanical analysis of steel columns using different finite element types and constitutive laws

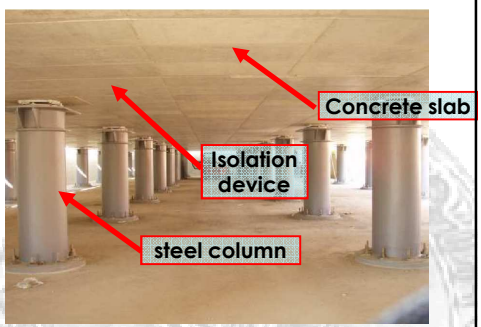
WG1 - E. Nigro
WG2 - G. Cefarelli
D. Sannino
A. Ferraro

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

Benchmark study: Progetto C.A.S.E. per L'Aquila

The "C.A.S.E. Project for L'Aquila" was developed in L'Aquila (province of Abruzzo, Italy) after the seismic event of 06/04/2009, in order to face up the housing emergency. The project was characterized by the fabrication of several seismic insulated buildings.





Hereafter the performance evaluation of the structure in lack of passive protection systems is analyzed

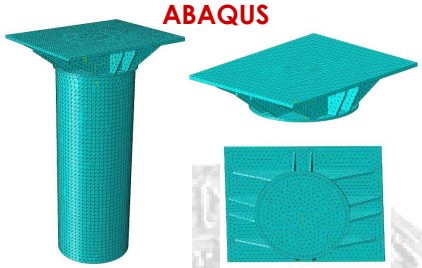
Analysis and Benchmark goals

Non linear analysis including large displacements effects

✓ Detailed analysis

Because the column is characterized by graet values of local slenderness, detailed analyses are developed in order to evaluate accurately thermal field and stress distribution in the capital of the column, as well as eventual local buckling phenomena in the stem of the column.

ABAQUS

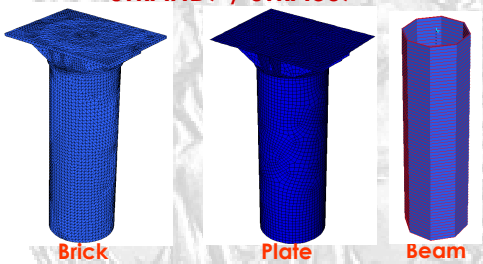


✓ Benchmark

The benchmark is developed in order to evaluate the influence of the finite element used in the analysis as well as the influence of simplified constitutive law for steel at high temperature

Model	Type of finite element
Abaqus	10 nodes tetrahedral elements
Straus7 brick	4 nodes tetrahedral elements
Straus7 plate	4 nodes quadrilateral elements
Straus7 beam	2 nodes monodimensional elements

STRAND7 / STRAUS7



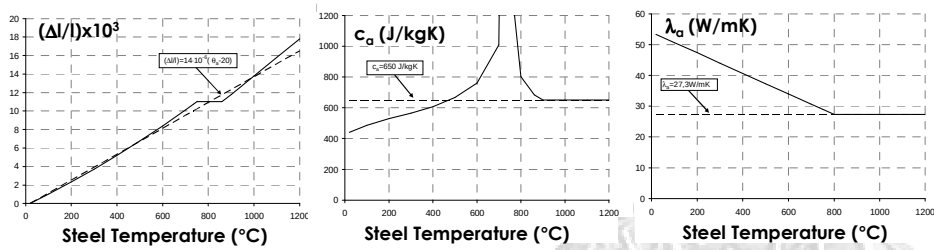
Brick
49075 elements
15185 nodes

Plate
6873 elements
6641 nodes

Beam
31
elements

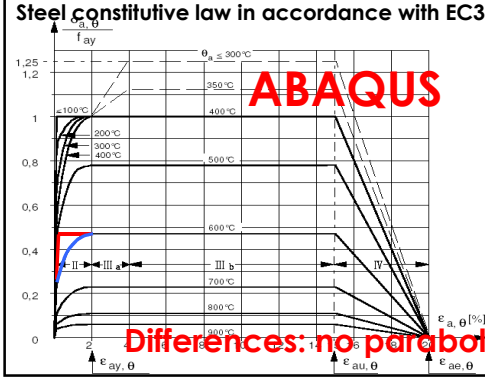
Comparison between thermo-mechanical properties

Steel thermal properties in accordance with EC3-1-2



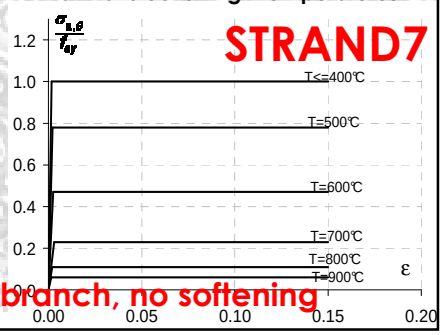
Steel constitutive law in accordance with EC3-1-2

ABAQUS



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

STRAND7

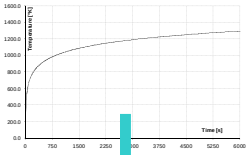


Differences: no parabolic branch, no softening

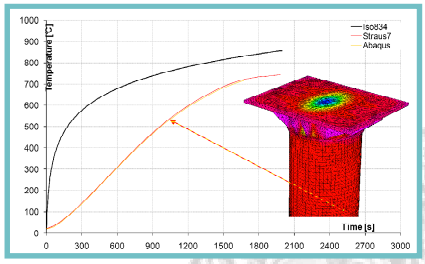
ABAQUS – STRAND7: different constitutive laws

Different constitutive laws for steel at high temperature

Fire Curve ISO834

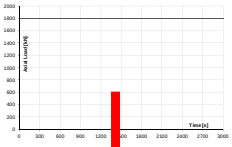


Thermal Analysis

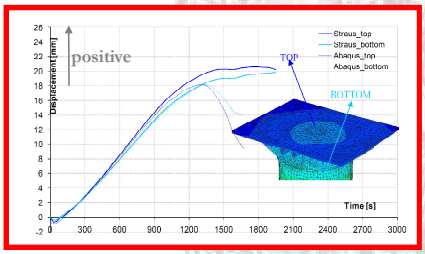


Thermal analysis results are obviously identical. This is fundamental to permit the comparison based on different constitutive law

Applied Axial Load



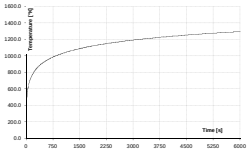
Mechanical analysis



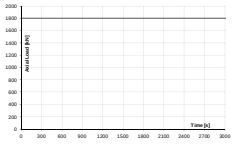
Mechanical analysis results are different in term of behaviour, however they are quite similar in terms of collapse time

ABAQUS – STRAUS7: different constitutive laws

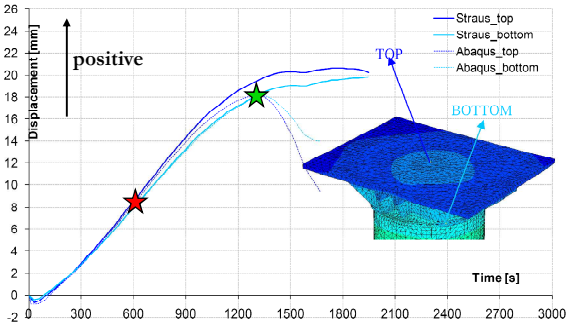
Fire curve ISO834

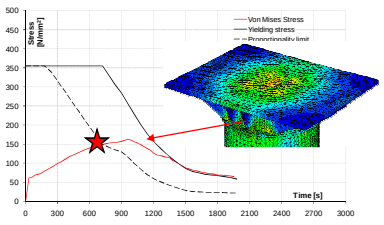


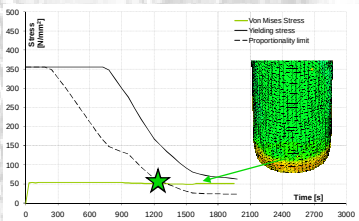
Applied Axial Load



Different constitutive laws for steel at high temperature



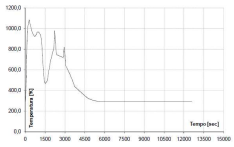




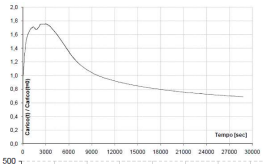
The differences of results are due to different constitutive laws.
The two models show different behaviour after the achievement of proportional limit

ABAQUS – STRAND7: different constitutive laws

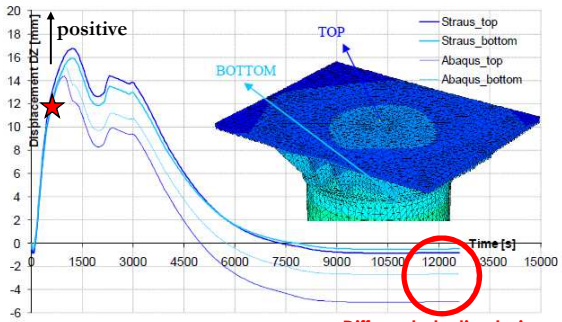
Localized Fire (Hasemi)



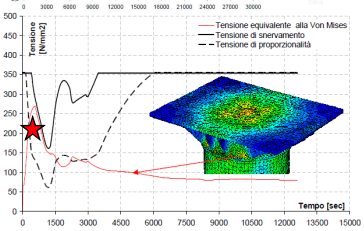
Applied Axial Load

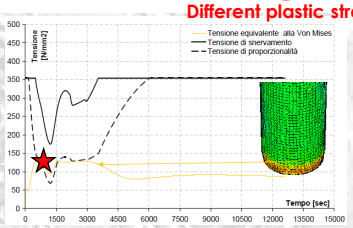


Different constitutive laws for steel at high temperature



Different plastic strain





The differences of results are due to different constitutive laws.
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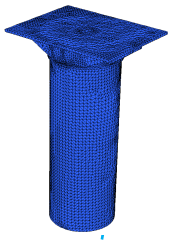
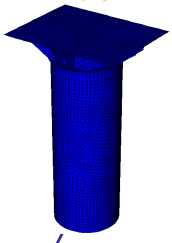
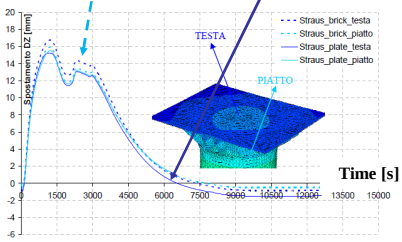
Influence of Different Finite Element : Strand7

Brick



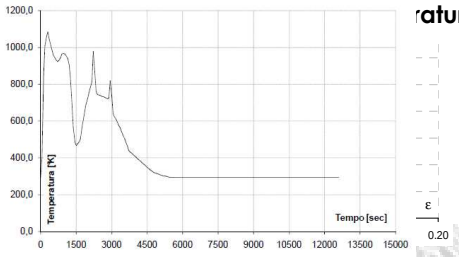
Plate

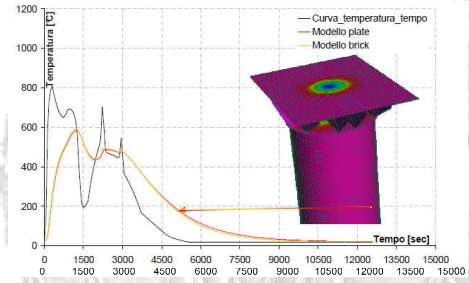




Fire curve Hasemi

Simplified constitutive law



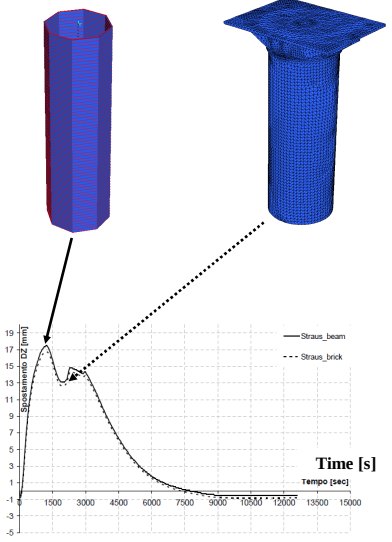


The plate model shows greater deformation due to local stress concentration

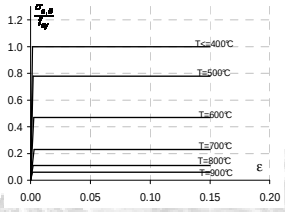
Influence of Different Finite Element : Strand7

Beam

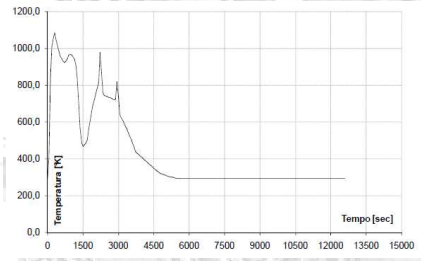
Brick



Simplified constitutive law for steel at high temperature



Fire curve Hasemi



The greater displacement shown by the beam model can be justified considering that in this model there aren't local plastic strain.

Conclusions

- **Influence of a simplified constitutive law for steel in case of fire**
  - Good evaluation of structural collapse
  - Different stress distribution in the member
  - Different evaluation of strain field and residual displacements
- **Modeling using 1-dimensional (BEAM) element**
  - Ignore local buckling phenomenon (column)
  - Ignore local crisis phenomenon
  - Ignore local stress concentration (capital)
- **Modeling using 2-dimensional (PLATE) element**
  - Thermal analysis consistent with 3D model
  - Excessive stress concentrations
- **Modeling using 3-dimensional (BRICK) element**
  - Correct thermal analysis
  - Evaluation of stress concentrations and local buckling phenomenon

Thanks for your attention