University of Ljubljana
Faculty of Civil and Geodetic Engineering

cost

The University Of Sheffield.

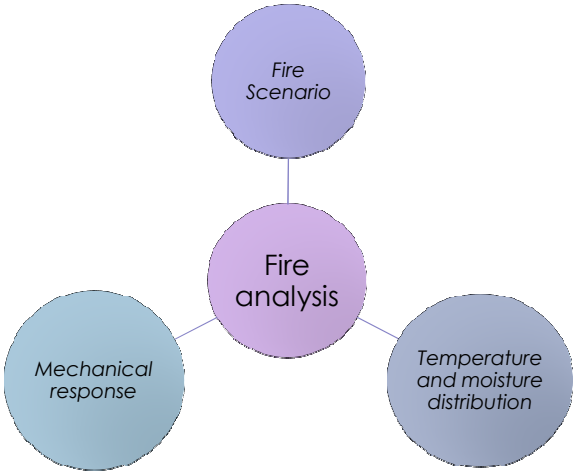
BENCHMARK STUDIES FOR STEEL BEAMS, STEEL FRAMES AND COMPOSITE STEEL BEAMS

Authors: Robert Pečenko, Tomaž Hozjan, Ian Burgess

Work

- Fire analysis of simply supported steel and composite steel-concrete elements:
  - simply supported steel beam
  - fully restrained steel beam
  - steel frame
  - simply supported composite steel-concrete beam
- Different software:
  - *Vulcan* (University of Sheffield)
  - *Fire, CompositeFire, HeatMoisture* (University of Ljubljana)

Fire analysis



HeatMoisture

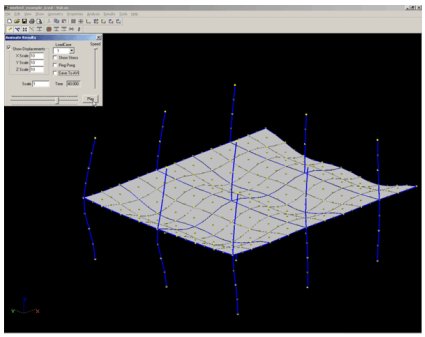
- Temperature and moisture analysis of a composite beam
- Mathematical model proposed by Davie et. al. is used.
- Basic assumptions of the used model:
  - There is thermal equilibrium between all phases within an infinitesimal volume.
  - Water vapour, air and their gaseous mixture behave as ideal gases.
  - There is no diffusion of bound water. It diffuses and evaporates only after it is released as free water.
  - Amount of free water is determined with the help of sorption curves.
- Primary unknowns: temperature T, pore pressure P_G, water vapour content ρ_V.
- Finite element formulation in Matlab environment

Fire and CompositeFire

- Reissner's geometrically exact beam theory.
- Shear strains are neglected.
- Stress-strain state is determined iteratively, where the calculation time is divided into time intervals $[t^{i-1},t^{i}]$
- The element is subjected to a conservative, time independent load, and a time-dependent growth of temperature.
- Additive decomposition of the increment of geometric strain on the increment of elastic, plastic, temperature, transient and creep strain
- FEM in Matlab environment

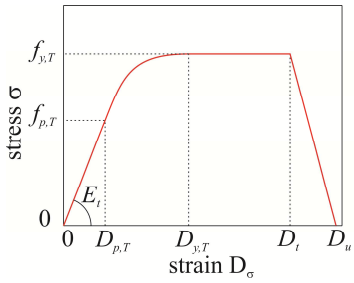
Vulcan

- Three-dimensional frame analysis program → behaviour of skeletal steel and composite frames under fire conditions
- Geometric and material non-linearities are included



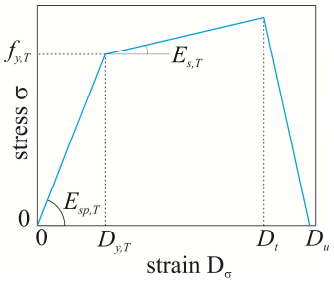
Stress-strain relationship

- EN 1993-1-2



creep implicitly included

- Bilinear (Srpčič,1991)



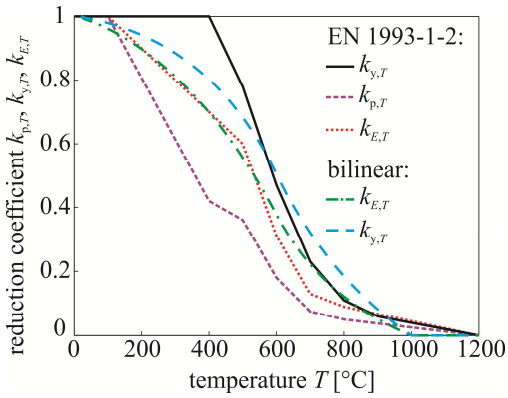
+explicitly creep of steel (Williams-Leir 1983):

$$\Delta\varepsilon_{cr,s} = sign(\sigma_s)\cdot b_1 \cdot \coth^2\left(b_2 \cdot \left|\varepsilon_{cr,s}\right|\right)\cdot \Delta t$$

type of steel Austin50

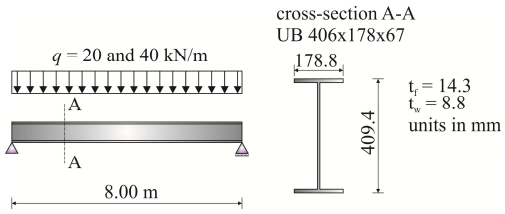
Stress-strain relationship

- Reduction factors



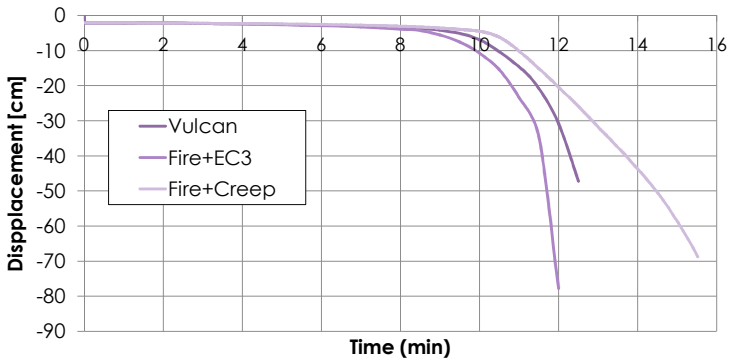
Simply supported steel beam

	Vulcan	Fire
Load	20 and 40 kN/m	
Fire scenario	BS476	
Temp. pattern	EN 1993-1-2 (2005)	
Modulus of elasticity	21000 kN/cm^2	
Strength of steel	S275	
Stress-strain	EC3	EC3 and Bilinear+Creep



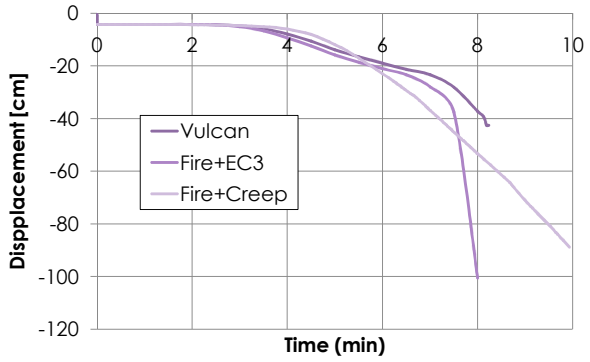
Simply supported steel beam

- Midspan displacement, Load 20 kN/m



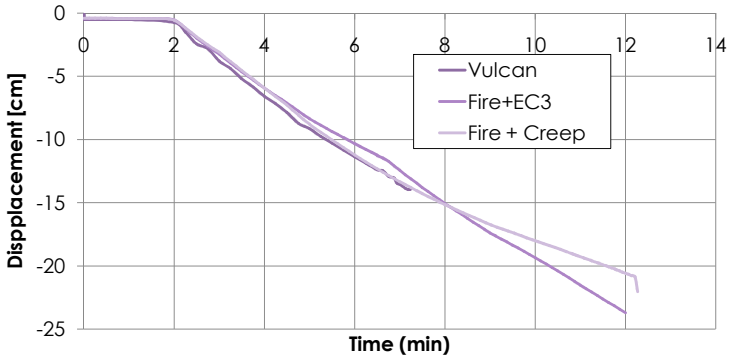
Simply supported steel beam

- Midspan displacement, Load 40 kN/m



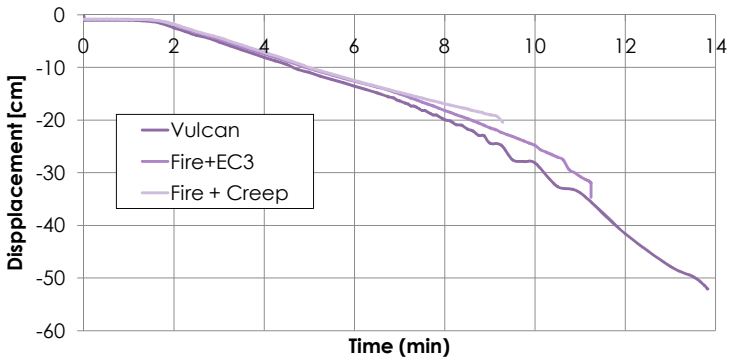
Fully restrained steel beam

- Midspan displacement, Load 20 kN/m



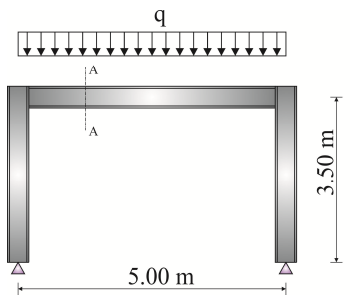
Fully restrained steel beam

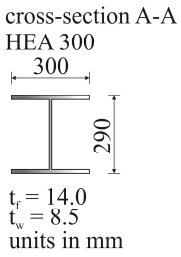
- Midspan displacement, Load 40 kN/m



Steel frame

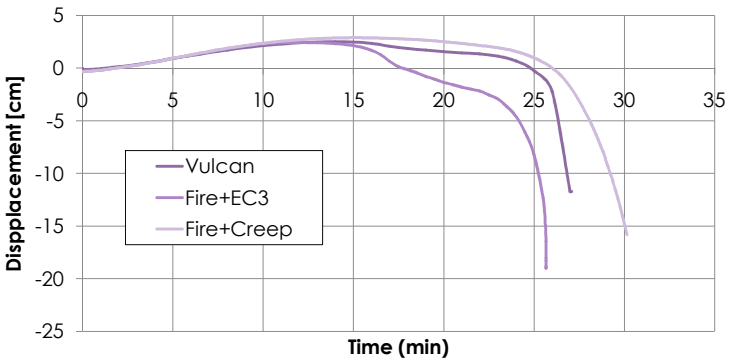
	Vulcan	Fire
Load	30 kN/m	
Temp. pattern	EN 1993-1-2 (2005)	
Modulus of elasticity	21000 kN/cm^2	
Strength of steel	S275	
Stress-strain	EC3	EC3 and Bilinear+Creep





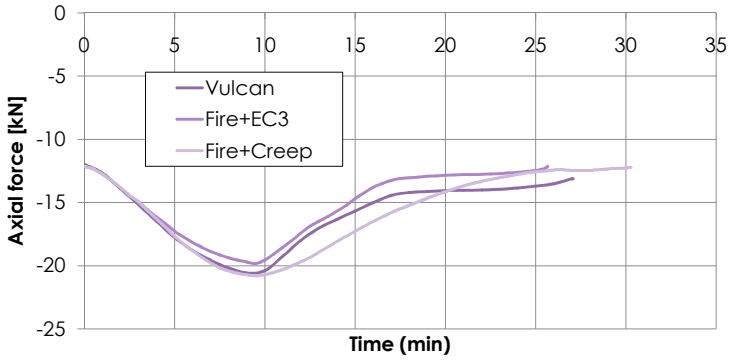
Steel frame

- Midspan displacement

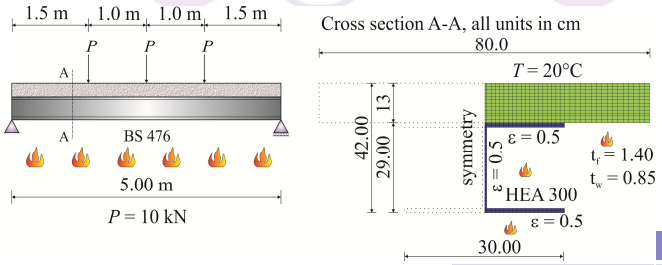


Steel frame

- Axial force in beam



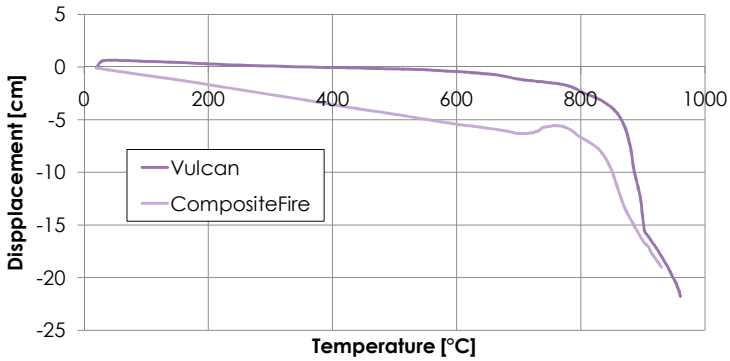
Composite concrete-steel beam



	Vulcan	CompositeFire
Load	3 × 10 kN	
Temp. pattern	EC3 –steel Bilinear model - concrete	HeatMoisture
E_S	21000 kN/cm²	
E_C	3300 kN/cm²	
Steel	S275	
Concrete	3.5 kN/cm²	
Stress-strain (steel)	EC3	
Shear connection	Rigid	

Composite concrete-steel beam

- Midspan displacement



Conclusions

- The comparison shows good agreement between the results, small deviation can be observed only in the vertical displacement of the composite beam.

Thank you for attention