2.13 Fire engineering in Switzerland – stability behaviour of steel structures in fire (short version)

Knobloch M., Switzerland

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

ibk Institute of Structural Engineering

Fire Engineering in Switzerland –
Stability behaviour of steel structures in fire

Markus Knobloch, Andrea Frangi, Jacqueline Pauli, Diego Somaini, Mario Fontana

ETH Zürich

Institute of Structural Engineering – Steel, Timber and Composite Structures

Presentation at COST Action TU0604 – Barcelona, July 6, 2010

1

Fire engineering in Switzerland

Fire test, Eduard Geilinger Werk Grüze, Winterthur 1947

Research reports of the Swiss Steel Society (1950 – 1962)

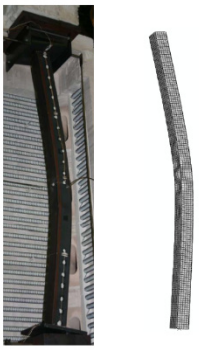
- Part 1: Basic principles (E.Geilinger, C.F. Kollbrunner), May 1950
- Part 2: Tests on claddings (E. Geilinger, W. Geilinger), July 1956
- Part 3: Fire tests of steel frames subjected to mechanical loading (C.F. Kollbrunner), February 1959
- Part 4: Fire safety of steel columns (W. Geilinger, S. Bryl), February 1962

Für Stahlbauten gelten folgende Kriterien

Gefahrenklasse	kg/m²	Stahlkonstruktion	Versuchsdauer
1	unter 25	ungeschützt	Std.
2	25— 50	ungeschützt	½
3	50—100	leicht geschützt	1
4	100—150	stark geschützt	1½

2

Stability behaviour of steel members in fire



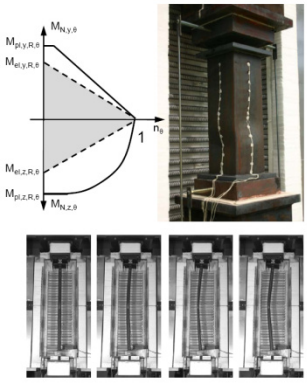
Buckling of SHS column at elevated temperature

Local buckling tests at elevated temperatures

- Structural behaviour of steel members is more complex in fire
  - large deflections
  - nonlinear material behaviour
  - thermal strains and stresses

3

Member buckling under fire conditions



- Structural resistance is limited by 3 limit states (and their interaction)
  - Full section yielding considering axial compression – bending moment interaction (limit state 1)
  - Local (and/or distorsional) buckling (limit state 2)
  - Overall structural stability (e.g. flexural and lateral-torsional buckling) (limit state 3)

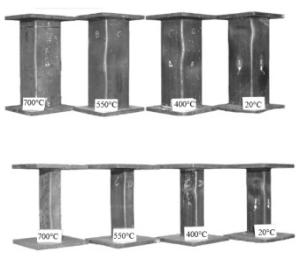
4

Cross-sectional capacity furnace tests

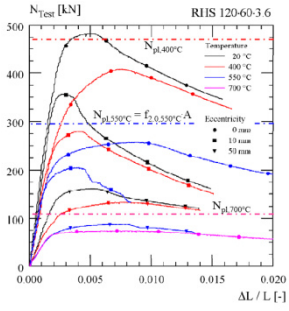
- Profiles
  - RHS 120·60·3.6
  - SHS 160·160·5
  - SHS 100·100·4
  - SHS 200·200·5
  - HEA 100
- Nominal eccentricities
  - 0, 10, 50 mm
- Temperatures
  - 20°C, 400°C, 550°C, 700°C
- Strain rates
  - 0.10, 0.02, 0.01 %/min

5

Cross-sectional capacity furnace tests – Test results



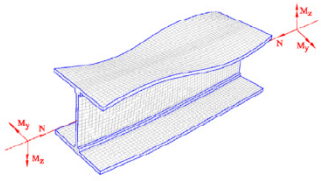
Cross-sectional capacity test specimens



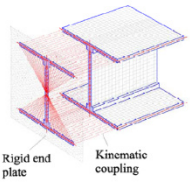
Load-end shortening curves as a function of steel temperature and load eccentricity

6

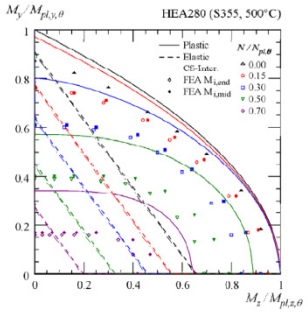
Numerical parametric study



Deformed shape and loading of the specimens



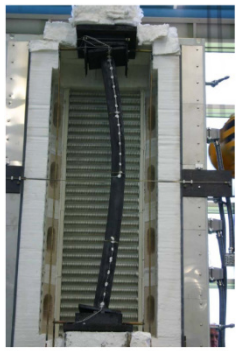
End conditions used for the numerical study



N-M-interaction curves for cross-sectional capacity at elevated temperatures

7

Buckling behaviour of steel beam-columns in fire



Buckling of a SHS section at elevated temperature

- Buckling behaviour in fire influenced by
  - decreasing stiffness of steel during heating
  - nonlinear stress-strain relationships
  - thermal strains and stresses
- Large strains are required to
  - reach yield strength
  - activate an increase in cross-sectional capacity due to plastification
- Resistance of beam-columns is usually reached for smaller strains
  - buckling resistance cannot take benefit of the strain hardening
  - buckling curves try to implicitly consider these effects
- Simplified methods are adopted from ambient temperature design

8

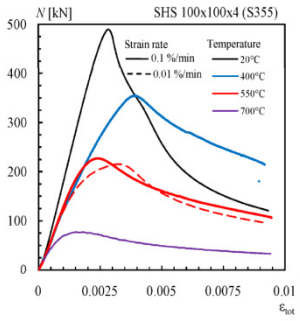
Slender beam-column tests at elevated temperatures

Slender column test at elevated temperature (SHS 100x100x4)

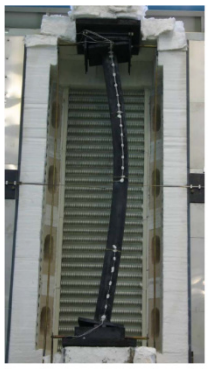
- Slender columns
  - Simply supported
  - Free thermal elongation during heating
  - Centric and eccentric axial compression
  - Buckling about one major axis
- Uniform steel temperature
  - Steady-state conditions
  - 20°C, 400°C, 550°C, 700°C
- Cross-sections
  - RHS 120x60x3.6
  - SHS 100x100x4
  - SHS 160x160x5
  - HEA 100
- Strain rate
  - 0.1 %/min
  - 0.01 %/min
  - 0.02 %/min

9

Slender column tests at elevated temperatures



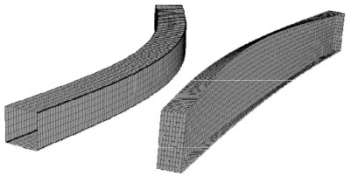
Axial load-end shortening behaviour of slender columns at elevated temperatures

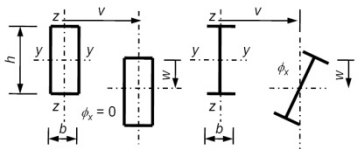


Test specimen after furnace test

10

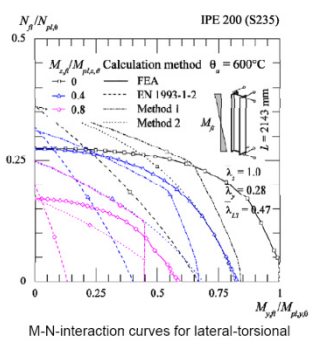
Numerical parametric study





Members not susceptible to torsional deformations

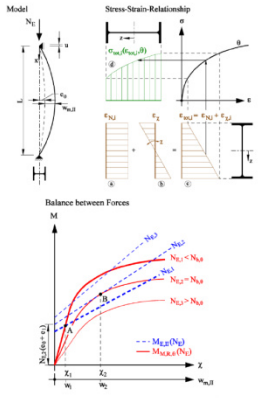
Members susceptible to torsional deformations

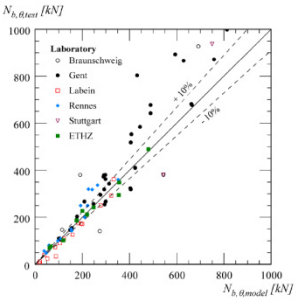


M-N-interaction curves for lateral-torsional buckling of an I section according to numerical results and European calculation models

11

Analytical model for beam-columns in fire





Full scale column tests compared with results of the simplified analytical model

12