2.15 Computer simulations of structures in fire - feasibility, verification and validation

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COST Action TU0904
Integrated Fire Engineering and Response

Working Group 2 - Structural Safety
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Computer simulations of structures in fire

feasibility, verification and validation

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Terminology

computer simulations, modeling and simulation, numerical analysis

Computational Science and Engineering (CS&E)
Computational Engineering and Physics (CE&P)

structural analysis	multiphysics	CFD
FEM	*ALE*	*FVM*
Finite Element Analysis	*Arbitrary Lagrangian-Eulerian*	*Finite Volume Method* *Fire Dynamics Simulator (FDS)*

for Structural Fire Engineering

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Computer Simulations in Structural Fire Engineering

Research methods:
- experimental
- analytical – design oriented
- numerical analysis

Challenges:
- nonlinearities *(geometrical, material, BC, loading, interactions)*
- uncertainties and measurements *(BC, temperature distributions)*
- repeatability *(sensitivity on parameter variation)*
- multiphysics *(thermo-hydro-mechanical interactions in concrete)*

Numerical analysis – objectives:
- addendum of experiments
- virtual testing
- parametric study

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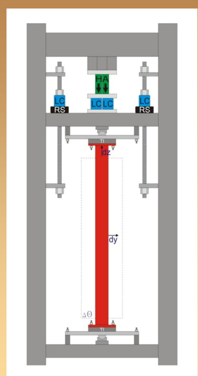
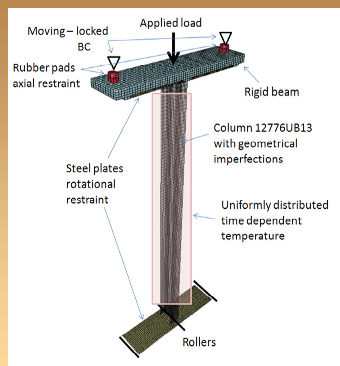
Example 1:
Virtual tests on axially and rotationally restrained steel columns under fire





Ali F., O'Connor D. 2001. Structural performance of rotationally restrained steel columns in fire, *Fire Safety Journal* 36.

L. Kwaśniewski, P. A. Król, K. Łącki 2010. Virtual tests on axially and rotationally restrained steel columns under fire, *Journal of Structural Fire Engineering, submitted for publication.*

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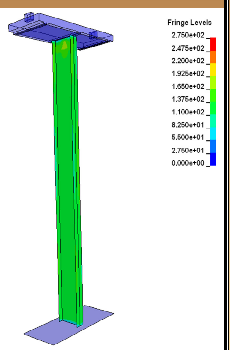
Example 1:
Virtual tests on axially and rotationally restrained steel columns under fire

Time history of axial force applied and generated by axial restraint .



Contours of effective Mises stress in buckled column.

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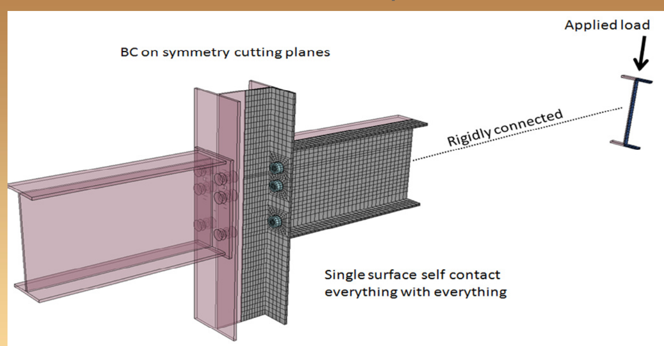
Example 2:
Beam to column connection at elevated temperatures



Detailed 3D FE model of a quarter of beam to column connection
Kwasniewski L. (2007) Numerical analysis of beam to column connection at elevated temperatures, *Proceedings of Workshop COST Action C26: Urban Habitat Constructions Under Catastrophic Events*, Prague, Czech Republic, March 30 - 31, 2007, pp. 59-63

Based on experimental work:
Al-Jabria, K.S. Seibib, A. & Karrechc, A. 2006. Modelling of unstiffened flush end-plate bolted connections in fire. *Journal of Constructional Steel Research. 62: 151–159.*

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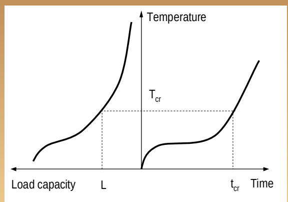
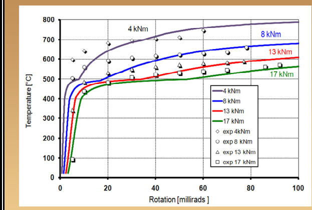
Example 2:
Beam to column connection at elevated temperatures

Possible test scenarios:

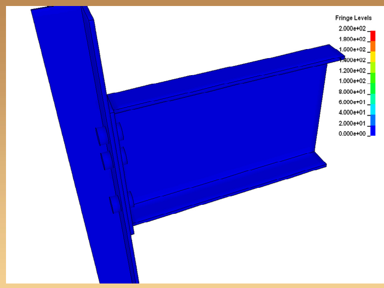
- 1st scenario: increasing static loading in constant elevated temperature - critical loading for selected temperatures.
- 2nd scenario: the structure is analyzed under constant loading but at increasing temperature - critical temperature and time.
- 3rd scenario:, e.g. following experiment, both temperature and loading are time depended. Loading due to thermal elongation.



Example 2:
Beam to column connection at elevated temperatures

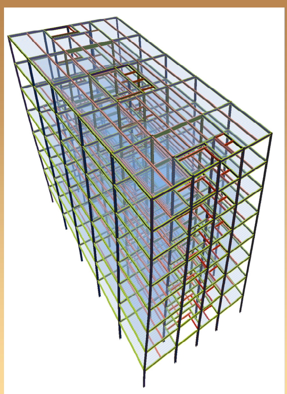


Rotation versus temperature for constant moments. Comparison with experiment according to Al-Jabria, Seibib & Karrechc (2006).



Contours of effective Mises stress for constant loading with moment M=17 kNm and increasing temperature.

Progressive collapse caused by local fires

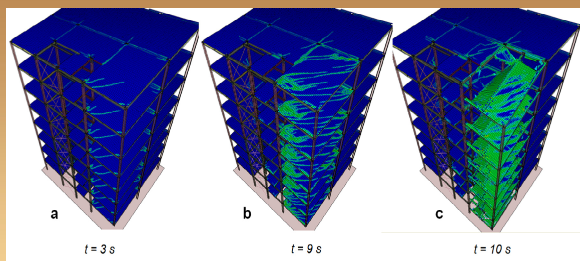


BRE. Cardington steel frame building.

http://www.mace.manchester.ac.uk/project/research/structures/strucfire/DataBase/TestData/default1.htm

Global analysis

threat independent approach - notional column removal

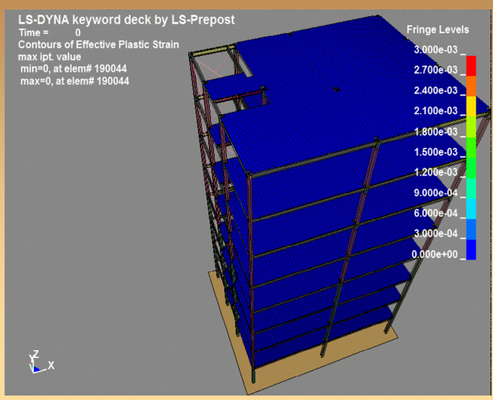


Multistory building (Cardington Large Building Test Facility)
Explicit transient dynamic analysis
Sheel elements – local effects
3D models of beams and columns
Global model
LS-DYNA

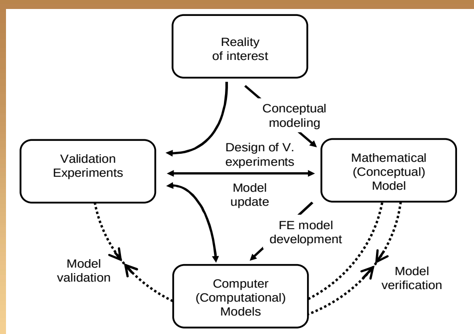
Massive parallel processing

High Performance Computing (HPC) @ FSU

TRACC at Argonne National Laboratory (ANL)



Modeling, verification and validation



„Essentially, all models are wrong, but some are useful''

Box G.E.P., Draper N.R. (1987) Empirical model-building and response surfaces, *John Wiley & Sons*., pp. 669