COST Action C26:
“Urban Habitat Constructions Under Catastrophic Events”

SYMPOSIUM ON
“URBAN HABITAT CONSTRUCTION UNDER CATASTROPHIC EVENTS”

BENCHMARKS TO GLOBAL ANALYSIS (IN FIRE)

L. Kwasniewski (PL), M. Gillie (UK), I. Burgess (UK), J.M. Franssen (BE),
S. Datoussaïd (BE), Y. Wang (UK)

Malta, 23-25 October 2008

Scope

- Global modeling
- Predictive capability of numerical modeling
- Verification and Validation V&V – general concepts
- Verification – code developer’s and analyst's perspective
- Validation – domain, hierarchy, metrics, uncertainties, calibration sensitivity study
- Databases of benchmark problems
- Test data for (global) analysis of structures in fire
- Papers on global modeling - numerical analysis vs. experimental data

Global modeling

Global Analysis (in Fire) (of complex systems)

↓

Computational Science and Engineering (CS&E)

Computational Engineering and Physics (CE&P)

(numerical, computational, computerized, computer -

- modeling, simulation)

↓

Finite Element Analysis (FEA)

Predictive capability of numerical modeling

How should confidence in modeling and simulation be critically assessed?

- "Essentially, all models are wrong, but some are useful“ - George Box

  Box, George E. P.; Norman R. Draper (1987). Empirical Model-Building and Response Surfaces, p. 424, Wiley.

- “…for many years the Journal of Applied Mechanics shunned papers on the finite element method because it was considered of no scientific substance.

  Belytschko T., Liu W. K., Moran B., "Nonlinear Finite Elements for Continua and Structures", John Wiley & Sons, LTD, Chichester, England, 2000.

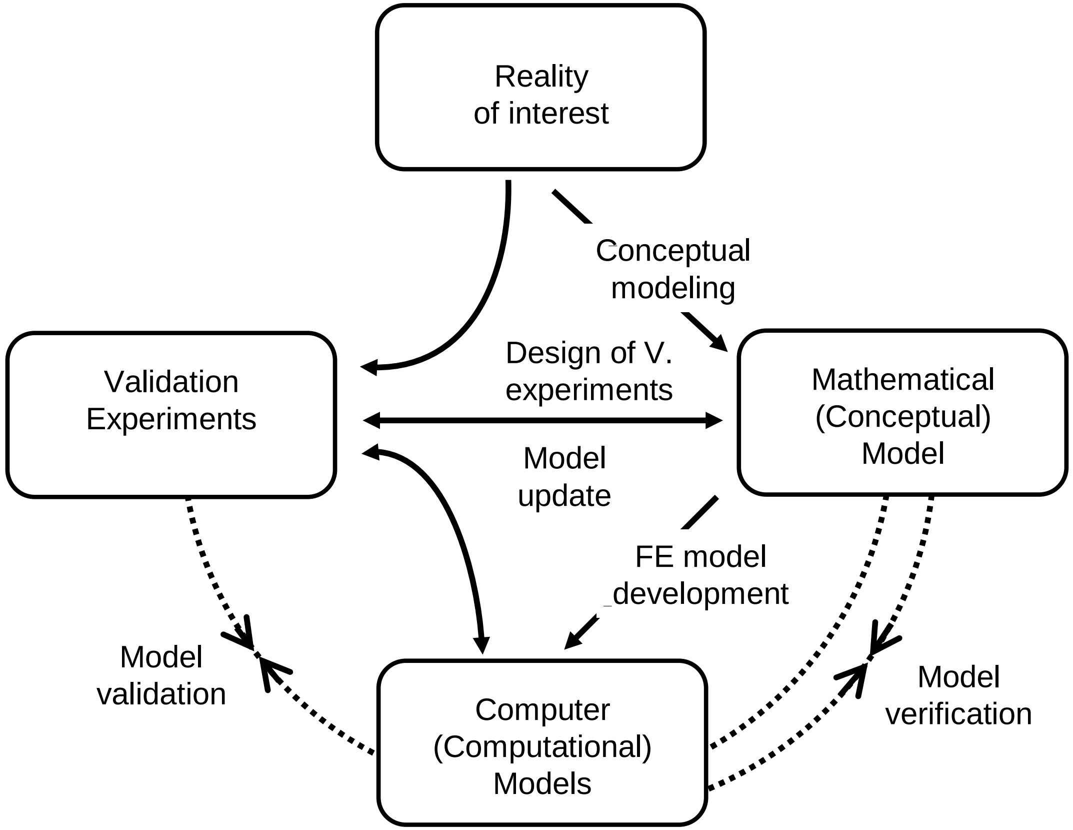
- Barriers to computability - smoothness and stability of the response, uncertainties, coupled physics, ...

  Belytschko T., Mish K., "Computability in nonlinear solid mechanics", http://www.tam.northwestern.edu/tb/computability_w_figs.pdf

Verification and Validation V&V

- "Verification deals with mathematics; validation deals with physics."

Roache, P.J. (1998) Verification and Validation in Computational Science and Engineering, Hermosa Publishers, Albuquerque, NM.

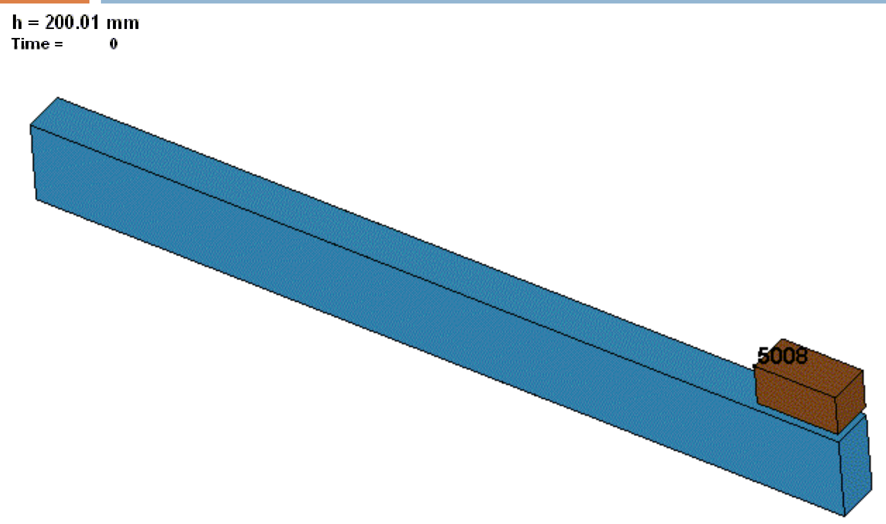


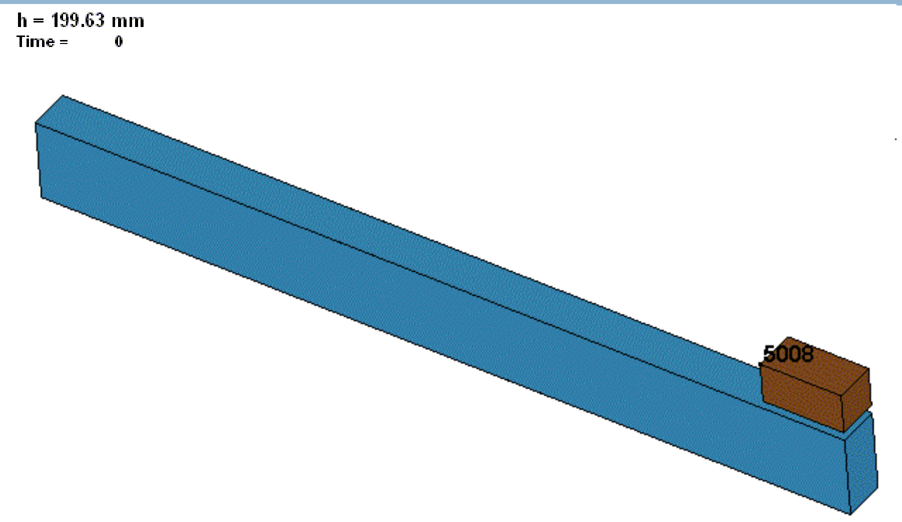
Modeling, verification and validation

Verification

- Comparison with benchmark solutions (analytical or numerical)
- Code and solution verification
- Code developer's perspective - software quality assurance (SQA), method of manufactured solutions
- Analyst's perspective:
- Posteriori numerical error estimation e.g. Richardson's extrapolation
- Check of conservation of mass, momentum, and energy
- Comparison between different solution options and different software
- Sensitivity study

Verification

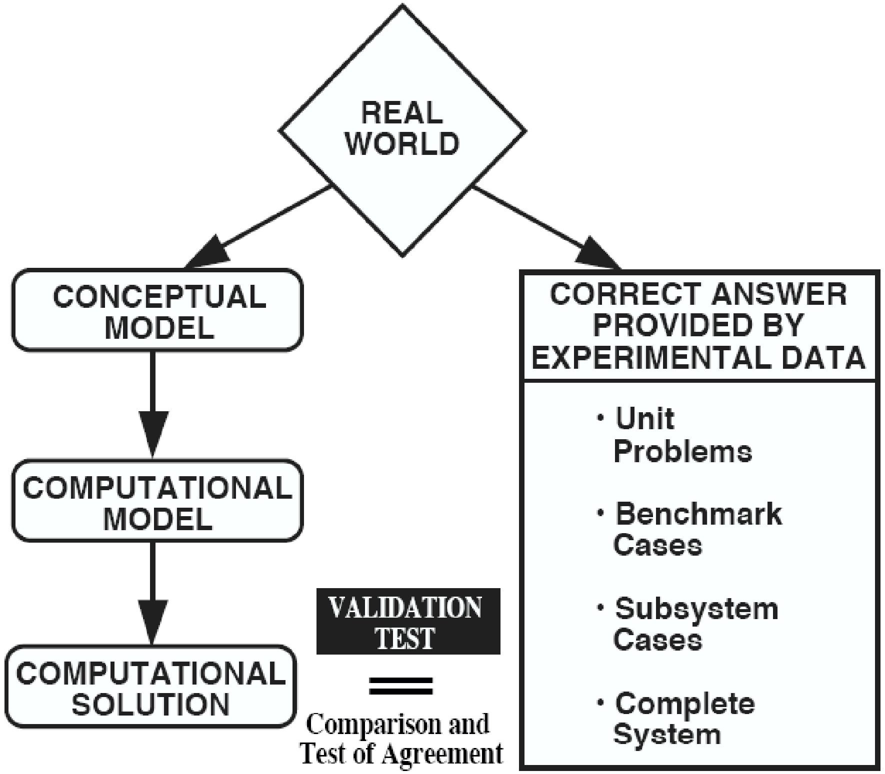




Example of on-off process – Δh = 0.38 mm (0.19%)

Verification task – identification of „sensitive” model parameters

Validation



AIAA. Guide for the Verification and Validation of Computational Fluid Dynamics Simulations, American Institute of Aeronautics and Astronautics, AIAA-G-077-1998, Reston, VA, 1998.

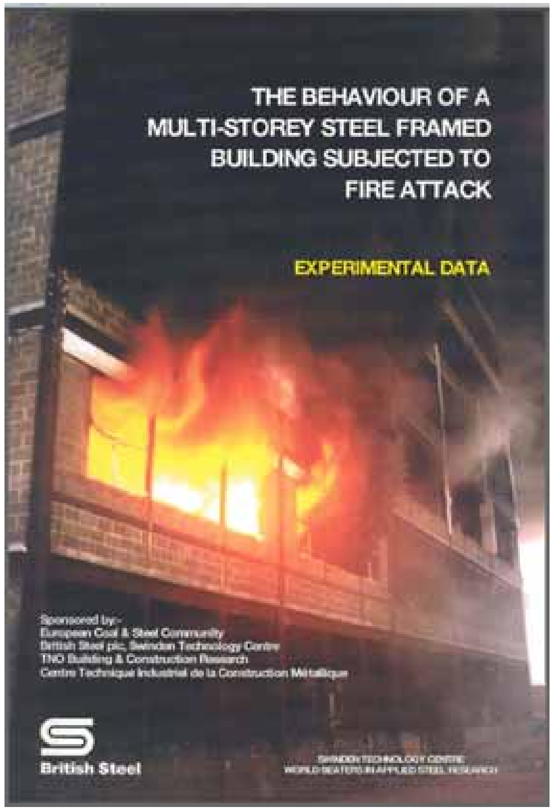
- Application and validation domains
- Validation hierarchy
- Validation experiments
- How to compare – validation metrics, selection of system response quantity (SRQ) significant
- Uncertainties and calibration, sensitivity study,
- Nondeterministic simulations

Databases of benchmark problems

- National Agency for Finite Element Methods and Standards (NAFEMS)
  ~ 280 verification benchmarks (thermal analysis-14, thermal stress analysis-8)
- ABAQUS (v6.6)
  Benchmarks Manual – 264 (93-NAFEMS, 15-thermal analysis)
  Verification Manual, Example Problems Manual
- ANSYS® - around 250 problems
- SAFIR – significant amount of evidence presented in publications
- VULCAN, Fluent, ...

http://www.mace.manchester.ac.uk/project/research/structures/strucfire/default.htm

Test data for (global) analysis of structures in fire



Cardington Fire Test - 1998

The Behaviour of a Multi-storey Steel Framed Building Subjected to Fire Attack
8-storey steel framed building

Experimental Data:
Two BRE (Building Research Establishment) large-scale fire tests: the Corner test and the Large compartment test

Four fire tests conducted by British Steel

Papers on global modeling – numerical analysis vs. experimental data

S. Foster, M. Chladná, C. Hsieh, I. Burgess, R. Plank, **Thermal and structural behaviour of a full-scale composite building subject to a severe compartment fire,** *Fire Safety Journal*, *Volume 42, Issue 3*, *April 2007*, *Pages 183-199*

S. Lamont, B. Lane, G. Flint and A. Usmani, **Behavior of structures in fire and real design--a case study,** *Journal of Fire Protection Engineering 16.1, Feb 2006, pp.5-35*

T. Lennon, **Integrity of Compartmentation in Buildings During a Fire**, 30thSeptember 2004, BRE, Garston

B. Zhao , J. Kruppa, **Structural behaviour of an open car park under real fire scenarios,** *Fire and Materials, 2004, 28, pp.269–280.*

J. Y. Richard Liew, and K. Y. Ma, **Advanced analysis of 3D steel framework exposed to compartment fire,** *Fire and Materials, 2004; 28:253–267*

P. J. Moss, G. C. Clifton, **Modelling of the Cardington LBTF steel frame building fire tests,** *Fire and Materials, 2004; 28:177–198*

T. Lennon, D. Moore, **The natural fire safety concept—full-scale tests at Cardington**
Fire Safety Journal, *Volume 38, Issue 7*, *November 2003*, *Pages 623-643*

Papers on global modeling – numerical analysis vs. experimental data

A. Y. Elghazouli, B. A. Izzuddin, A. J. Richardson, **Numerical modelling of the structural fire behaviour of composite buildings,** *Fire Safety Journal*, *Volume 35, Issue 4*, *November 2000*, *Pages 279-297*

Y. C. Wang, **An analysis of the global structural behaviour of the Cardington steel-framed building during the two BRE fire tests**, *Engineering Structures*, *Volume 22, Issue 5*, *May 2000*, *Pages 401-412*

A. D. Pintea & J.-M. Franssen, **Evaluation of the thermal part of the code SAFIR by comparison with the code TASEF,** *Proc. 8th Int. Conf. on Steel Structures, Vol. 2, M. Ivan ed., MIRTON, Timisoara, (1997),* 636-643,

J. M. Franssen, G. M. E. Cooke, D. J. Latham, **Numerical simulation of a full scale fire test on a loaded steel framework,** *Journal of Constructional Steel Research*, *Volume 35, Issue 3*, *1995*, *Pages 377-408*

J.-M. Franssen, J.-B. Schleich, L.-G. Cajot, D. Talamona, B. Zhao, L. Twilt and K. Both, **A comparison between five structural fire codes applied to steel elements**, Fourth International Symposium on Fire Safety Science, Ottawa, 1994, 1125-1136

Z. Sokol, F. Wald, M. Pultar, M. Benes, **Numerical Simulation of Cardington Fire Test On Structural Integrity,** ……

Thank you for your attention