Global Structural Modelling in Fire

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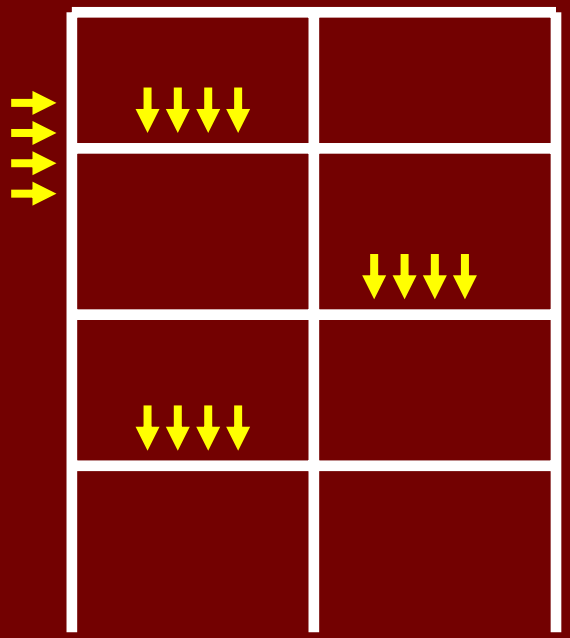
Introduction

- The need for global modelling
- Development and Examples
- Current problems
- Benchmarks for
  - Good practice
  - Code validation

Global Modelling in Fire

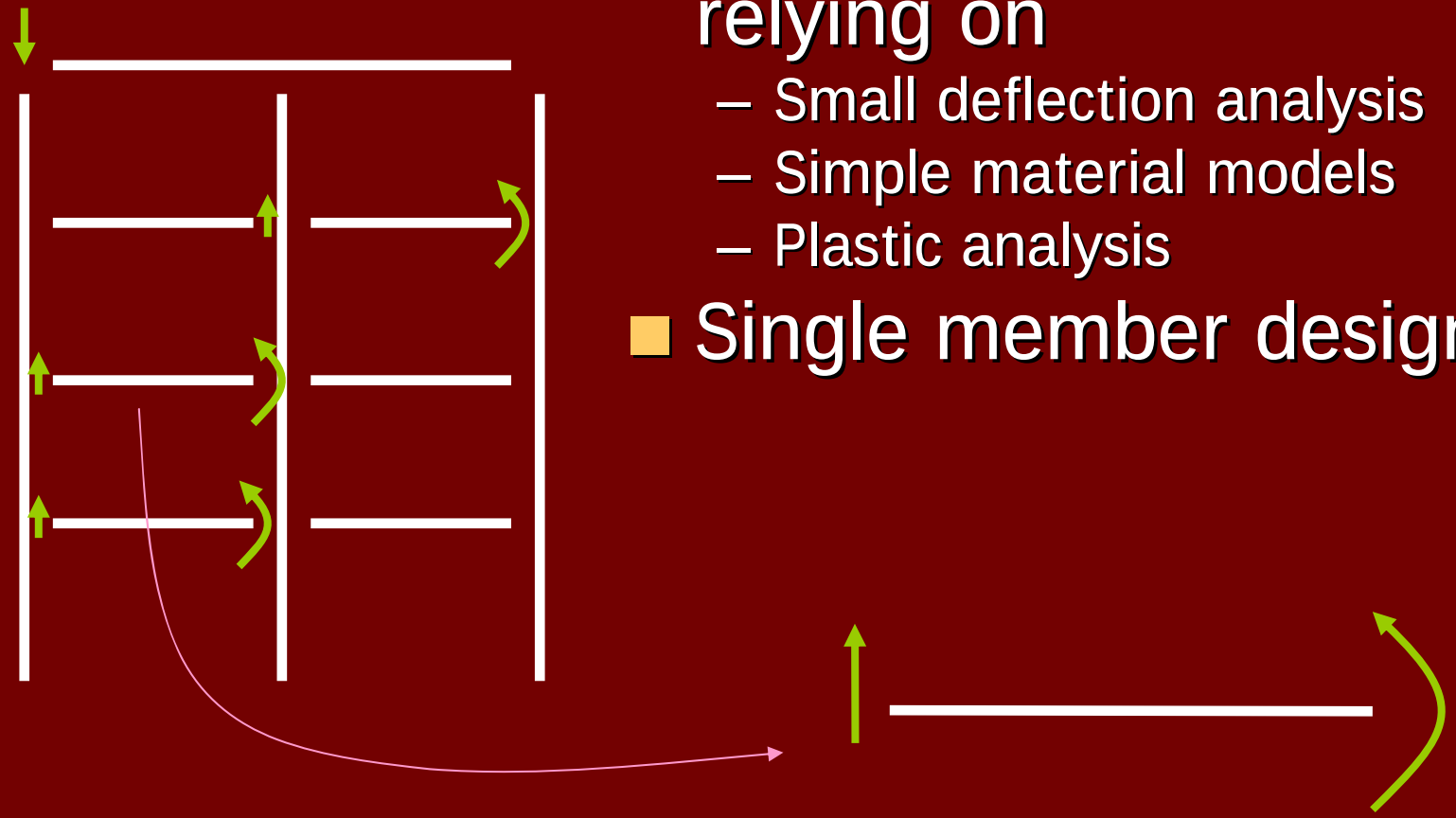
- Modelling whole structure
- Not isolating single elements
- Not focussing on local buckling, connections, cracking etc.

At ambient temperature



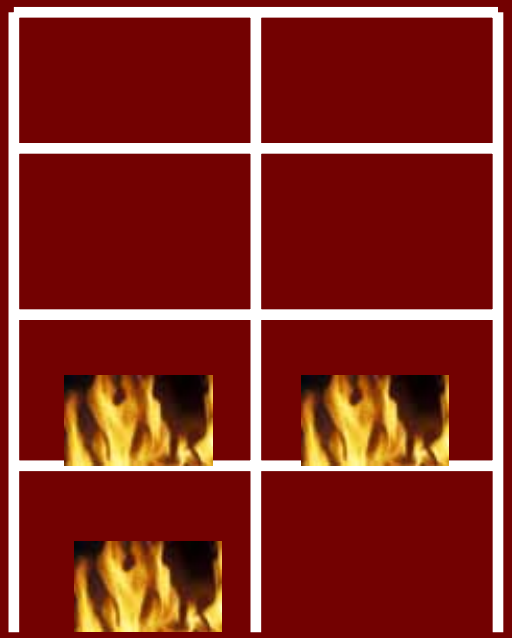
- Actions are forces
- Non-varying (even wind)
- Lead to constant stresses
- Strains/deflections small
  - Ensured by stiff materials...
  - ...and serviceability check
- Rigid-plastic material behaviour

...allows for



- Calculation of forces relying on
  - Small deflection analysis
  - Simple material models
  - Plastic analysis
- Single member design

At High Temperature

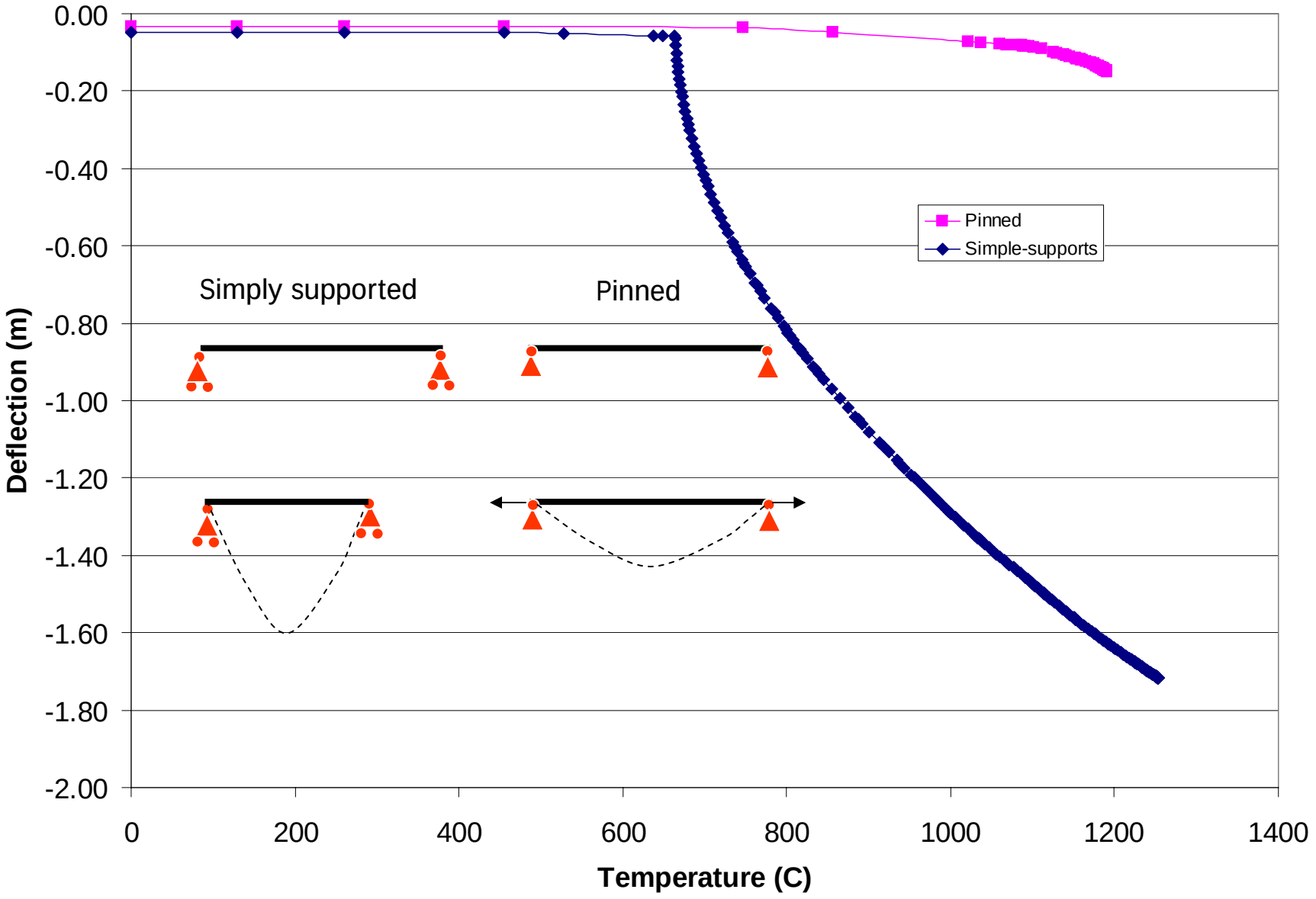


- Actions are temperatures (heat fluxes?)
- Varying
- Lead to varying stresses
  - (Unless determinate)
- Large strains/deflections small
  - Can be very large
  - Do not necessarily imply failure
- Non-linear material behaviour

this means

- Full temperature-time history of each part of the structure needed
  - Not possible by hand
  - Loading not montonic
  - Design not possible on member by member approach
- Global analyses

Simple Example



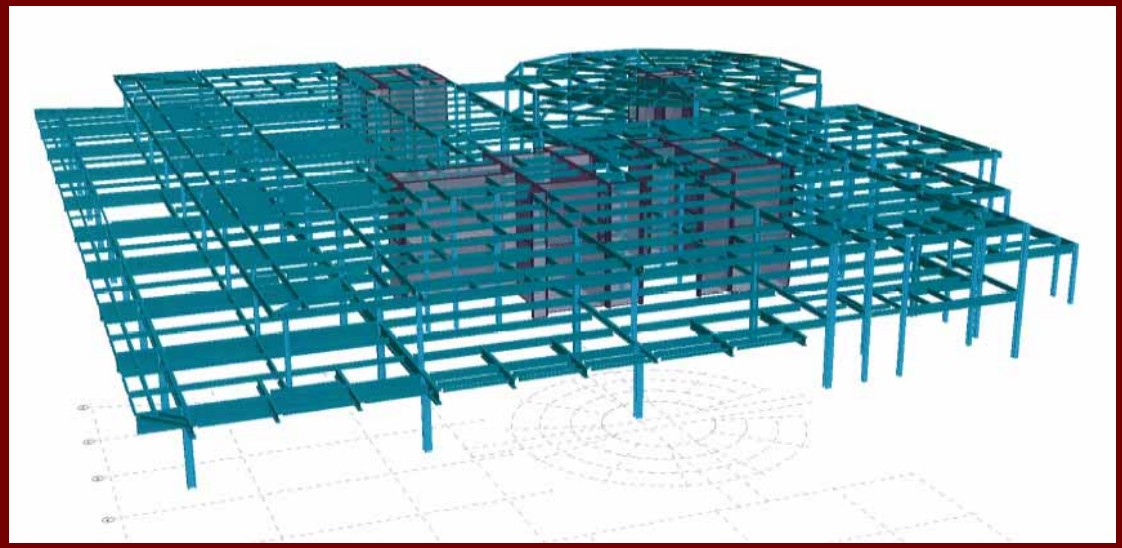
What's possible -Cardington

- Edinburgh
- Sheffield
- Imperial
- Manchester

Research leading to

- Very complex problem
- Importance of
  - Thermal expansion
  - Large deflections
  - Material behaviour
- Enhancement of codes

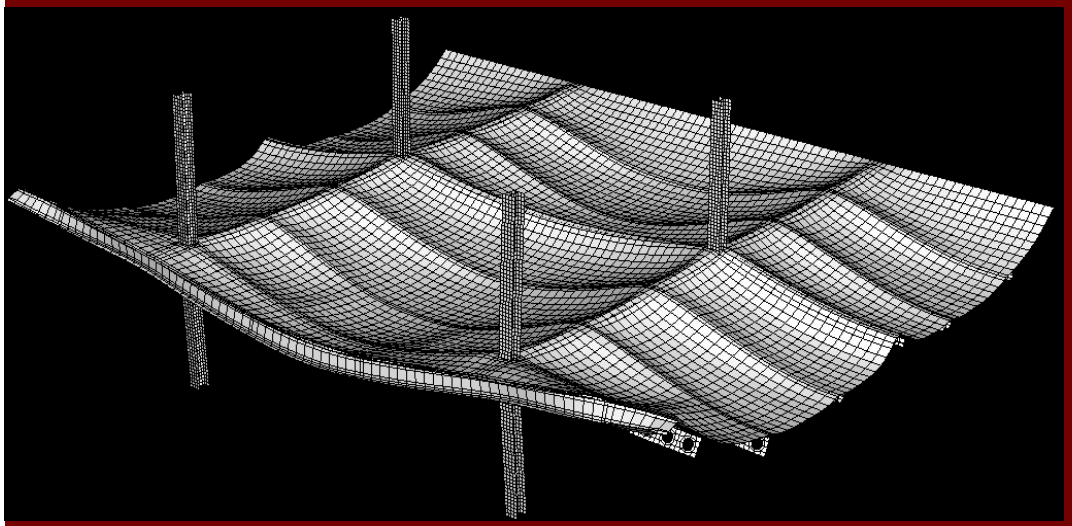
Commercial Use

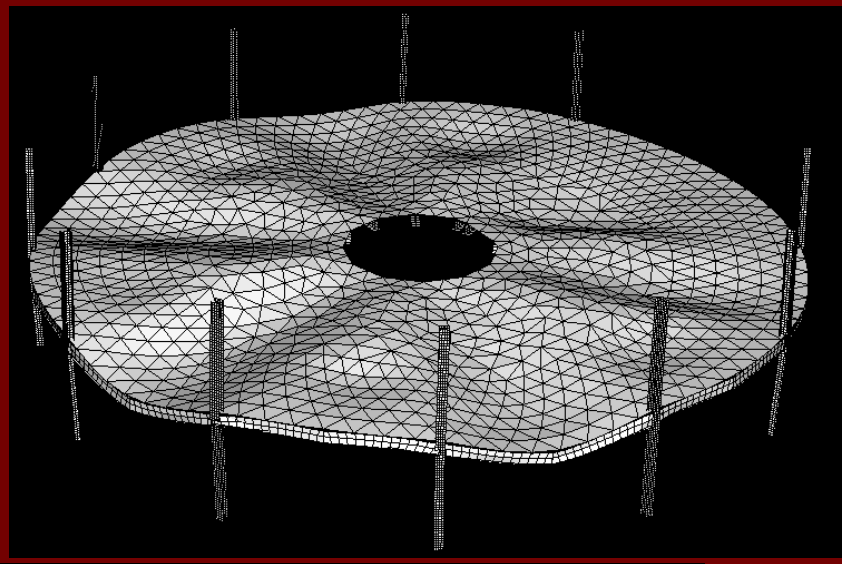


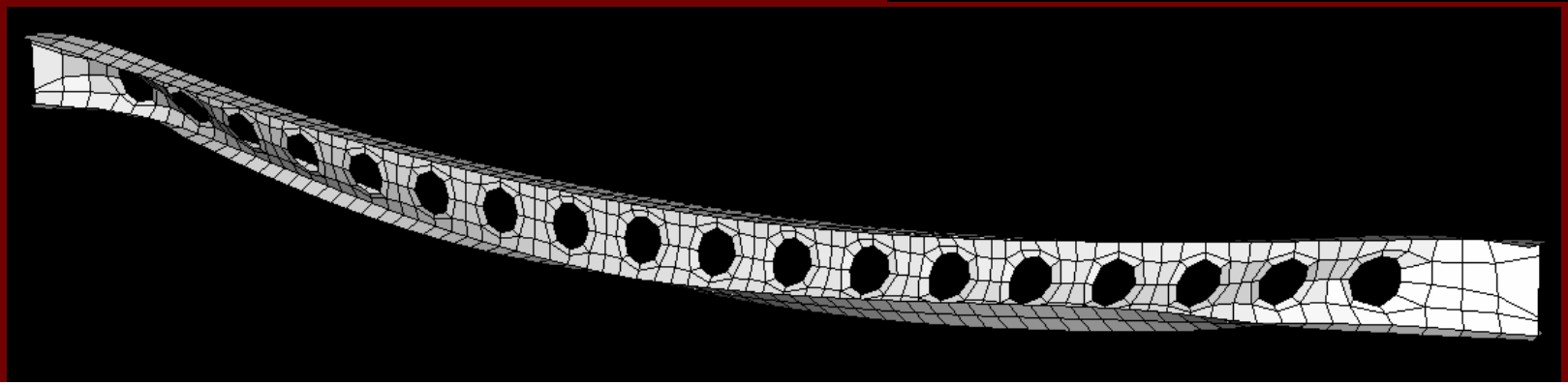
(images courtesy Arup Fire)

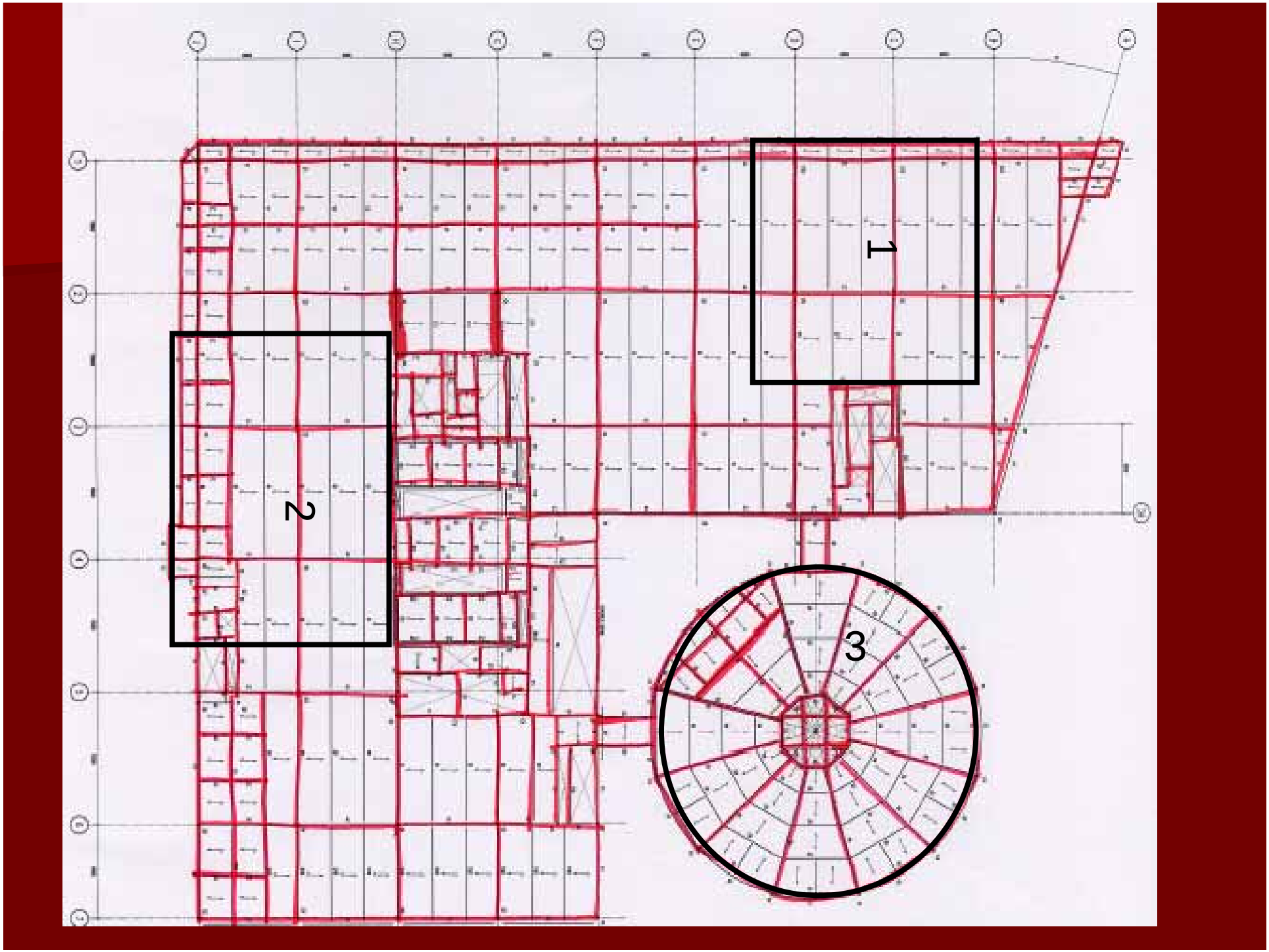
Finite Element Models

(images courtesy Arup Fire)





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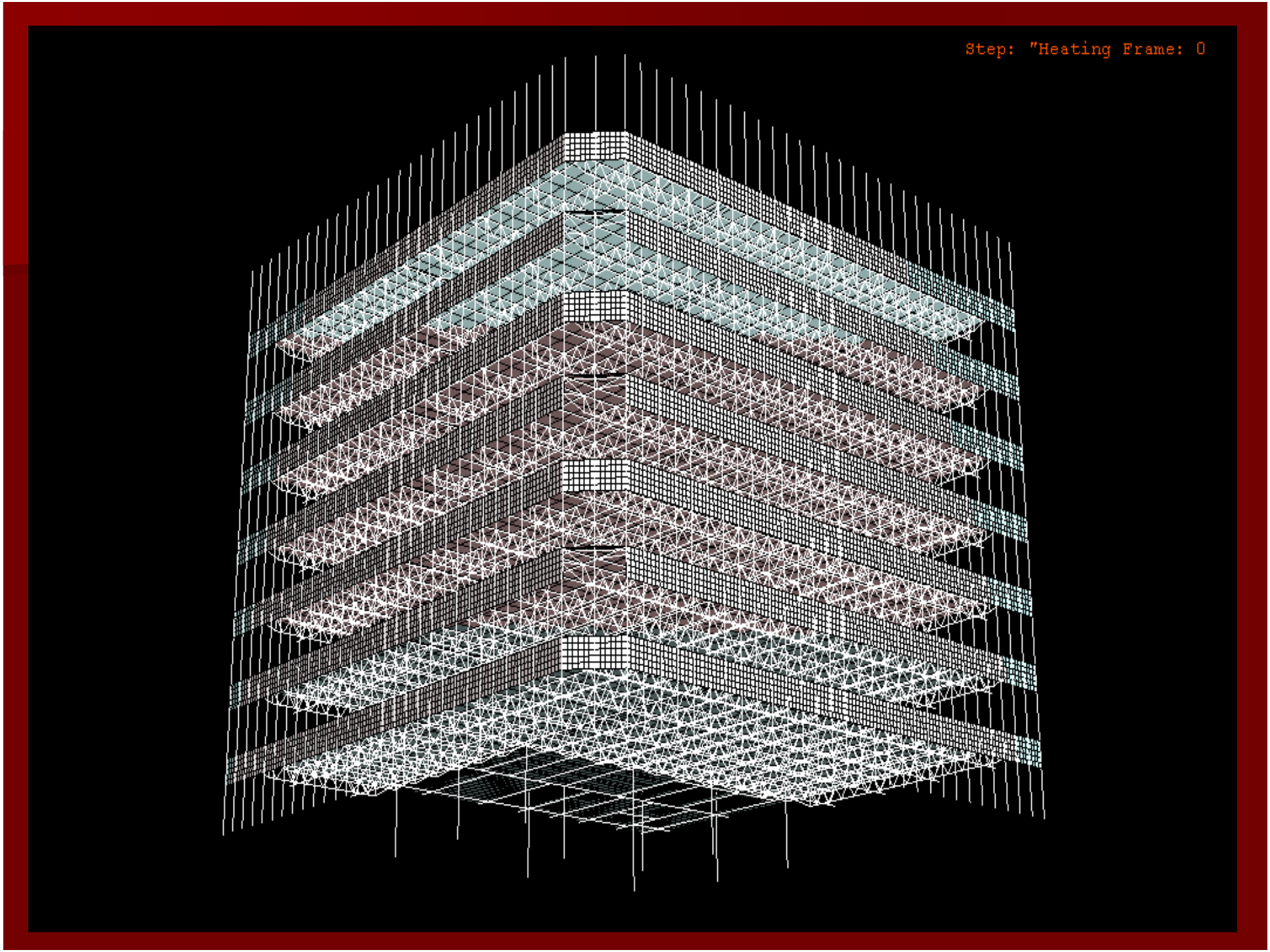
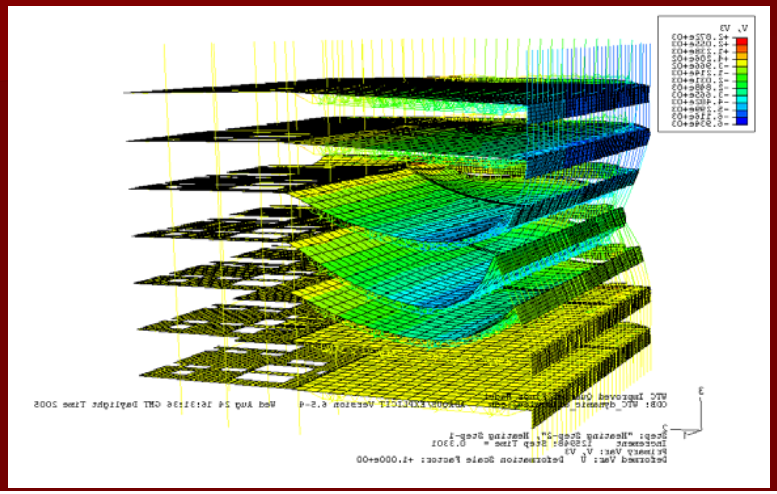
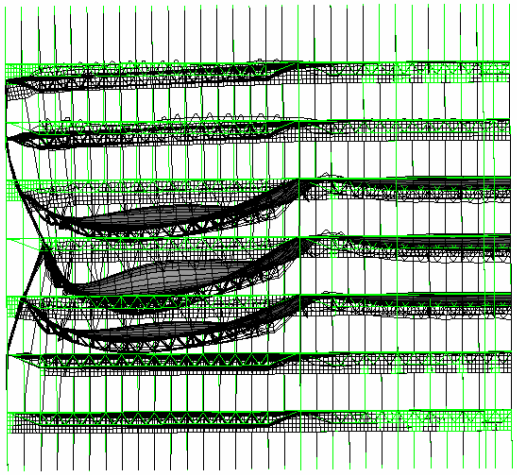
Fire Induced Collapse Analyses

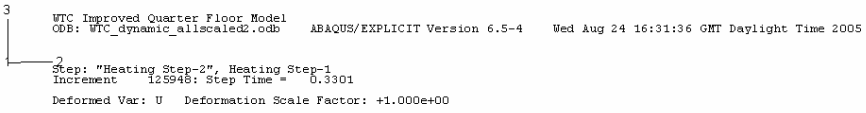
- WTC
- Dynamics important...
- Quasi-static analysis
  - Inertia forces not captured
  - Local instability can cause loss of convergence
- Dynamic explicit
  - Inertia forces captured
  - Local instabilities not longer problem
  - Conditionally stable

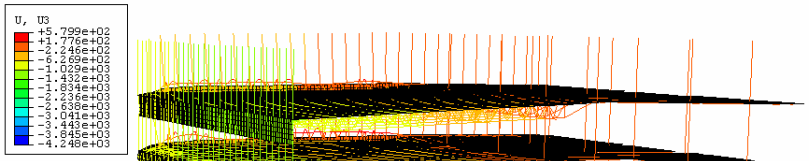

Step: "Heating Frame: 0

WTC Collapse









The Tools

- General / Commerical codes
  - Abaqus
  - Ansys
  - Others
- Pros
  - Fast
  - Reliable
  - Very general
  - Support
- Cons
  - (Very) expensive
  - Black-box

- Research Codes
  - Vulcan
  - Adaptic
  - Safir
  - Others
- Pros
  - Cheap
  - Access to source
  - Focussed on fire
- Cons
  - Struggle with large problems
  - Not support
  - Credibility

Current Limitations and Problems

- Concrete material behaviour (need test data)
- Connection behaviour
- Web openings
  - Test data
  - Model complexity
- Computer power (always true!)
- Cooling behaviour (in hand)

Benchmark Tests

- Demonstrate capability of codes...
- ...and users
- Beam
- Cardington?
- Must test
  - Large-displacements
  - Material
  - Boundary conditions
  - ??