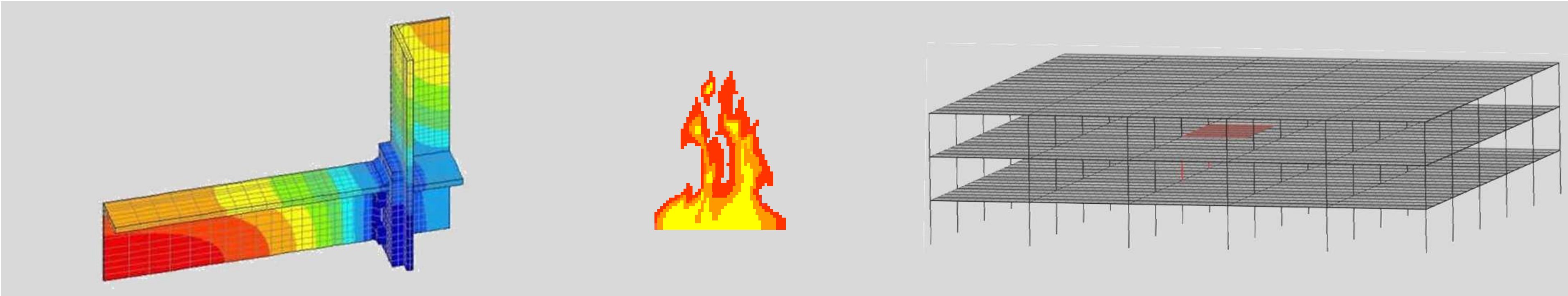
University of Liege – Fire Safety Engineering



SAFIR®

Capabilities and examples of applications

September 2015

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Description of SAFIR®

SAFIR is a **computer program** that models the **behavior of building structures subjected to fire**. The structure can be made of a 3D skeleton of linear elements such as **beams and columns**, in conjunction with planar elements such as **slabs and walls**. Volumetric elements can be used for analysis of details in the structure such as **connections**. Different materials such as **steel, concrete**, **timber**, **aluminum**, **gypsum** or thermally insulating products can be used separately or in combination in the model.

Process in a SAFIR analysis

1. The **thermal attack from the fire** is given as an **input data**
2. SAFIR computes the **evolution of temperature** in the sections
3. Then, SAFIR computes the **mechanical response** of the structure at elevated temperatures, taking into account the thermal elongations as well as the reduction of strength and stiffness in the materials

Capabilities

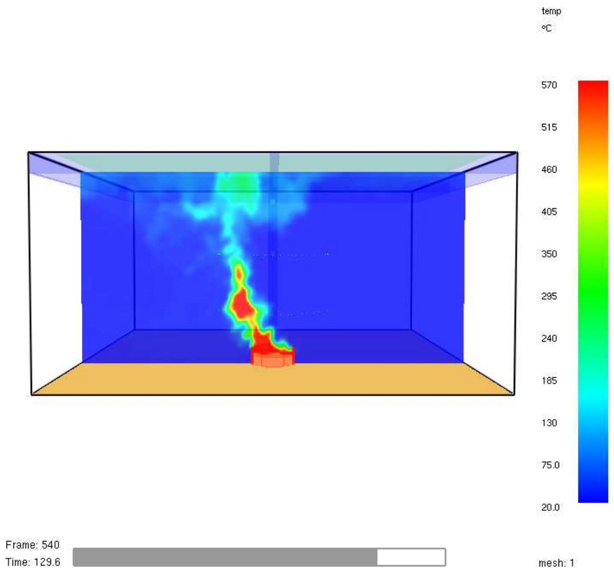
1. The thermal attack from the fire may be represented by:

   ✓ Temperature of the gas (standard fires are proposed, but the user can enter any time-temperature relationship)

   ✓ Thermal flux from a local fire to a beam or ceiling (Annex C of EN 1991-1-2)

   ✓ Thermal flux from a local fire to a column (RFCS project “LOCAFI”)

   ✓ Thermal flux from an FDS CFD calculation



Capabilities

2. Calculation of temperature distributions in structures subjected to fire

   ✓ 2D or 3D thermal calculations

   ✓ Finite elements: triangular, quadrangular, prismatic (6-8 nodes)

   ✓ Transient calculation (temperature varies with time)

   ✓ Predefined thermal material models proposed: concrete, steel, wood, aluminium, gypsum

   ✓ Possibility to introduce other materials by specifying their thermal properties (either constant or temperature dependent)

Capabilities

3. Calculation of the behavior of a structure under elevated temperatures

   - ✓ 2D or 3D structural calculations
   - ✓ Finite elements: truss, beams, shell, solid
   - ✓ Nonlinear mechanical properties that are temperature dependent
   - ✓ Large displacements
   - ✓ Predefined mechanical material models proposed: concrete, steel, wood, aluminium
   - ✓ SAFIR gives as a result the displacements of the nodes plus information about the support reactions, stresses, tangent modulus and effects of actions, as a function of time

4. Calculation of the torsional stiffness of a section

Pre-processors and postprocessor

1. Pre-processors

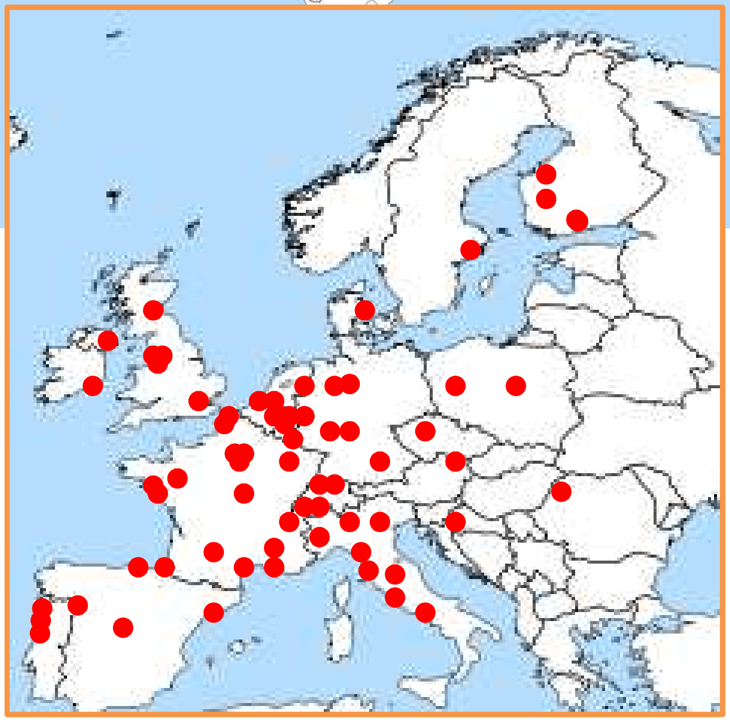
   - The general pre-processor **GiD** is favoured for use with SAFIR. GiD allows the generation of any input file for 2D or 3D, thermal or structural problem.

     Note: GiD (http://www.gidhome.com/) is a commercial software developed independently to SAFIR.

   - The pre-processor **Wizard** allows the very fast creation of an input file for the 2D thermal analysis of a section based on a hot rolled steel H section.

2. Postprocessor

   - The postprocessor **DIAMOND** allows visualizing the structure and the results. It also allows plotting charts for the evolution of various output variables during the fire, and exporting these charts to Excel.



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in the world

Non linear finite element software for structures in fire

190 licenses sold
37 countries
5 continents

User community

120 academic users

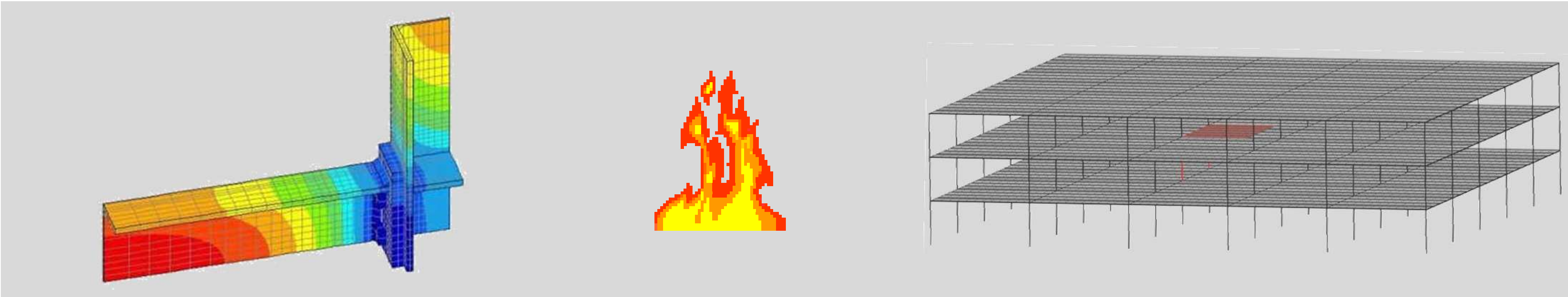
- 12 in USA (Princeton, Michigan State, ...)
- Japan, Australia, China, Canada, U.K., ...

70 commercial users

- 18 in France
- Switzerland, USA, U.K., Sweden, Australia, ...
- Arup Fire, ArcelorMittal, Ingeni, ...

Scientific papers

- SAFIR paper in AISC: 272 citations since 2005 (source: Google Scholar) http://hdl.handle.net/2268/2928



Examples of applications

2D thermal calculation
Protected steel beam heated on one side
1 225 nodes - 1 021 quadrangular elements

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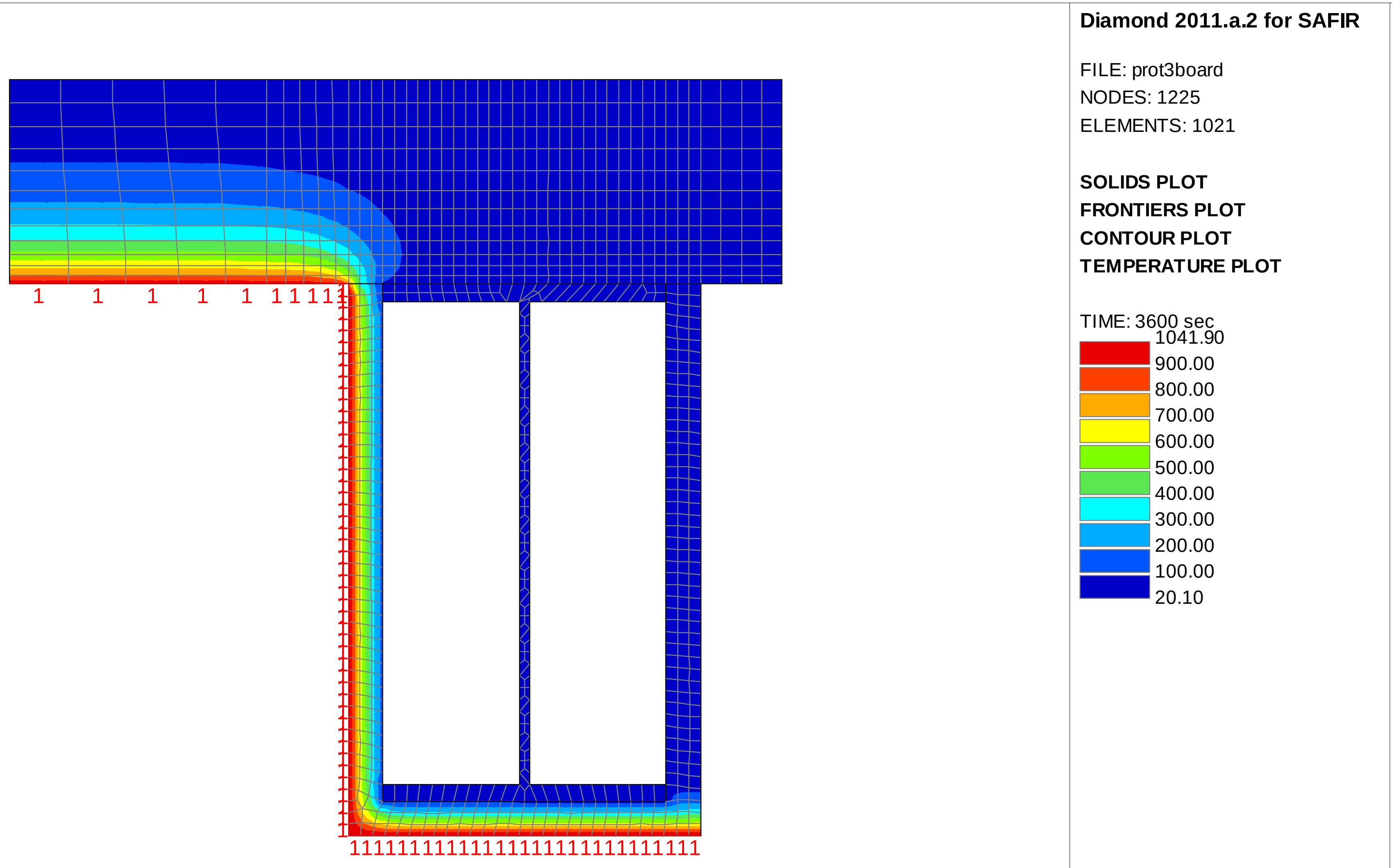

2D thermal calculation
Radiation in internal cavity – shadow effect
201 nodes - 124 elements

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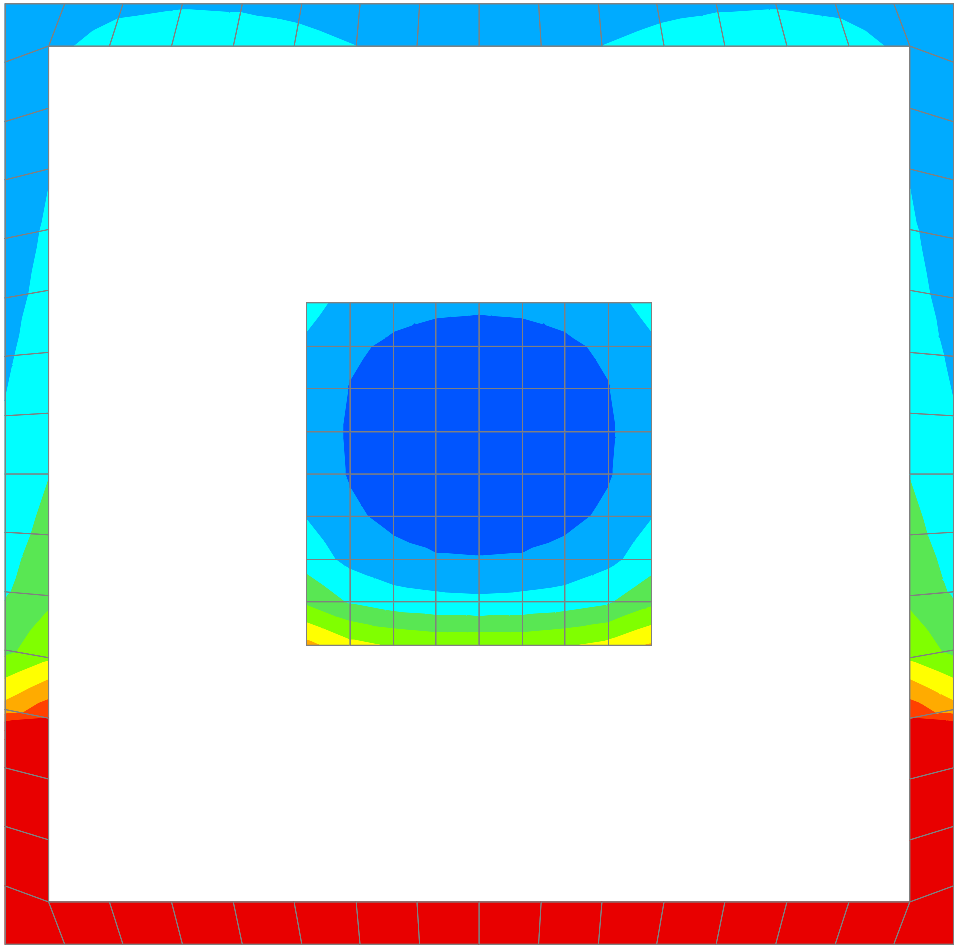

Diamond 2011.a.2 for SAFIR

FILE: test_void2
NODES: 201
ELEMENTS: 124

SOLIDS PLOT
TEMPERATURE PLOT

TIME: 3600 sec
482.00
40.00
37.50
35.00
32.50
30.00
27.50
25.00
22.50
20.00
<Tmin

2D thermal calculation
Reinforced concrete column with hollow core
1097 nodes - 2012 triangular elements

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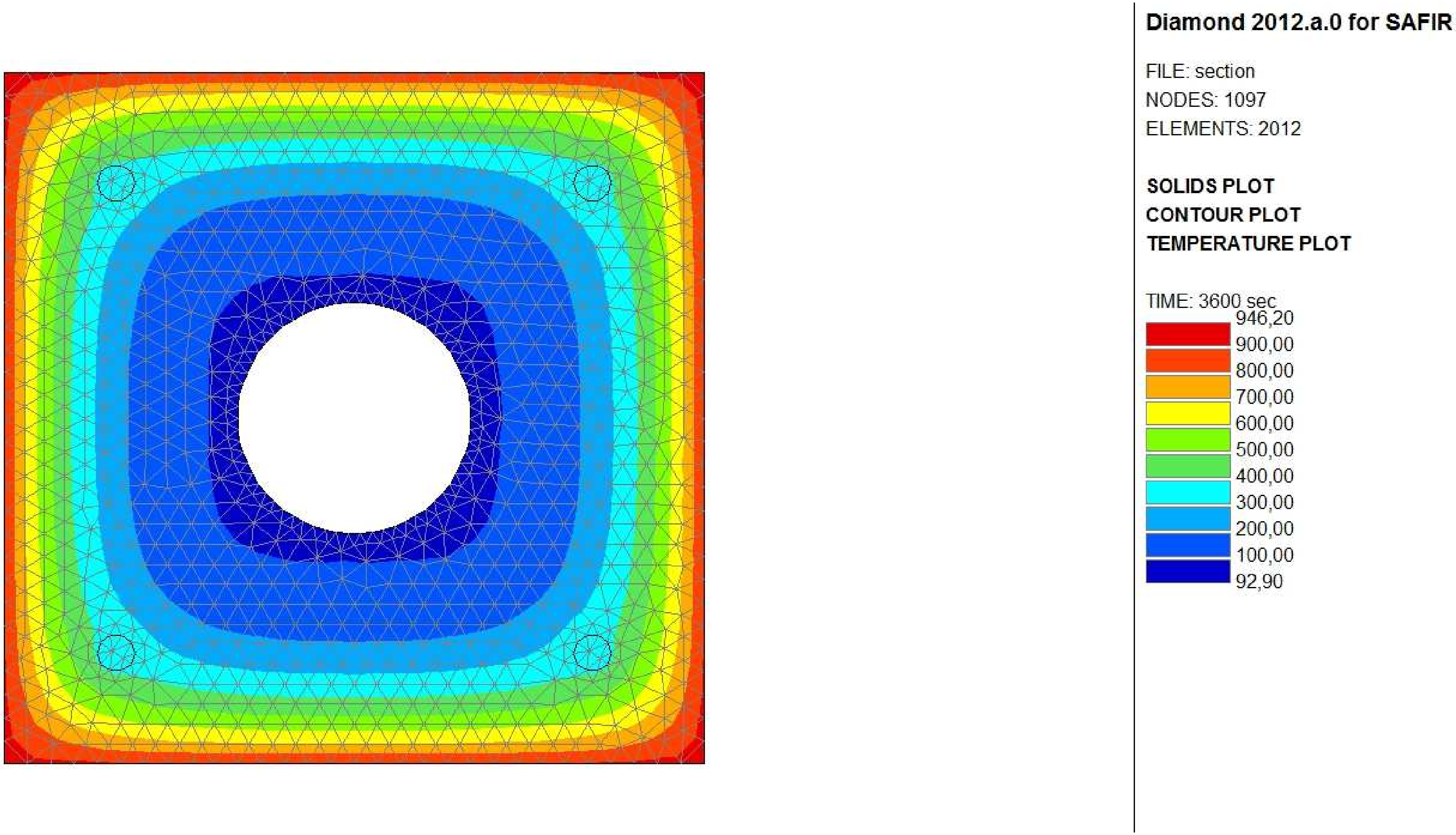

2D thermal calculation
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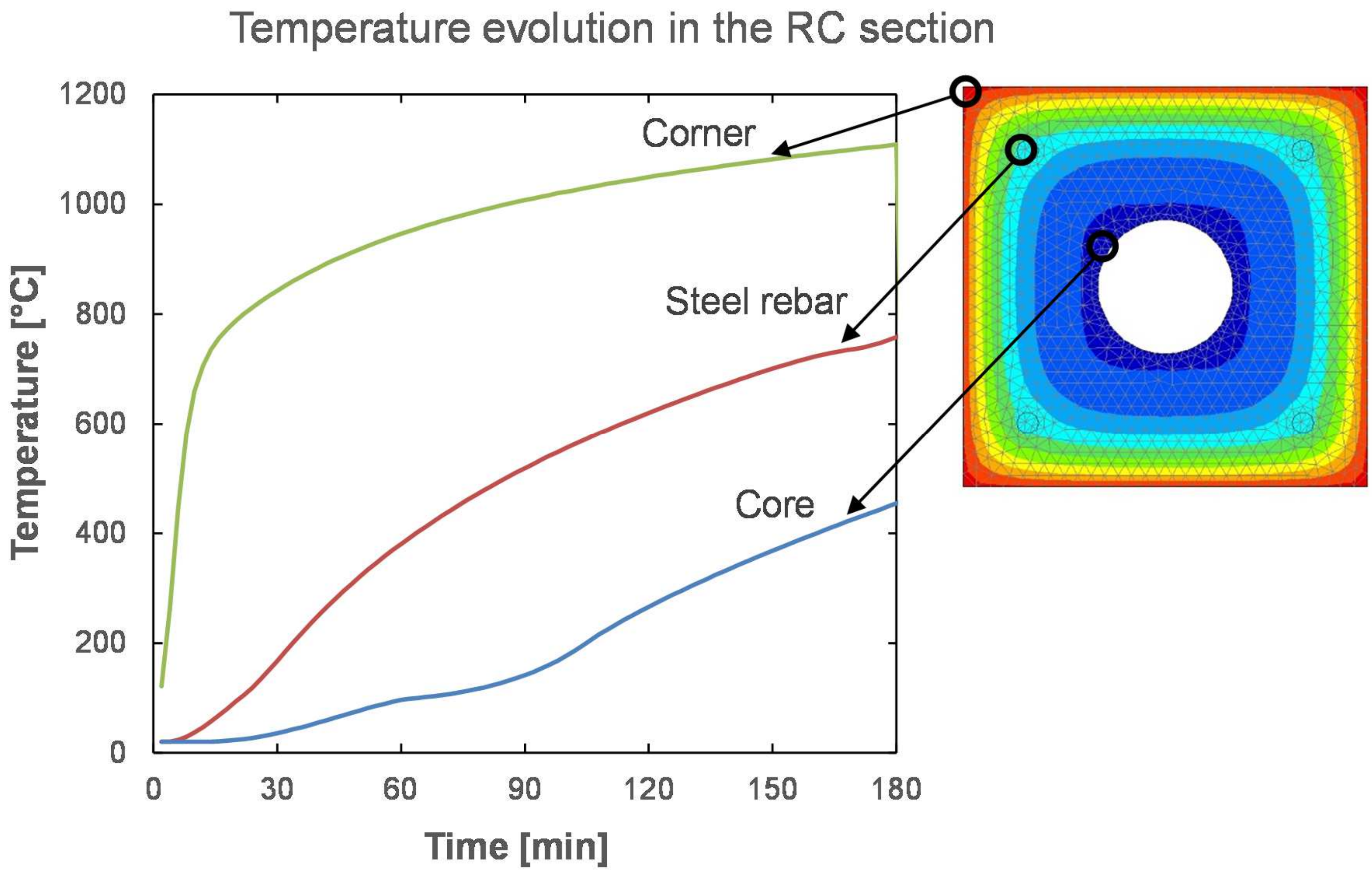

3D thermal calculation
Concrete beam
6 183 nodes - 5 060 solid elements

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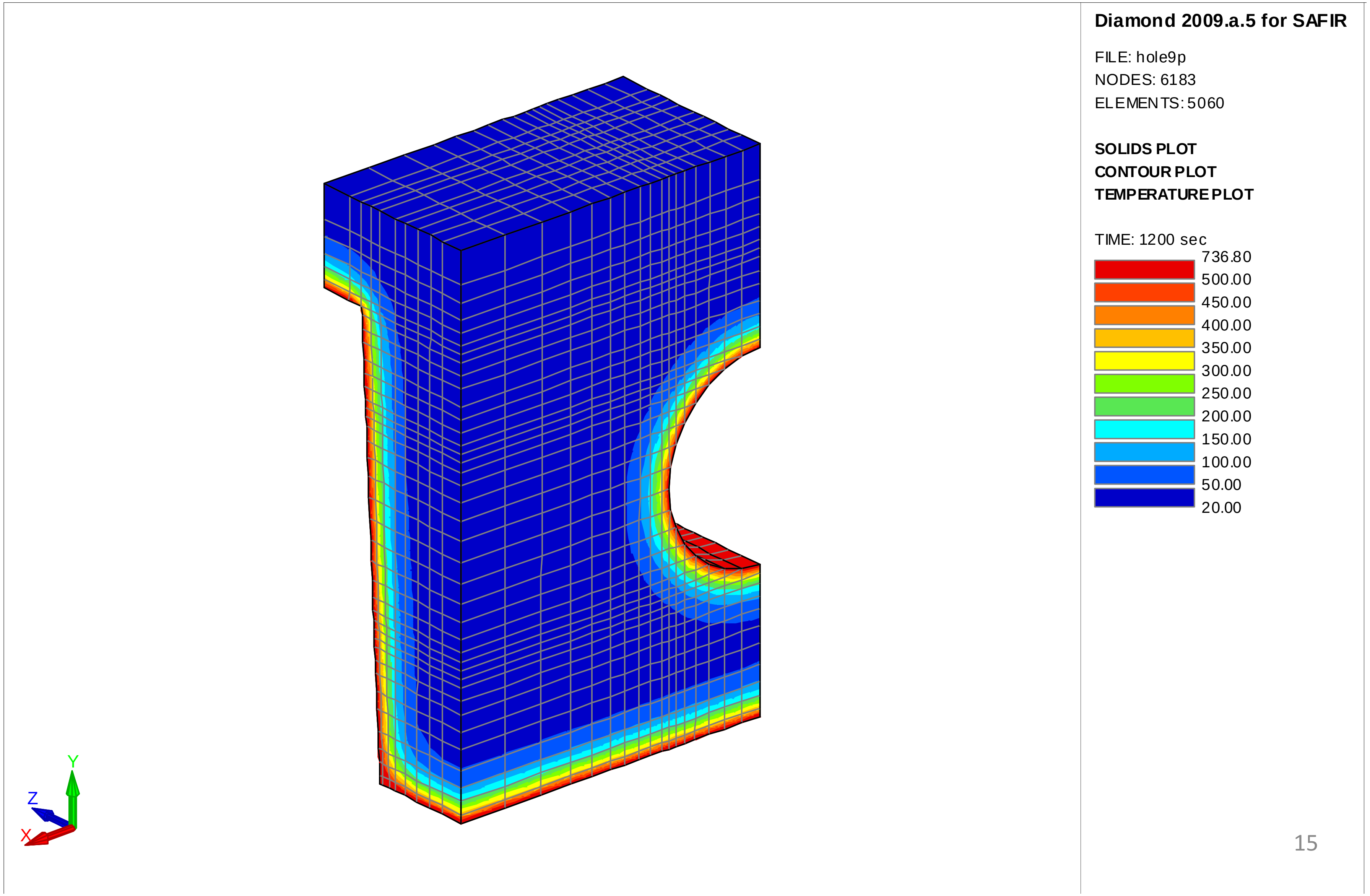

3D thermal calculation
Composite steel-concrete joint
31 502 nodes - 25 411 solid elements

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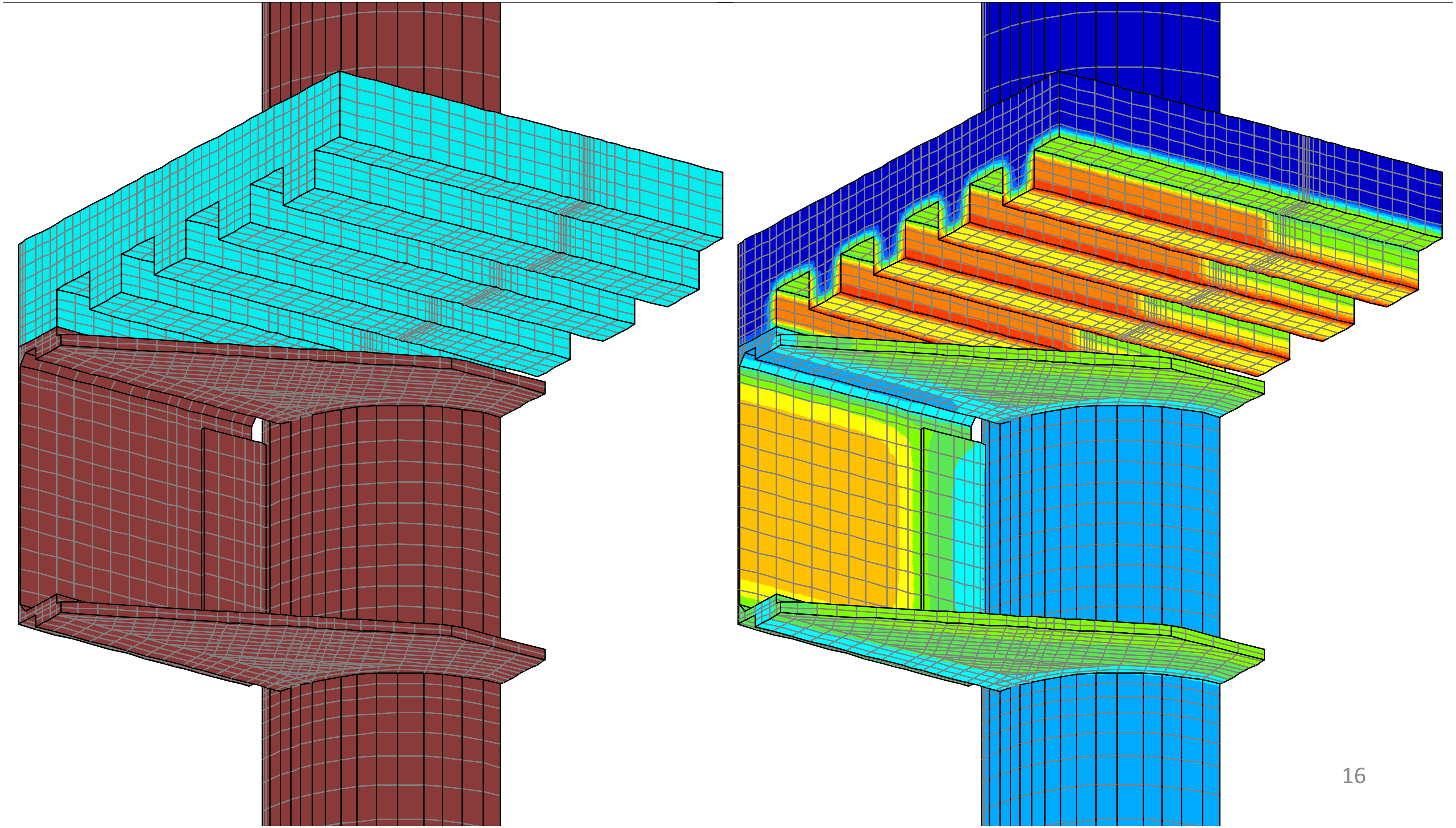

2D structural calculation
Example of a frame structure

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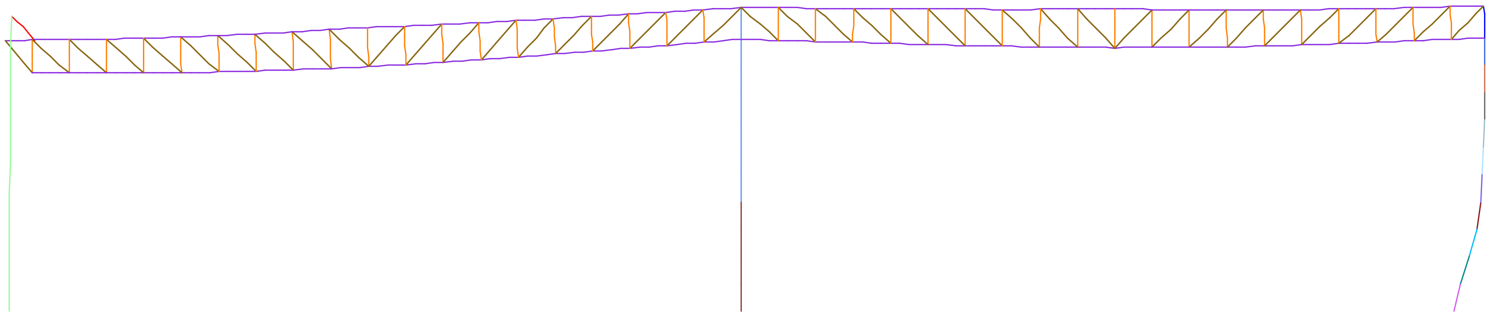

3D structural calculation
Case study by R. Fike and V. Kodur – Michigan State University, USA
Partial model of an eight story steel frame office building

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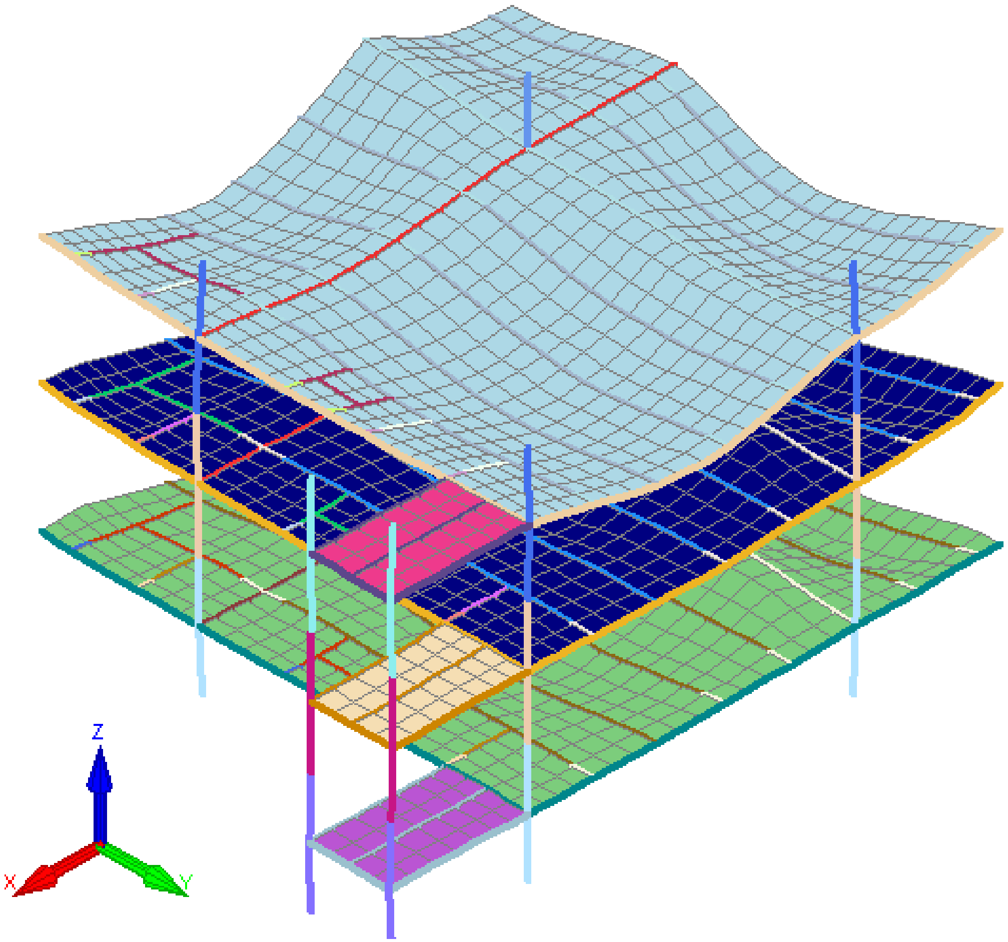

3D structural calculation
NRC report - part 2. H. Mostafaei, P. Leroux, P.-S. Lafrance
Hybrid Fire Testing for Performance Evaluation of Structures in Fire

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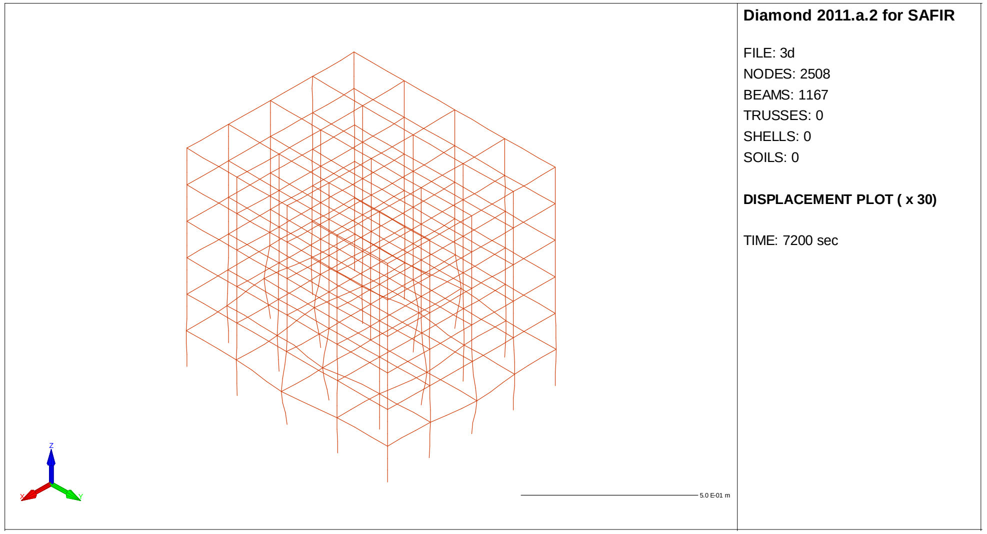

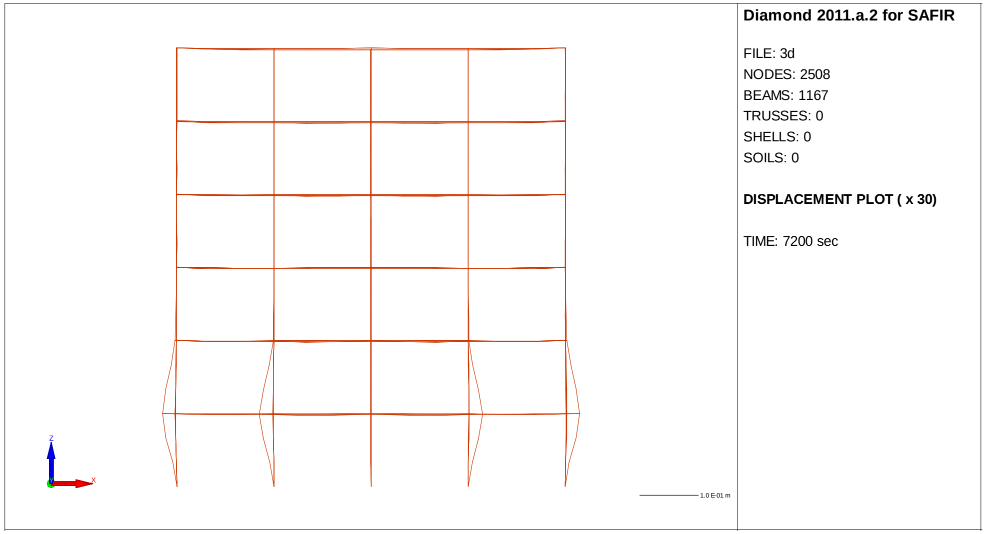

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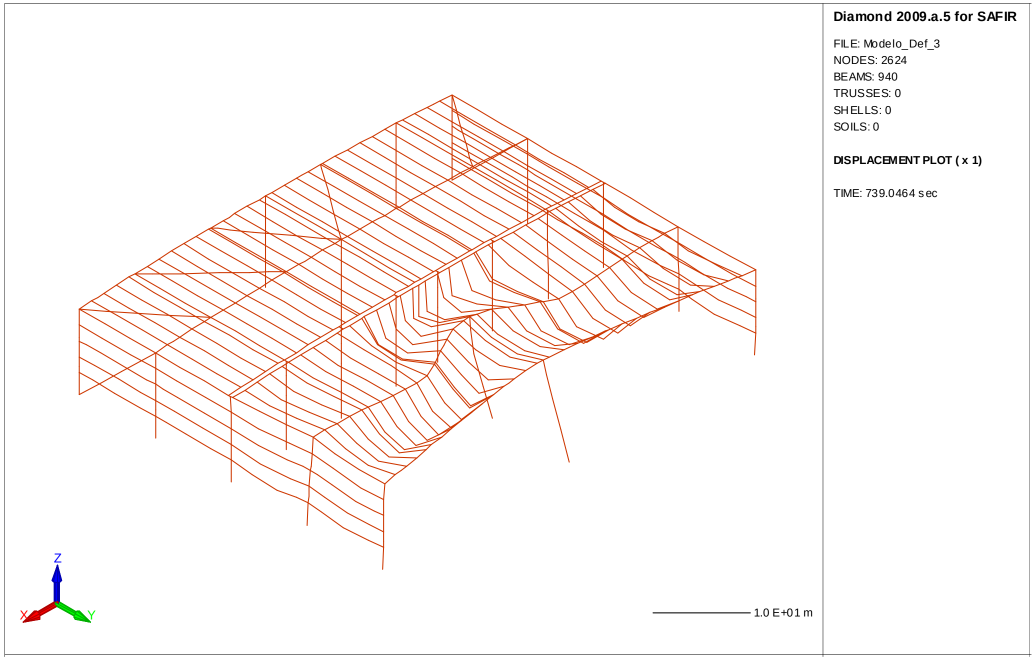
3D structural calculation
Flumilog test, INERIS France
2 624 nodes - 940 beam elements



Timber box flooring system
3 892 nodes - 4 428 shell elements

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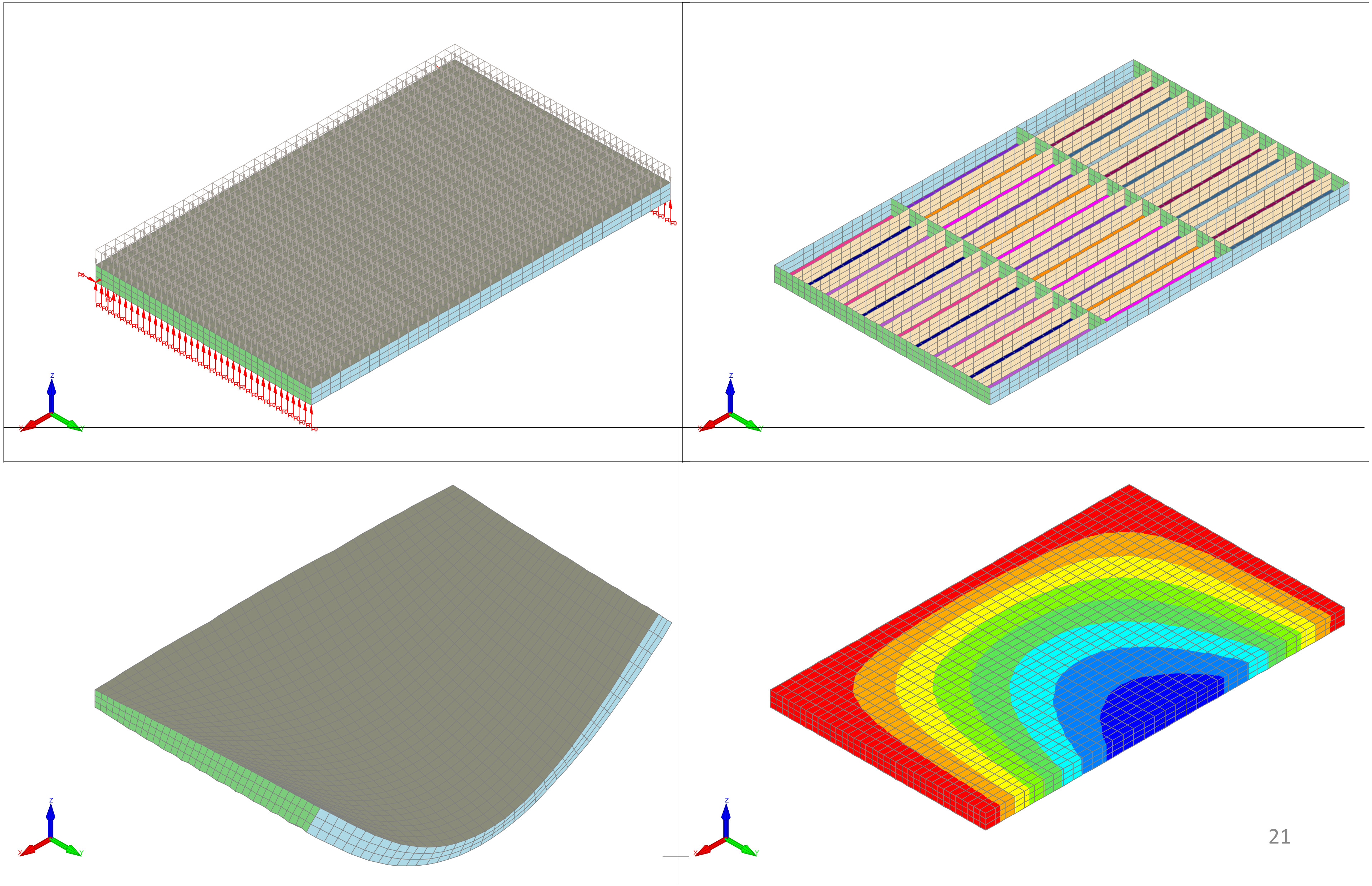

3D structural calculation
Cellular steel beam in fire

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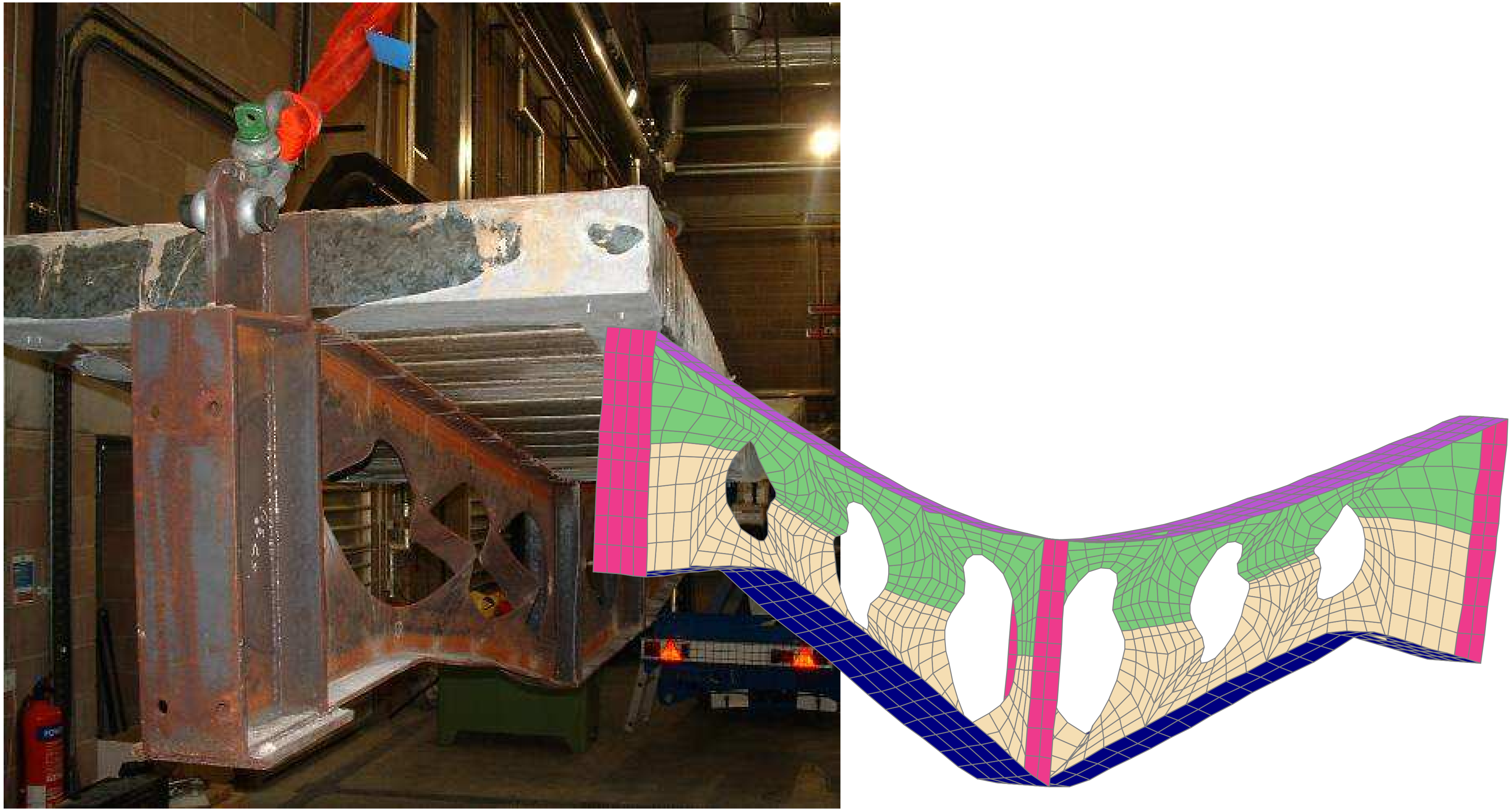

3D structural calculation
Cellular steel beam in fire

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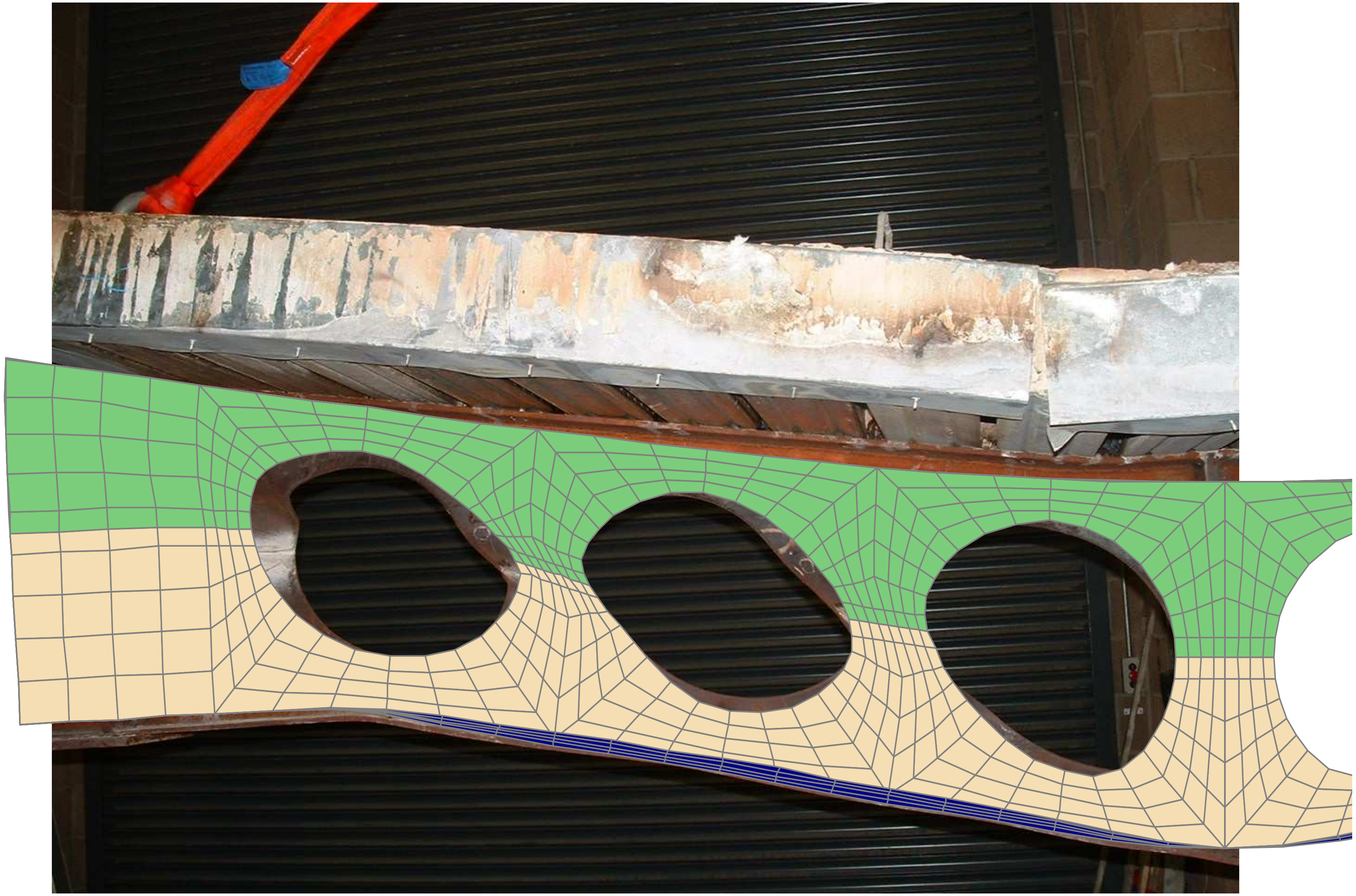

3D structural calculation
Structural Fire Analysis of a building with an arched concrete roof
ICB

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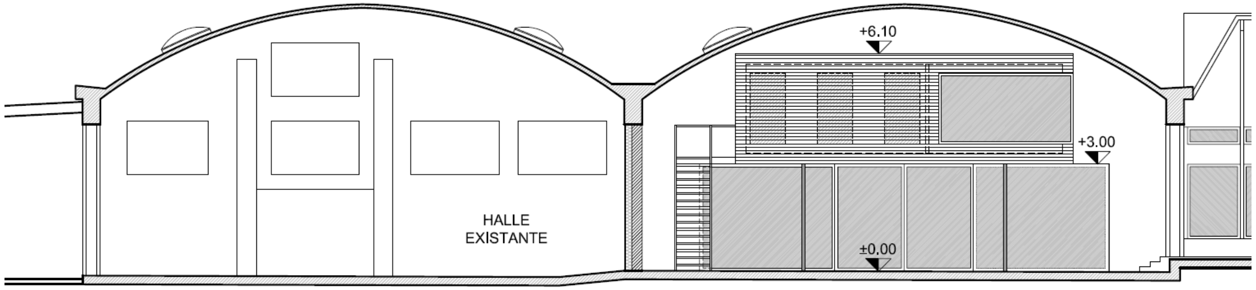
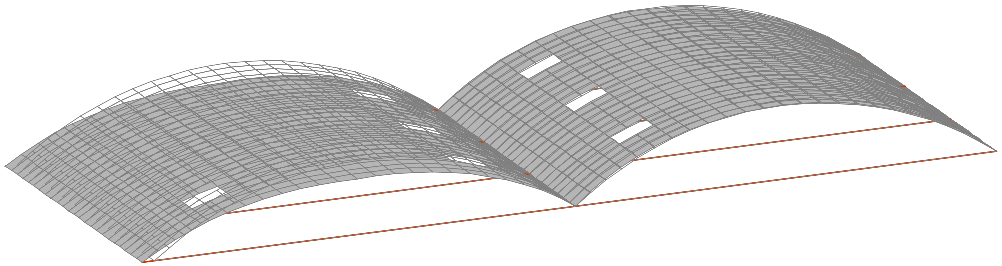
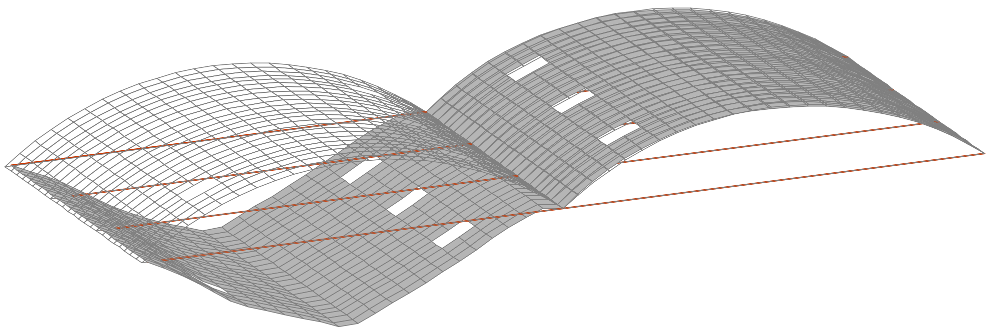




Snap-through collapse under fire when the steel tie rods fail



3D structural calculation
Plot of the membrane forces in the concrete shells

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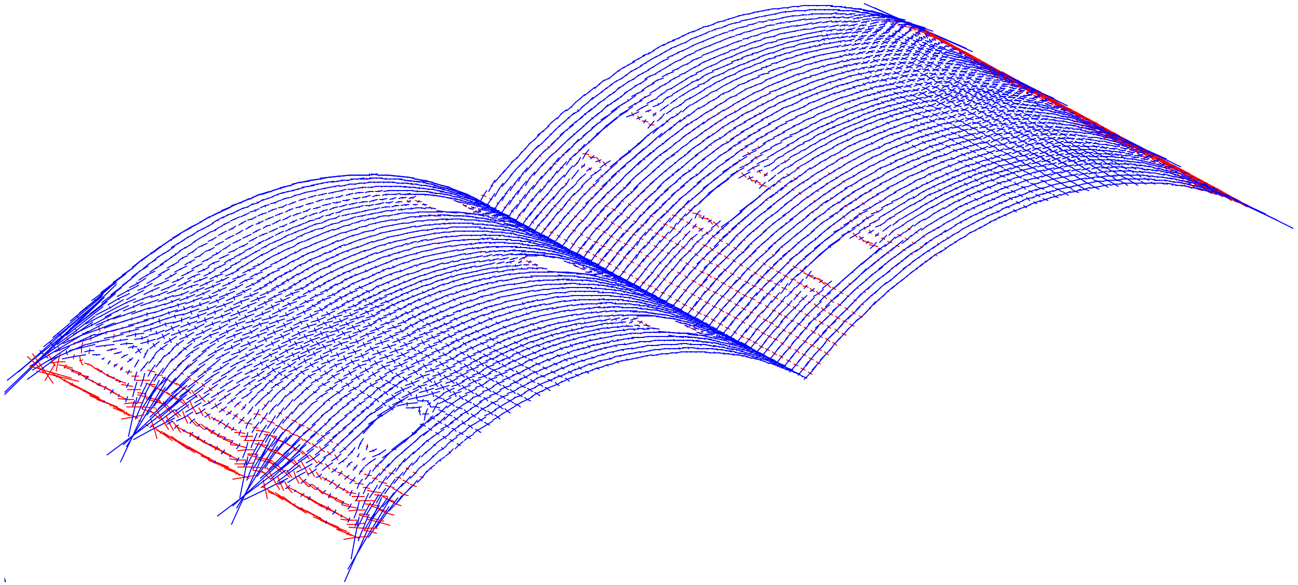

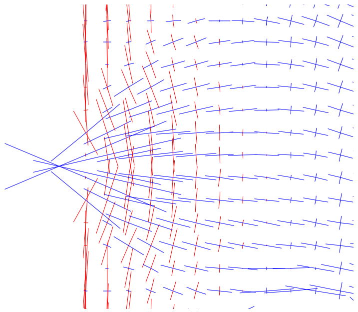

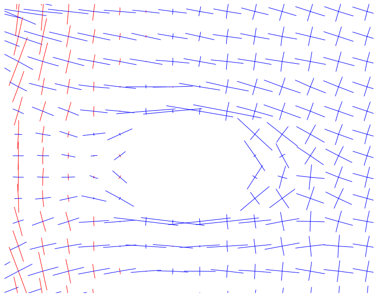

3D structural calculation
Full scale fire test – Ulster 27-02-2010
RFCS project (Vassart, et al., 2012)

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3D structural calculation
Full scale fire test – Ulster 27-02-2010
RFCS project (Vassart, et al., 2012)

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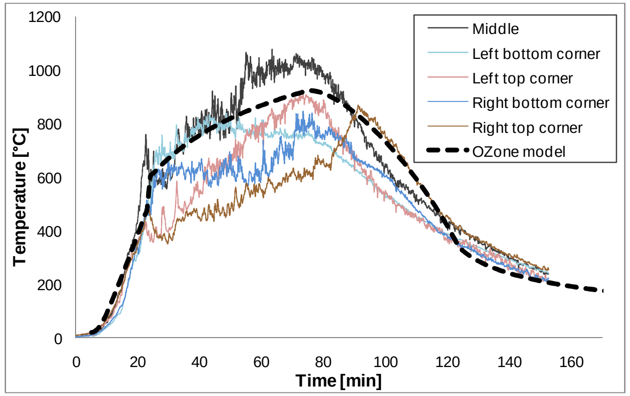
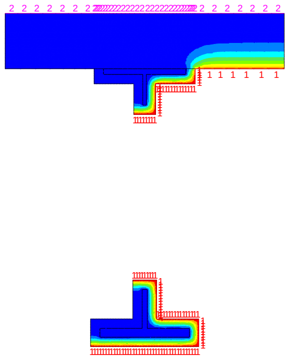
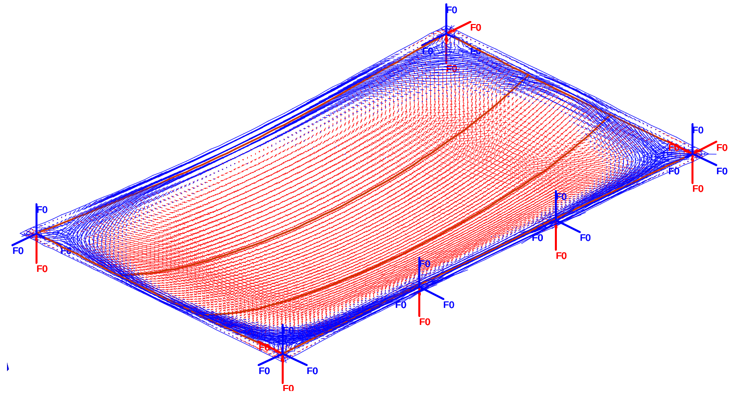
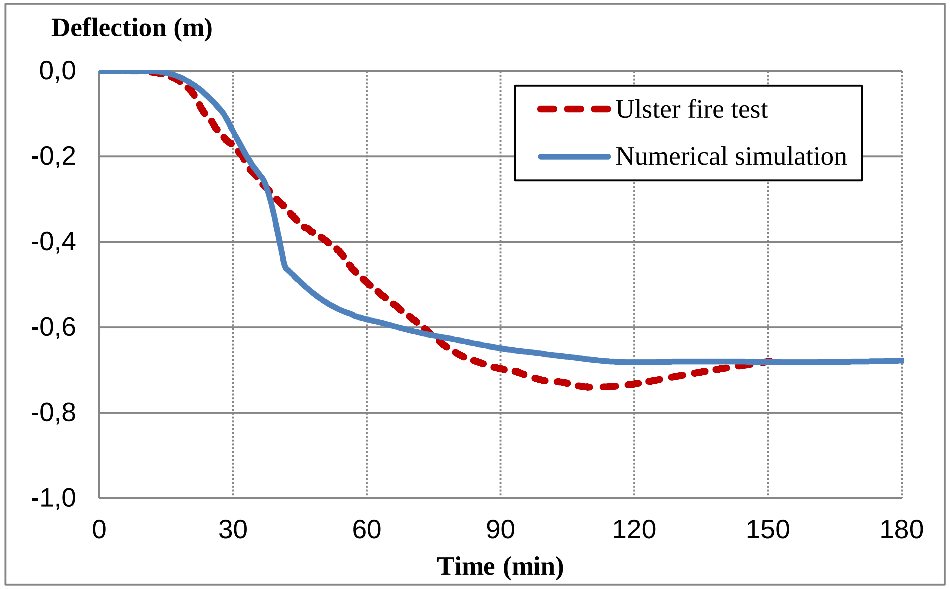
1 → 2 → 3









Recent references in the literature

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