Université de Liège

Numerical simulations in support of fire resistance tests

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Who are we?

A fire resistance laboratory in a university.

University of Liege

Faculty of Applied Science

Department of Architecture, Geology, Environment and Construction

Structural Engineering division

Fire Safety Engineering group

Fire Safety Engineering group

Professor

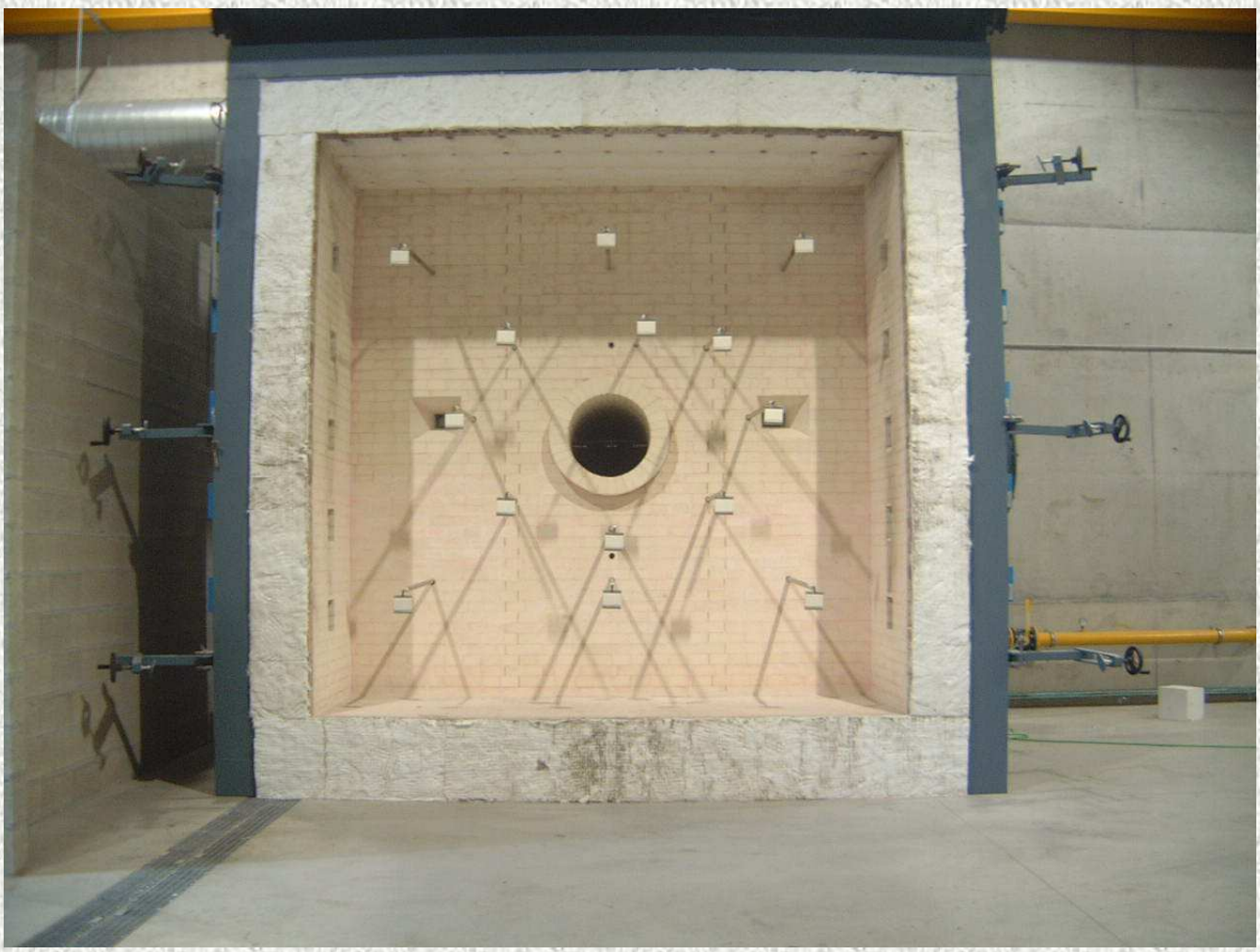
<u>Theoretical research</u>
Assistant
Research engineer
Ph. D. student
Post doc visitors

Experimental research
<u>(fire lab)</u>
Manager
Quality Insurance
Technician

The fire lab

Horizontal (and multi-purpose) furnace (3x4 m^2)
with loading system (1000 kN)

The fire lab

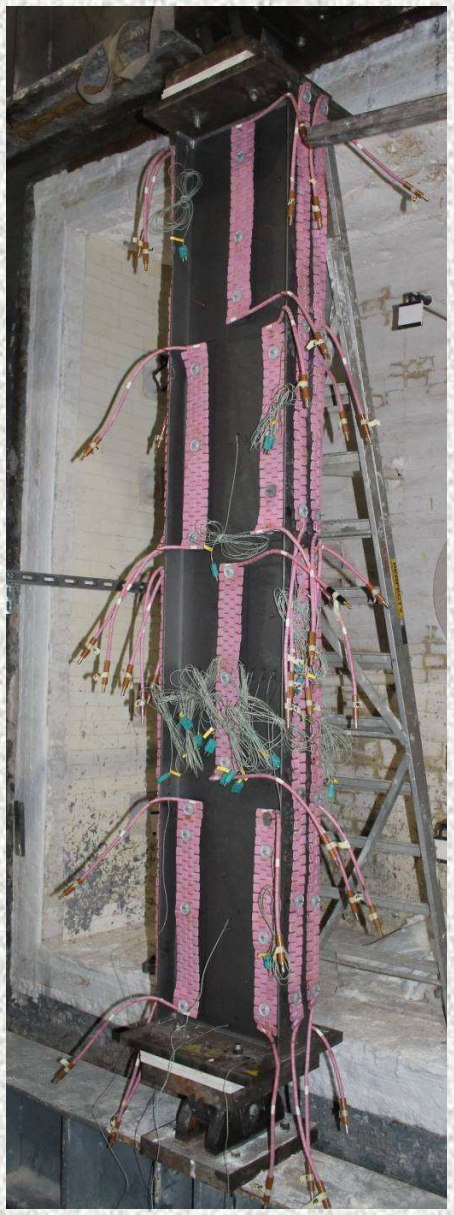


Vertical furnace (3x3) for walls and columns
Can receive a loading system (2000 kN)

The fire lab

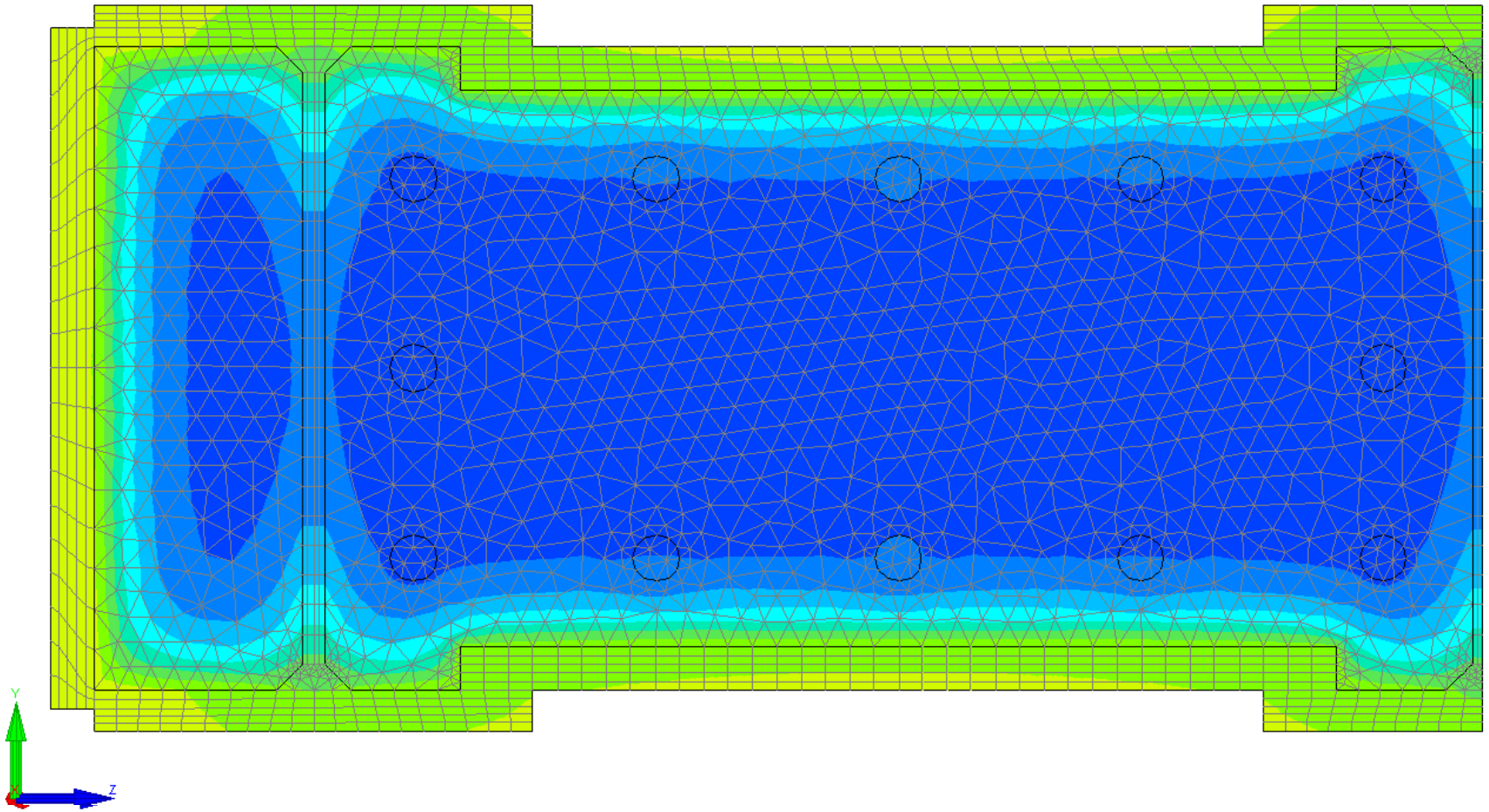
Electrical heating system (65 kVA)
6 channel control

Electrical system used in a column test



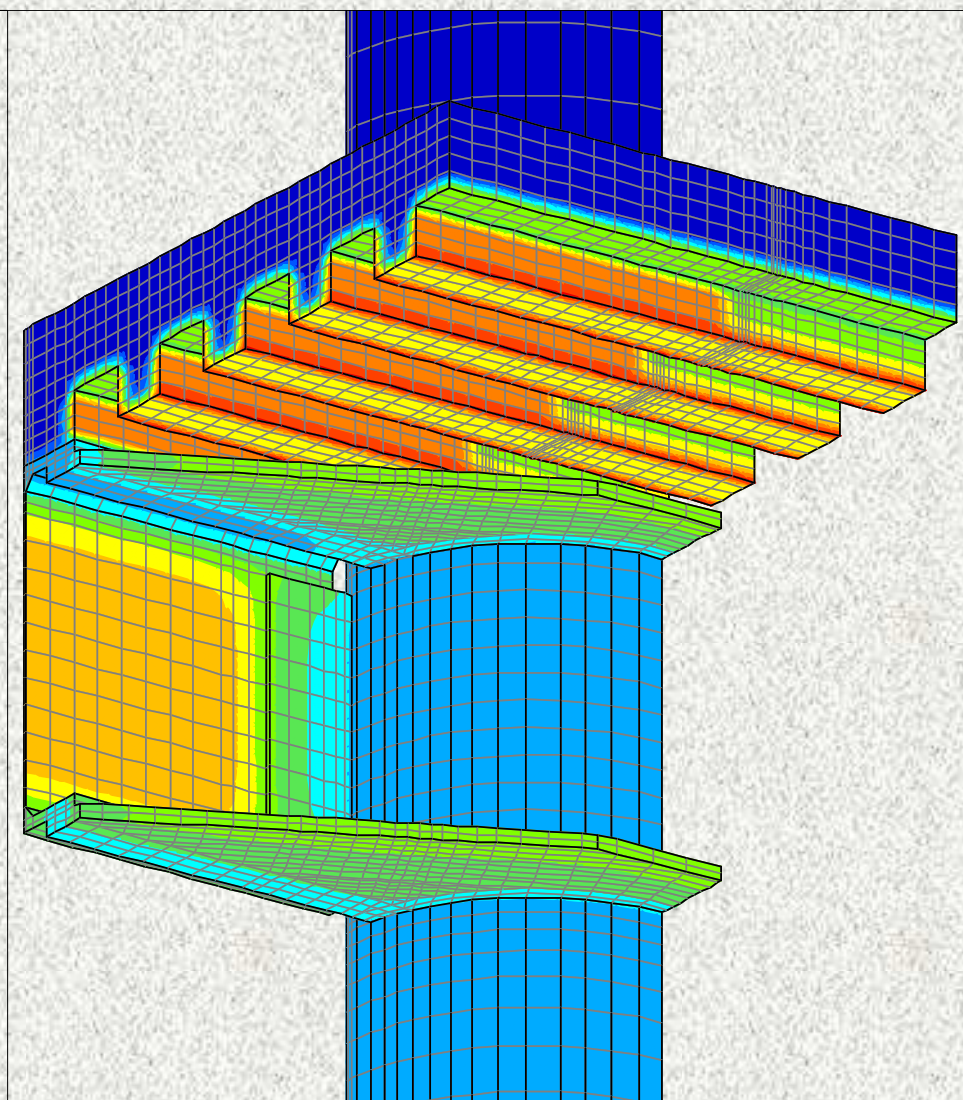
Theoretical research

Software SAFIR for the modelling of building structures subjected to fire

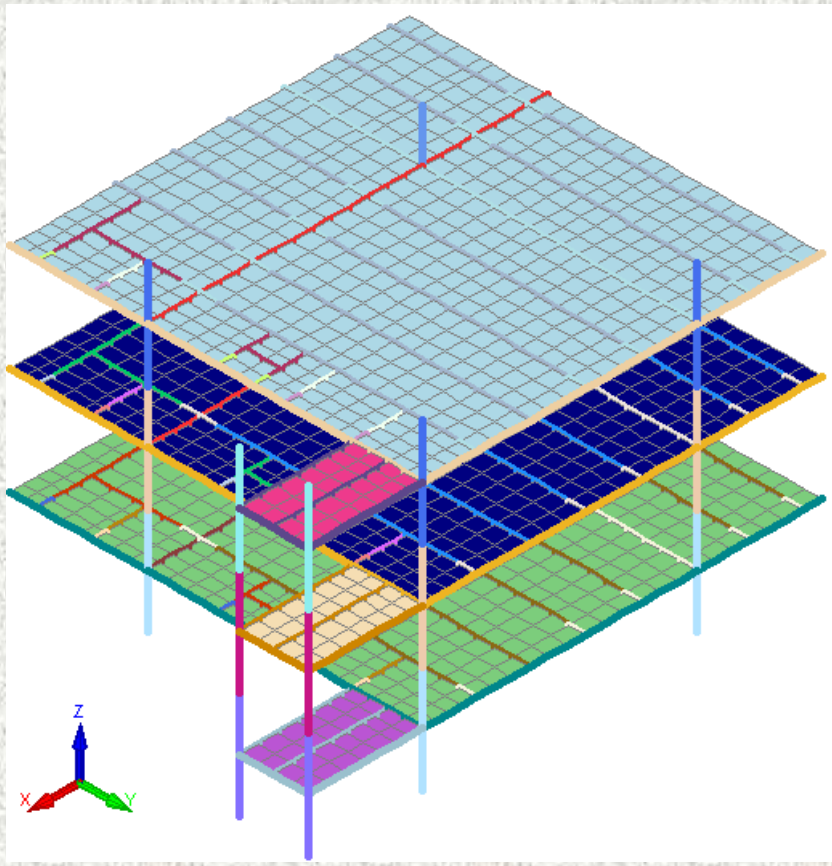


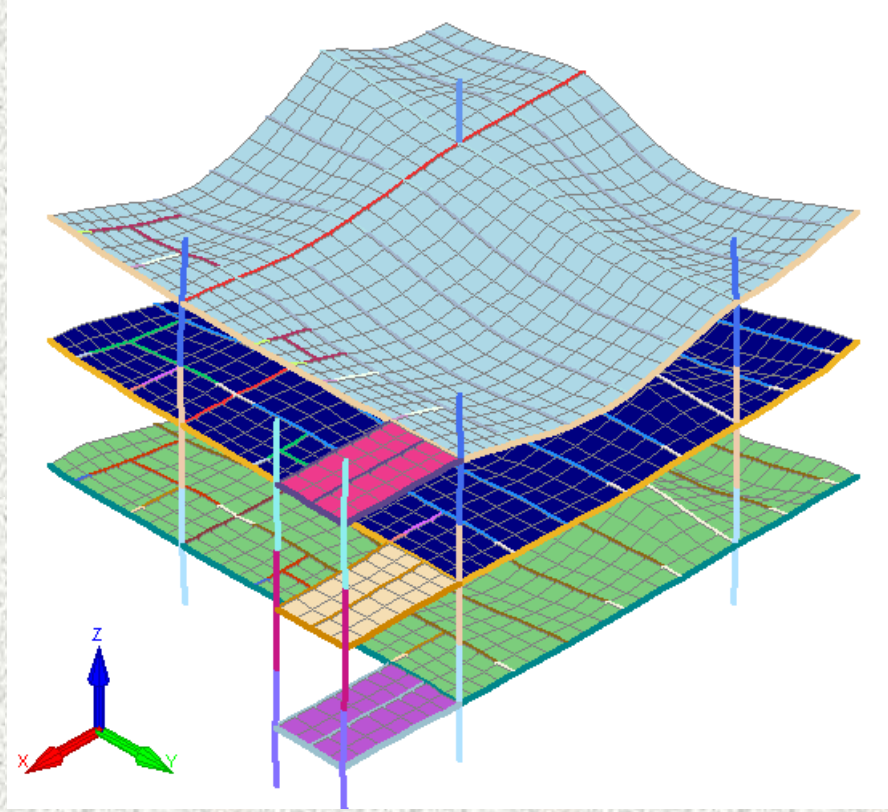
Composite steel-concrete columns (1/2)
Courtesy: Technum

Thermal analysis - Numerical model by Alderighi, Univ. of Pisa
Composite steel-concrete joint – 31502 nodes – 25411 solid elements

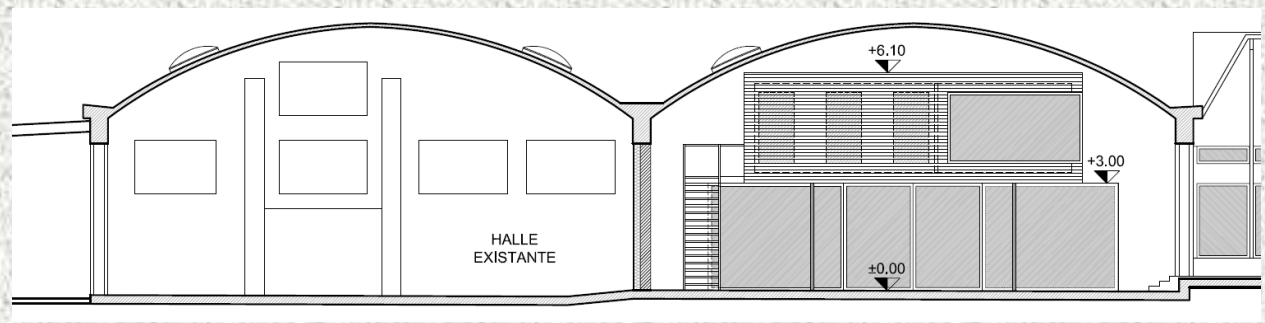


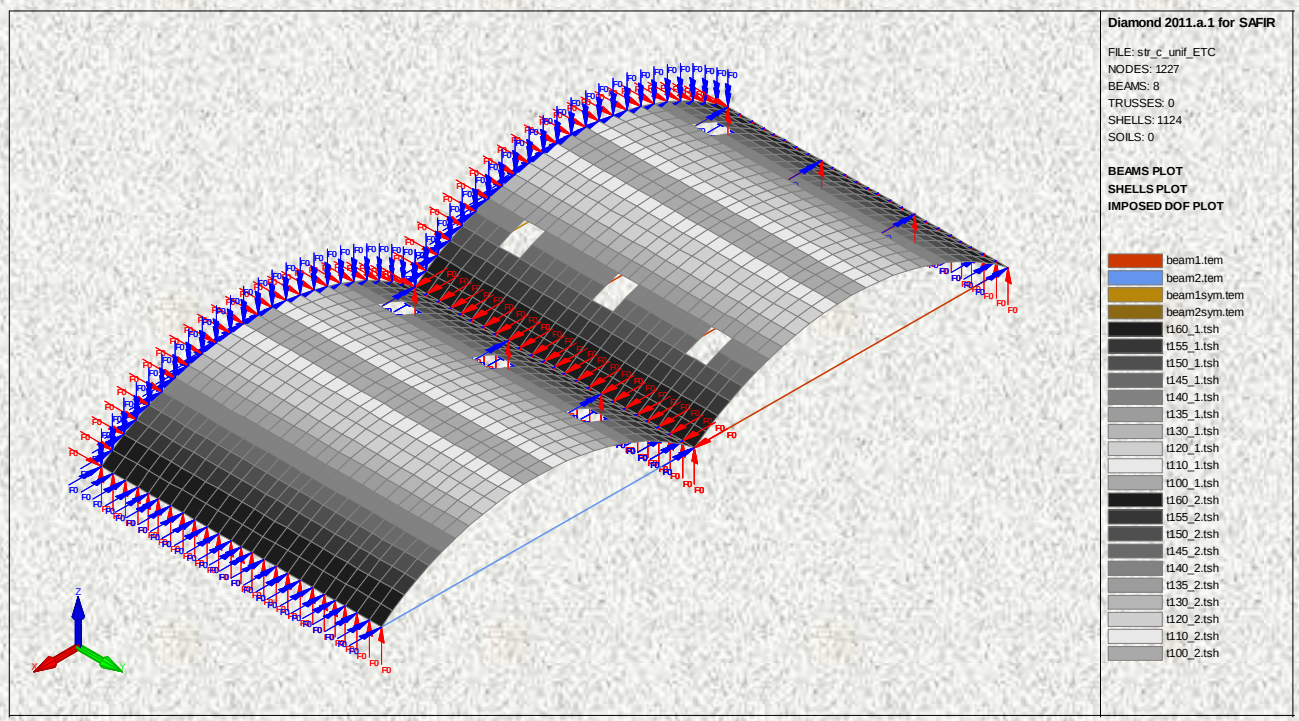
Case study by R. Fike and V. Kodur – Michigan State University, US
Partial model of an eight story steel frame office building





Structural Fire Analysis of a building in Luxemburg –University of Liege
Study performed for ICB





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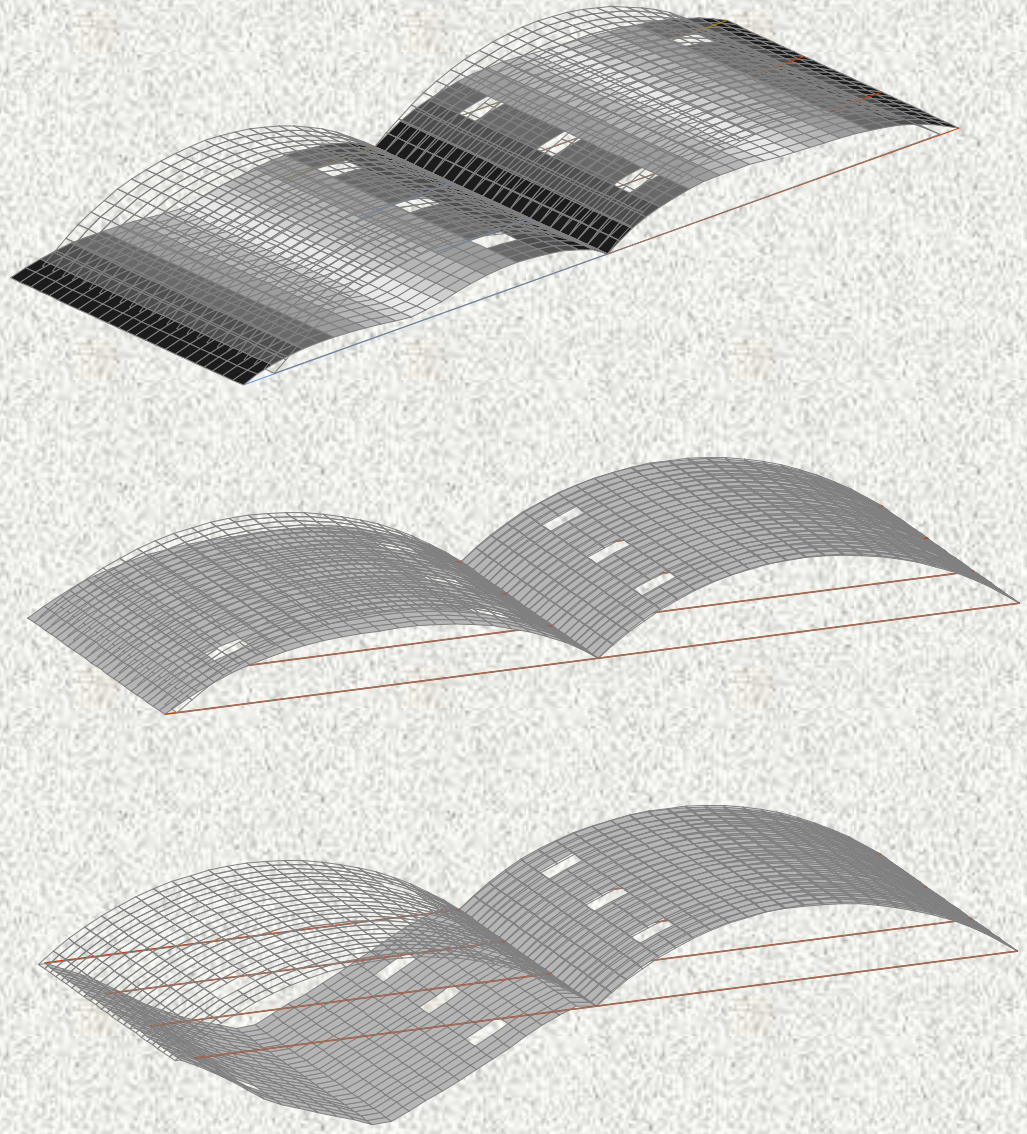

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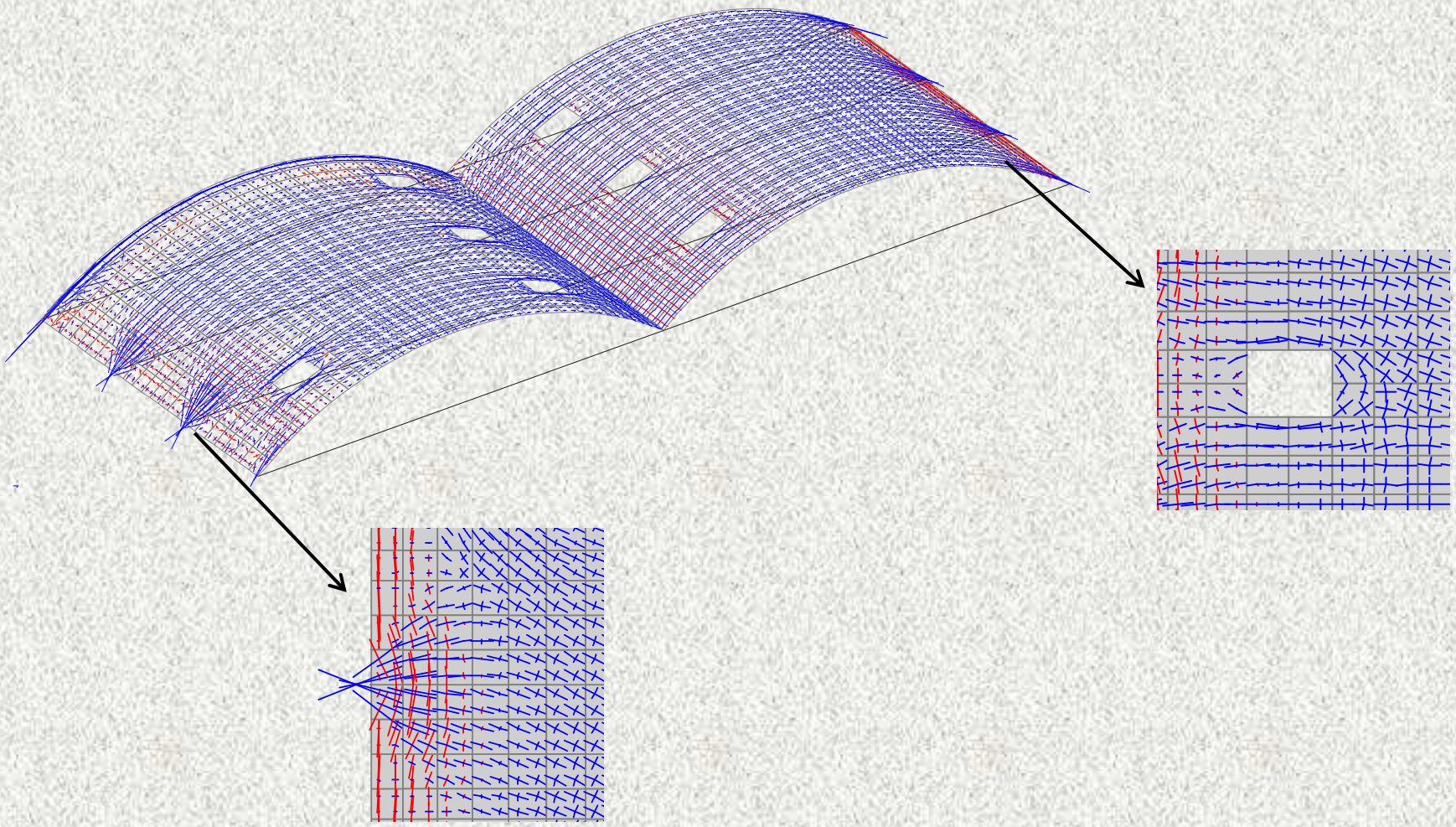
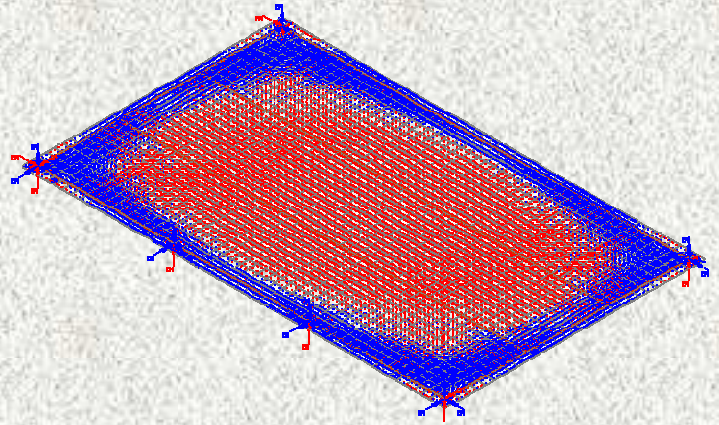
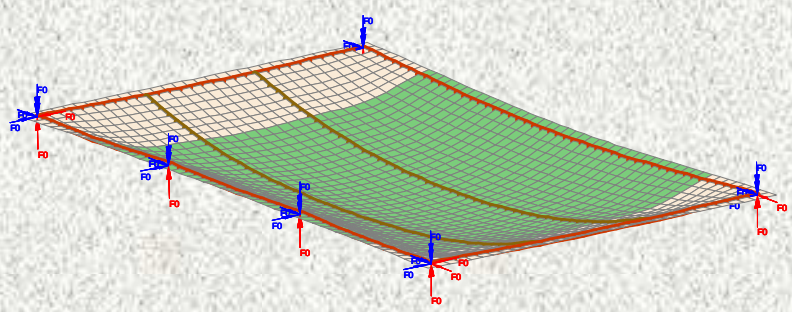
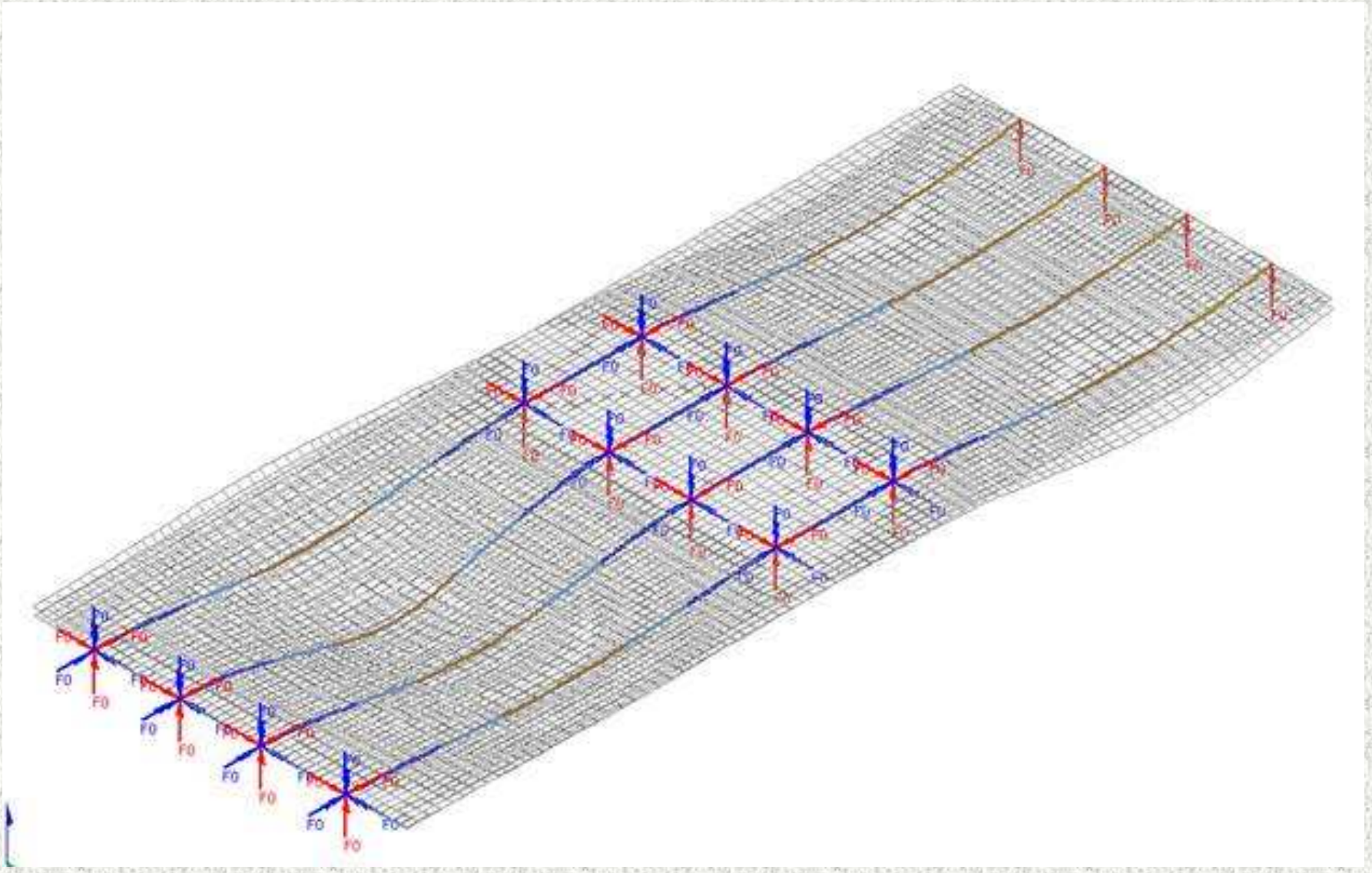


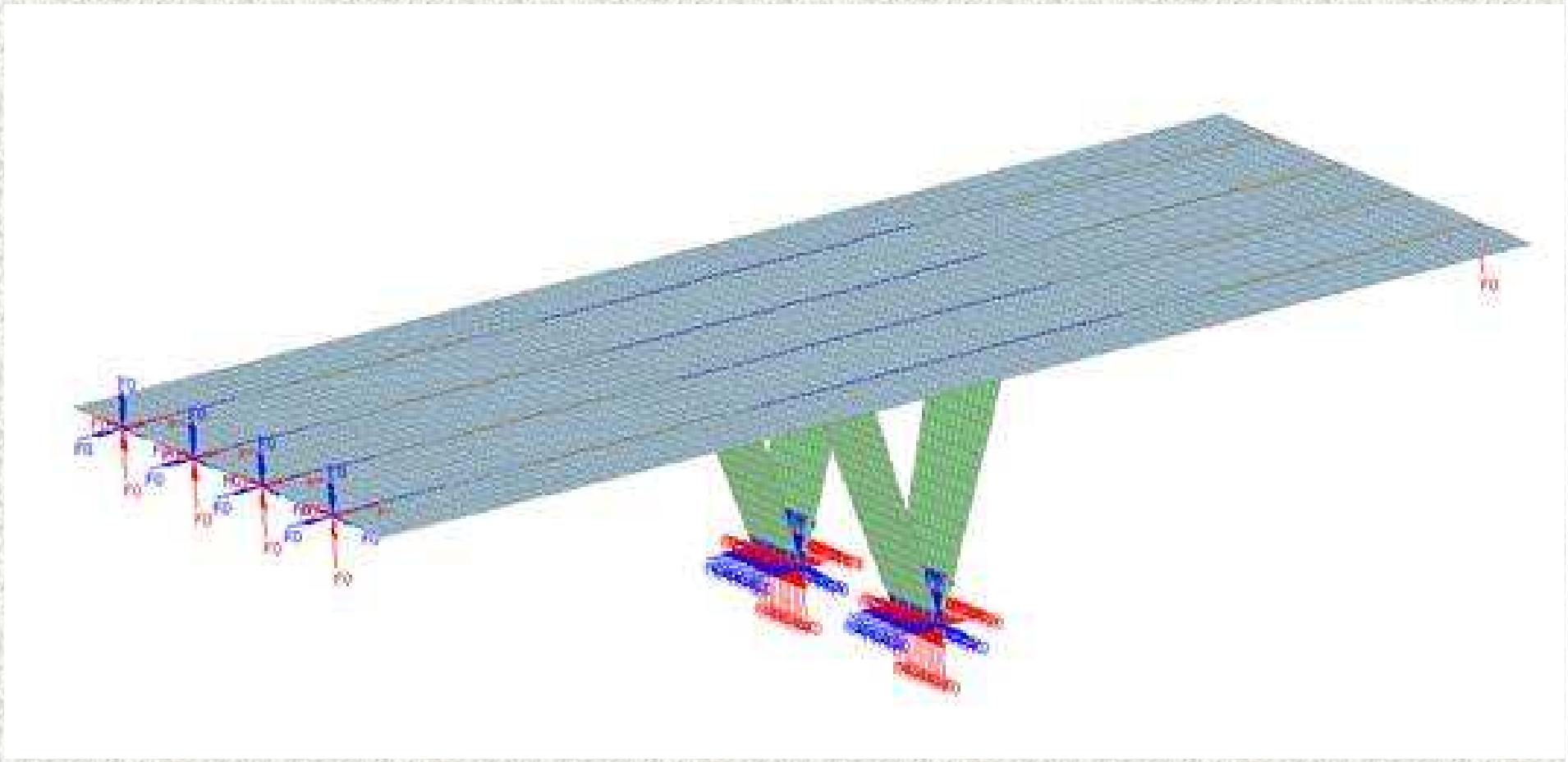
Ulster test (2010) – FICEB project (funded by RFCS)
Membrane behavior of a composite steel-concrete slab





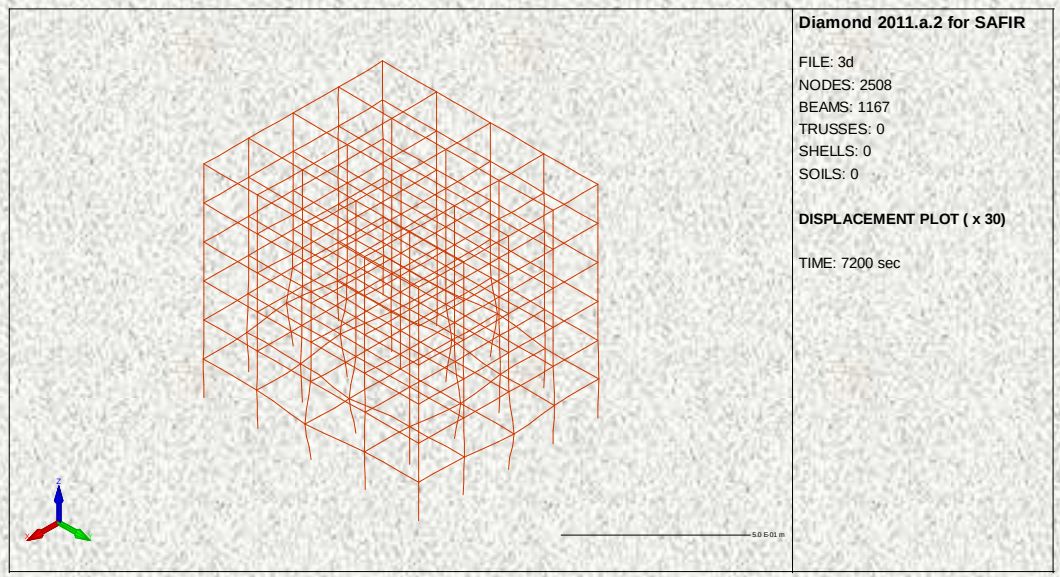


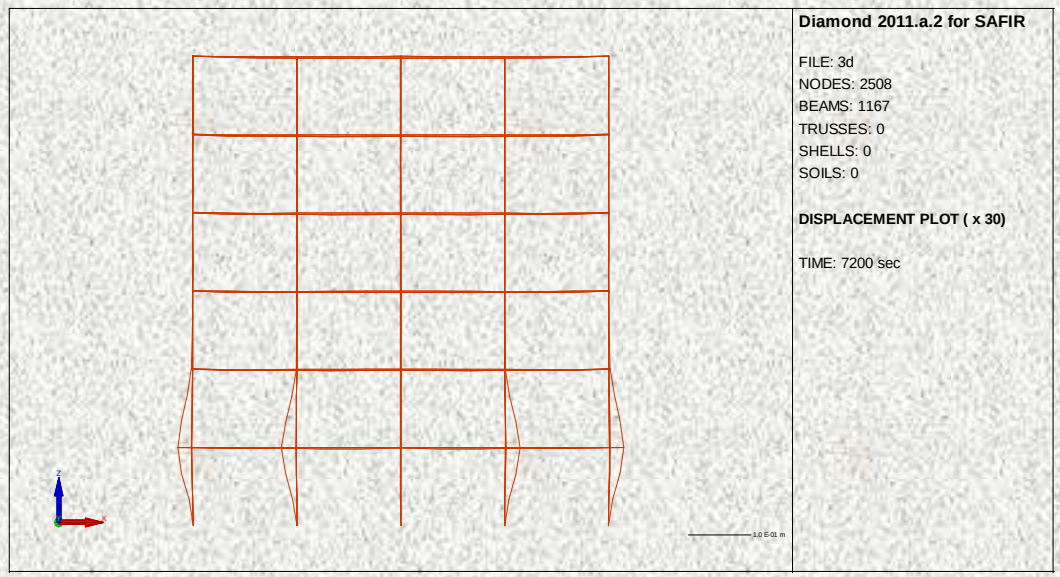
Bridge in the Tessin region, Switzerland (E. Tonicello, MP Ingénieurs)

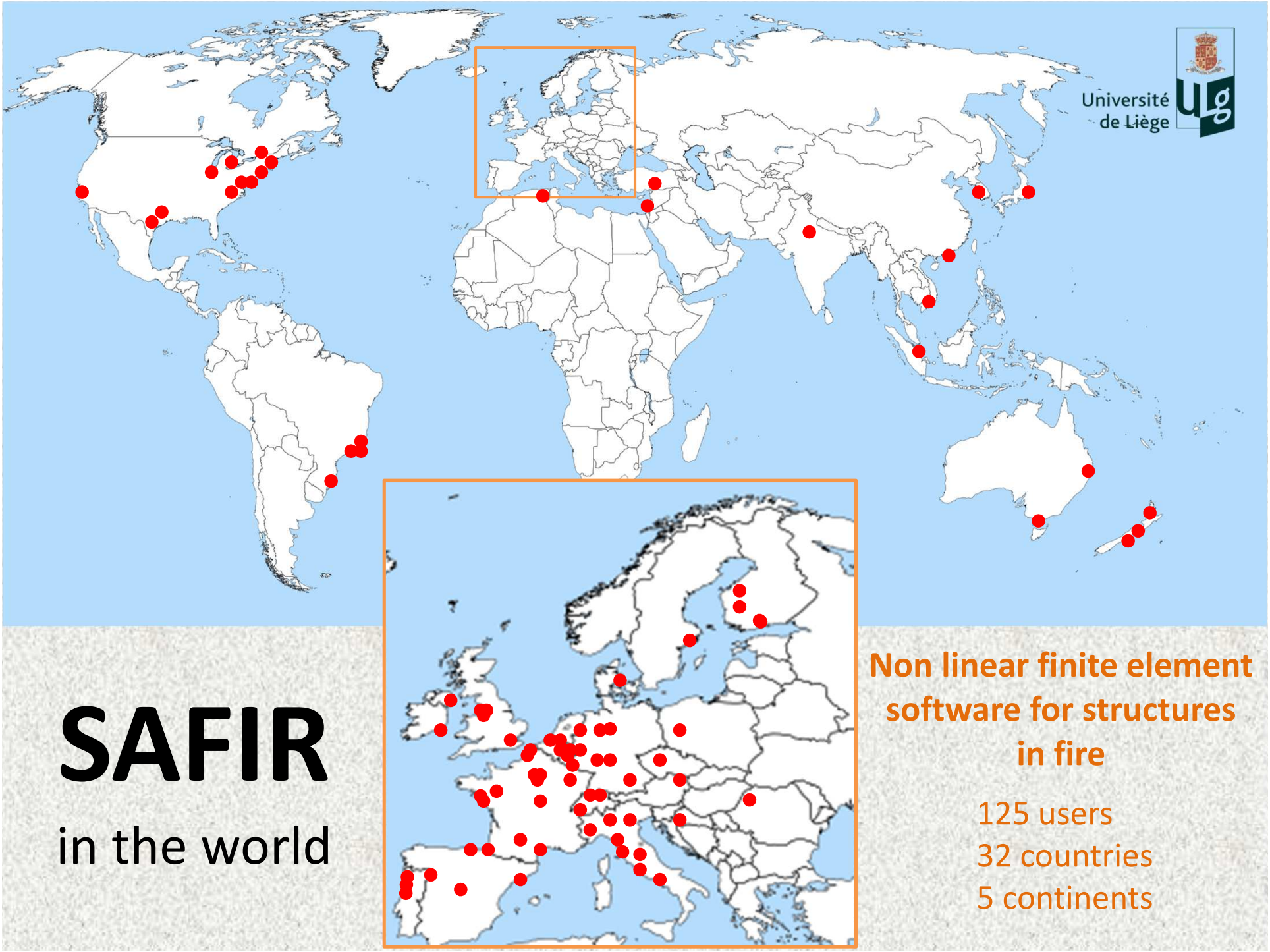


Bridge in the Tessin region, Switzerland (E. Tonicello, MP Ingénieurs)

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







SAFIR

in the world

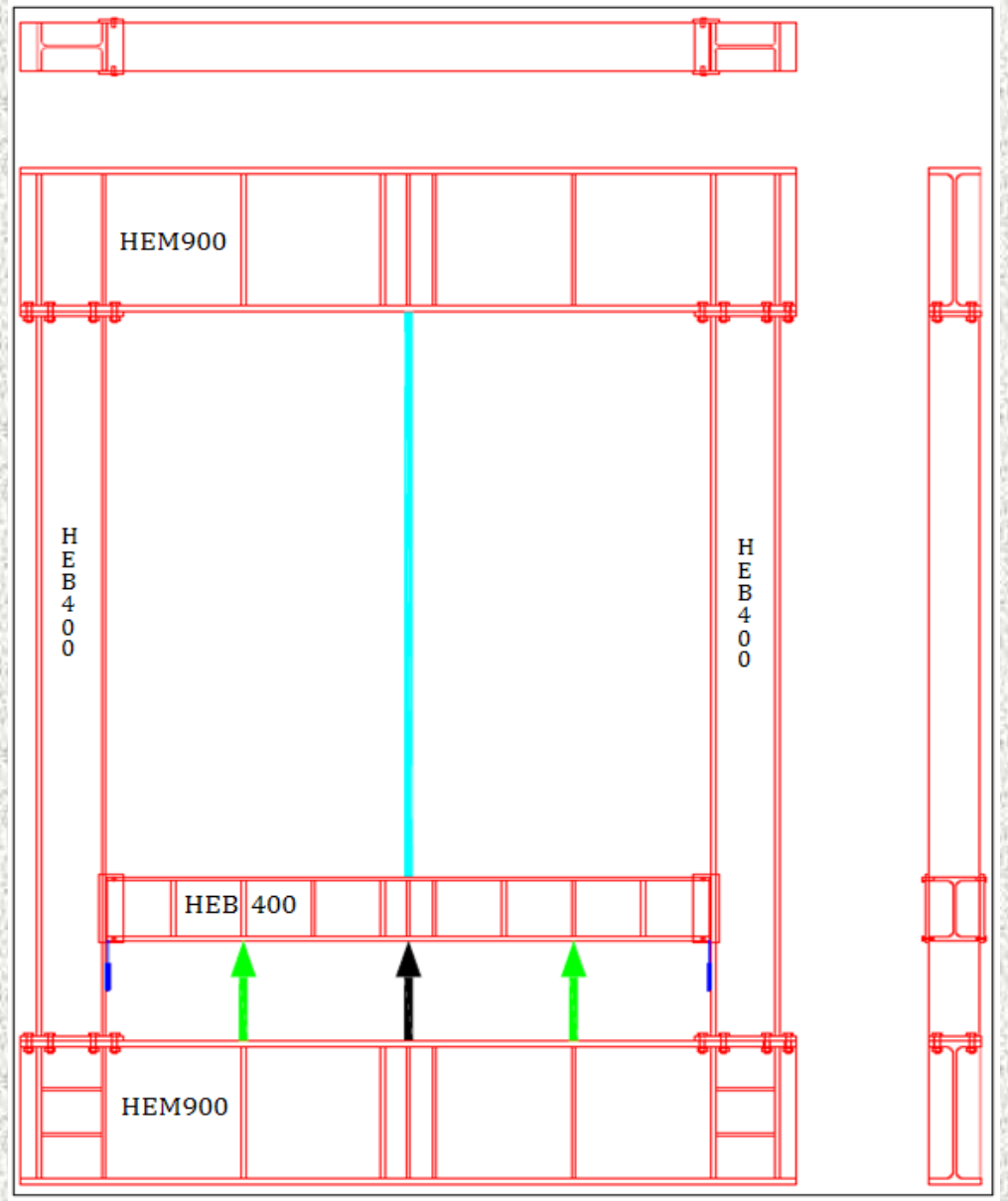
Non linear finite element software for structures in fire

125 users
32 countries
5 continents

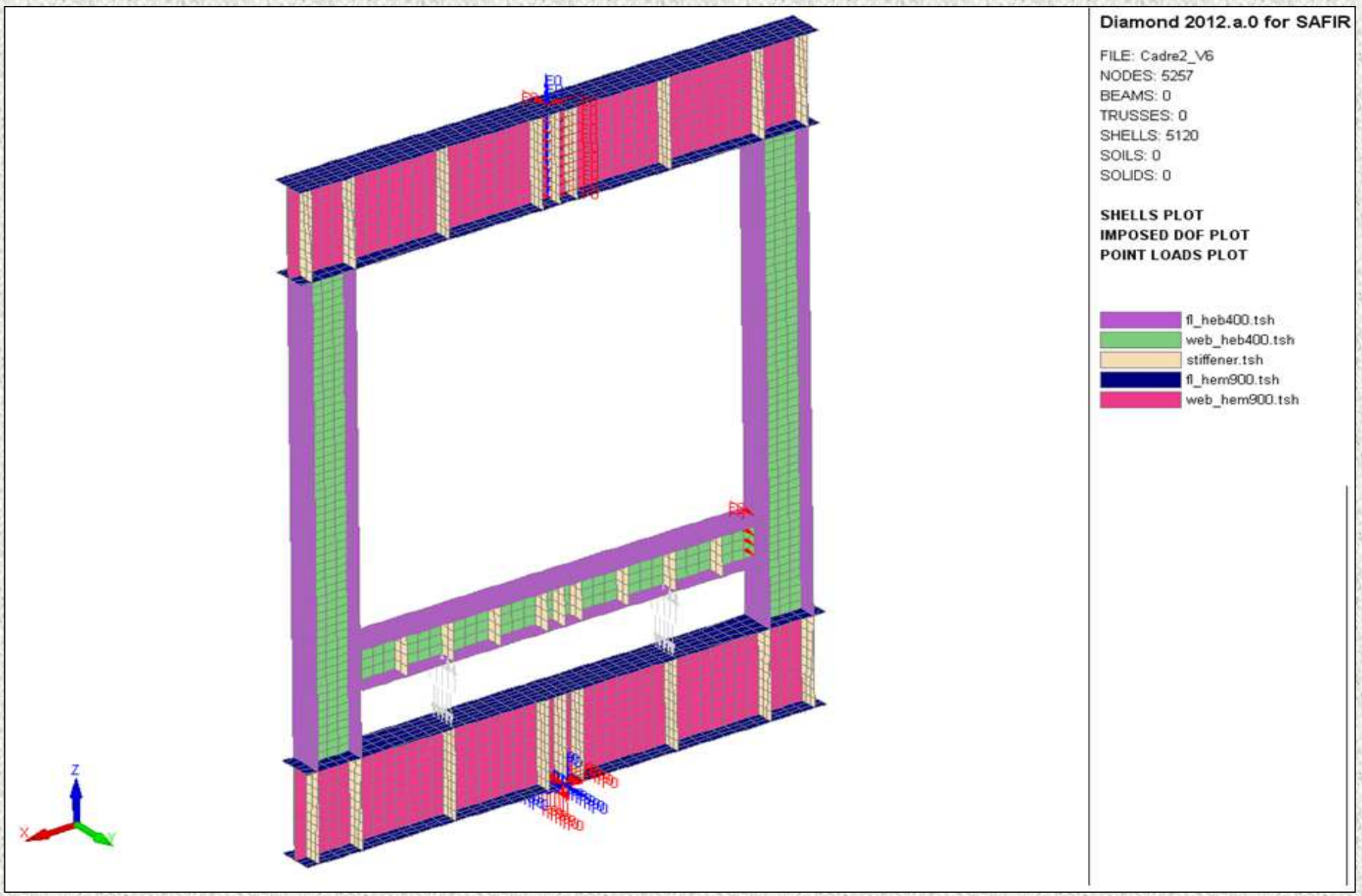
Experimental tests are performed to validate and callibrate numerical models.

But how can numerical models be helpfull to experimental tests?

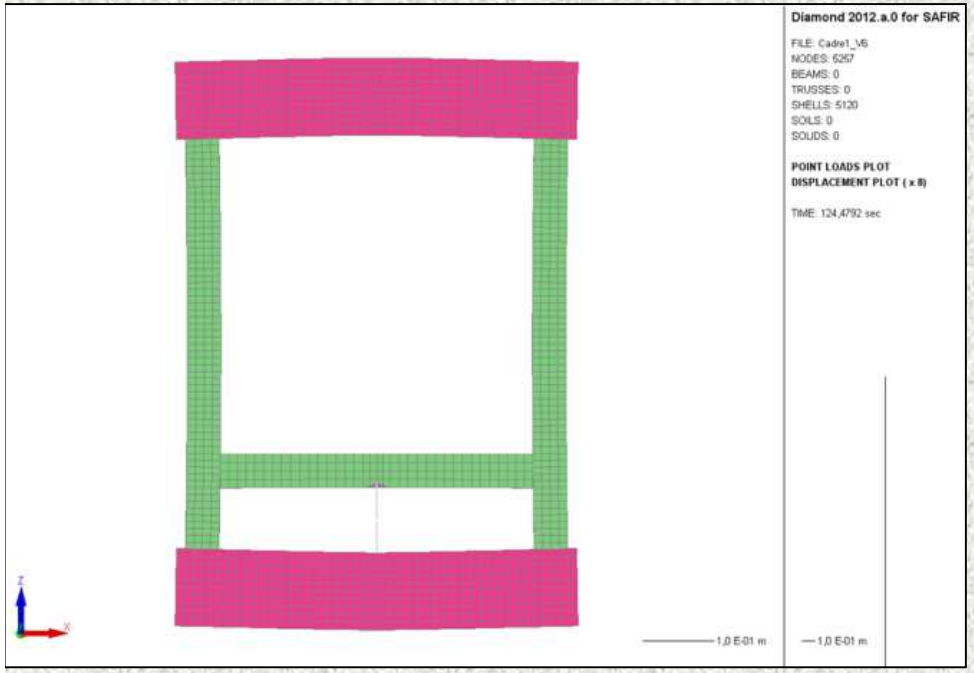
1) Calculate precisely the flexibility of the loading frame.

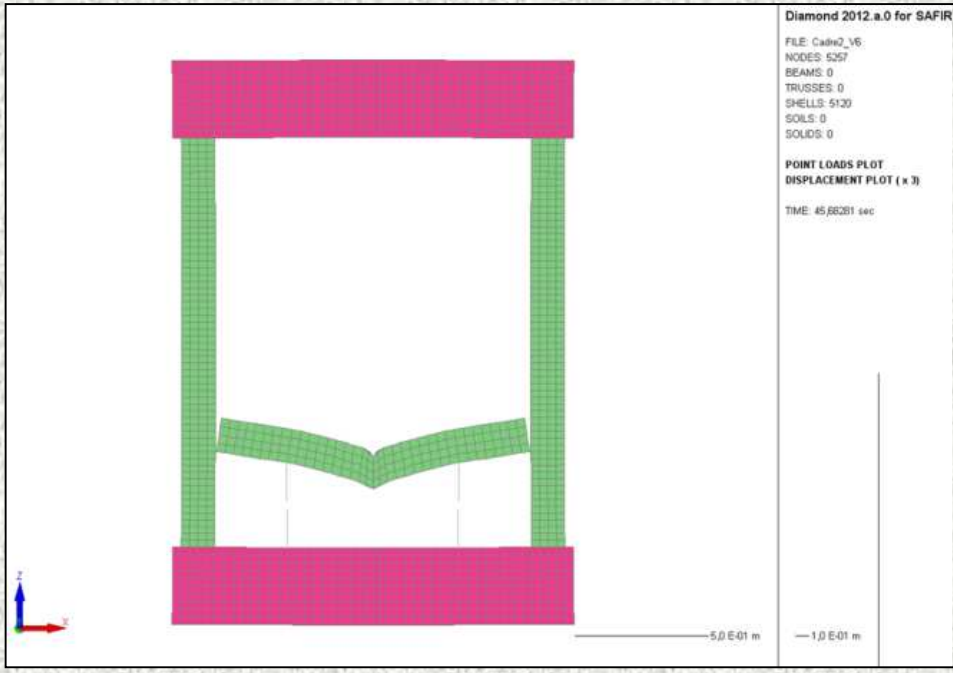


The frame



The numerical model



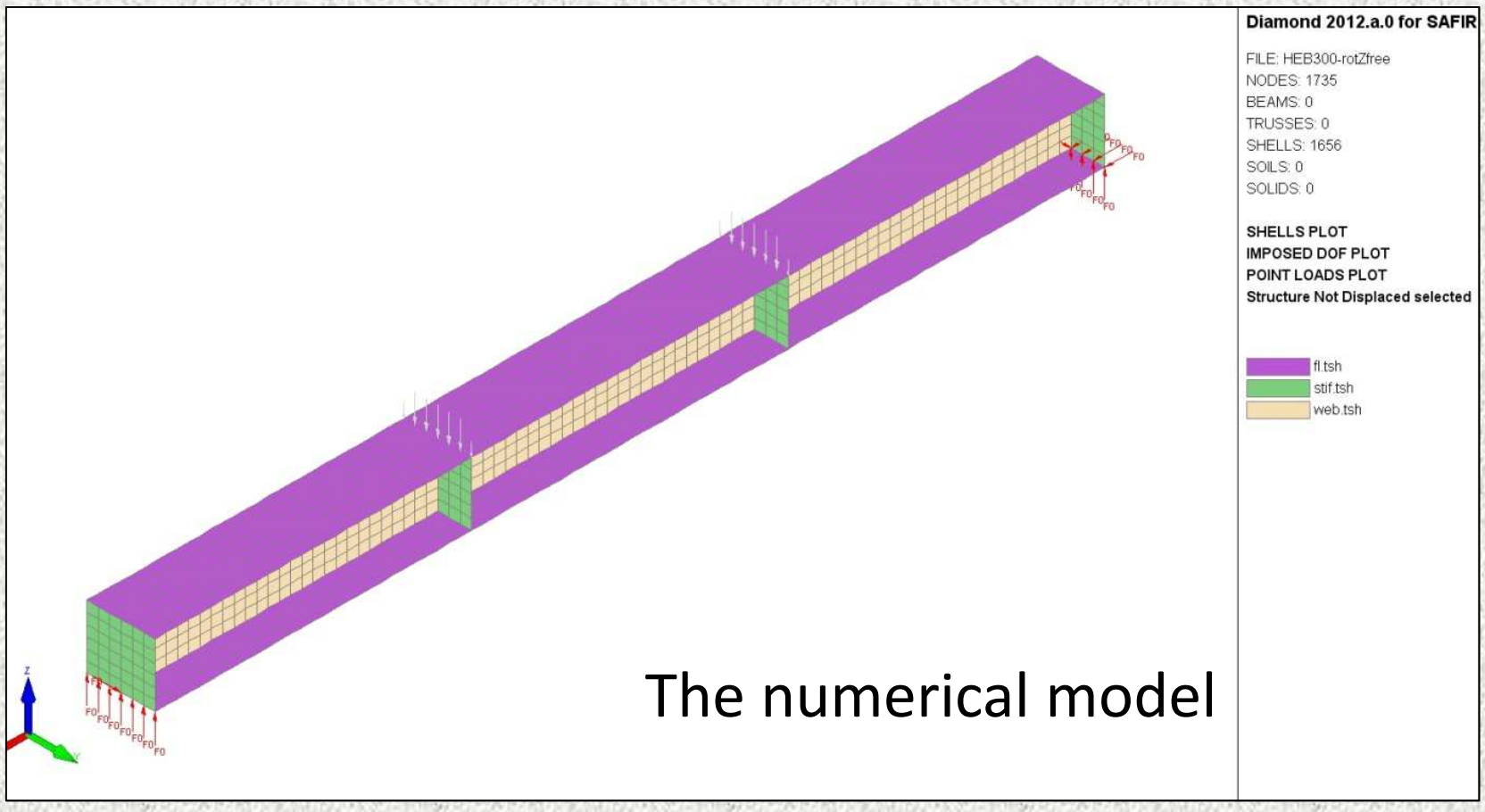


The deformed shape for 2 loading arrangements

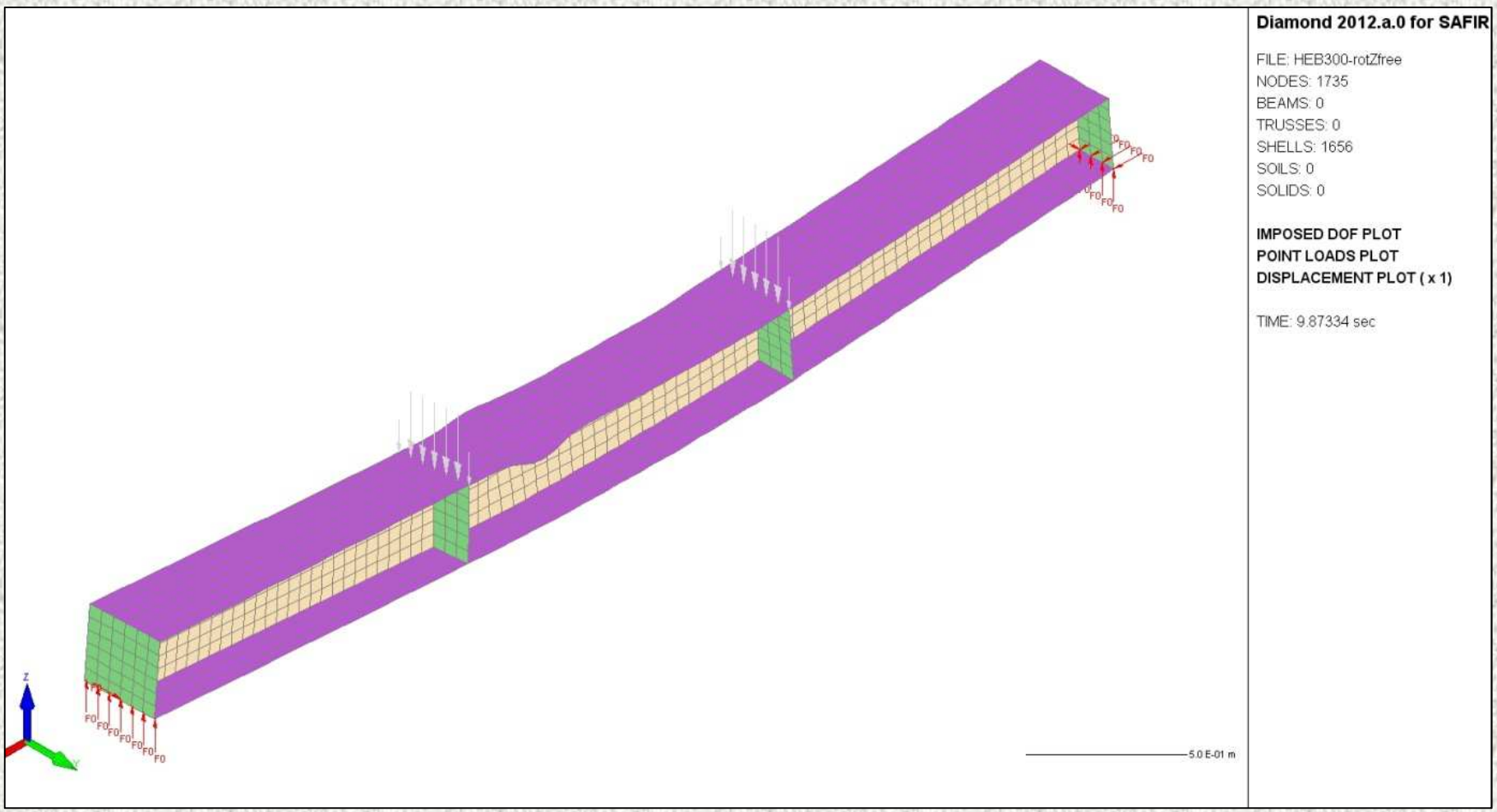
=> Flexibility = … mm/kN

2) Verify that no undesirable failure mode will develop.

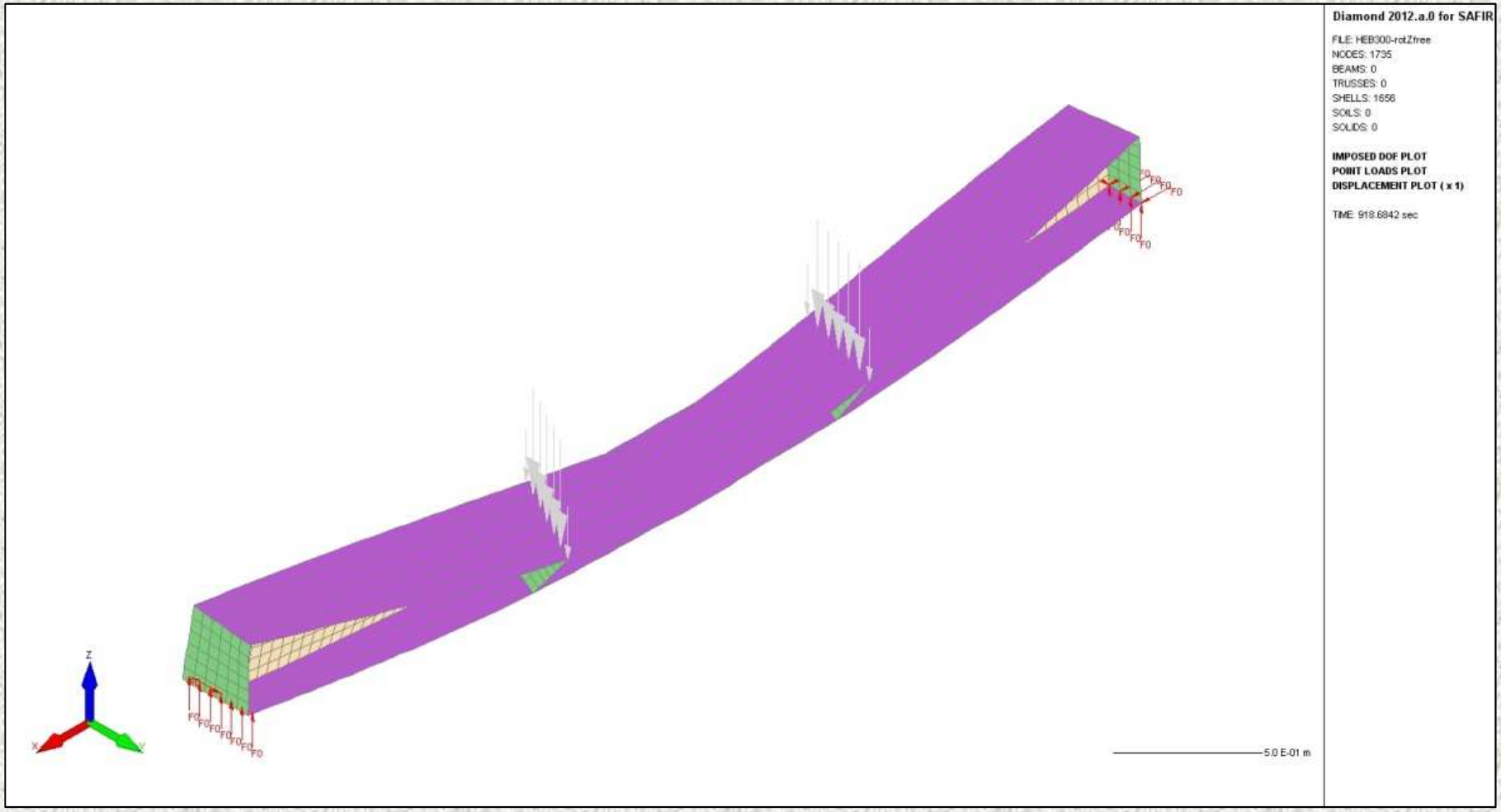
Example 1: a steel beam with an H section that must not exhibit lateral torsional buckling



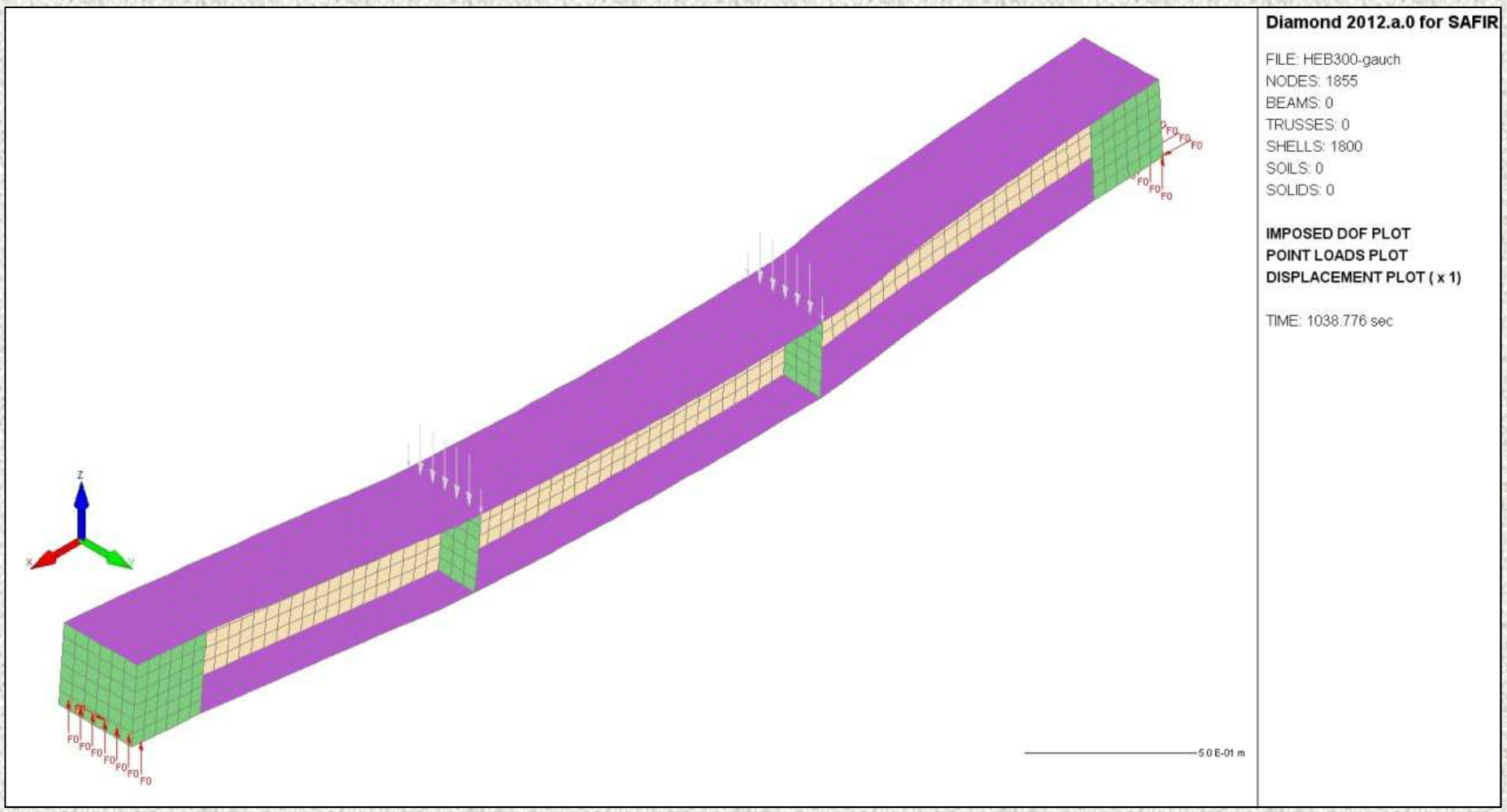
The numerical model



Failure mode at room temperature



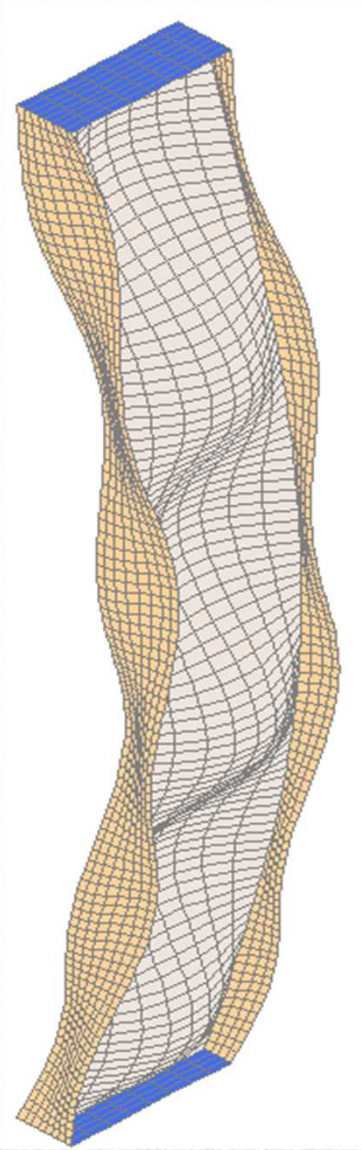
Lateral torsional buckling is predicted at elevated temperatures.



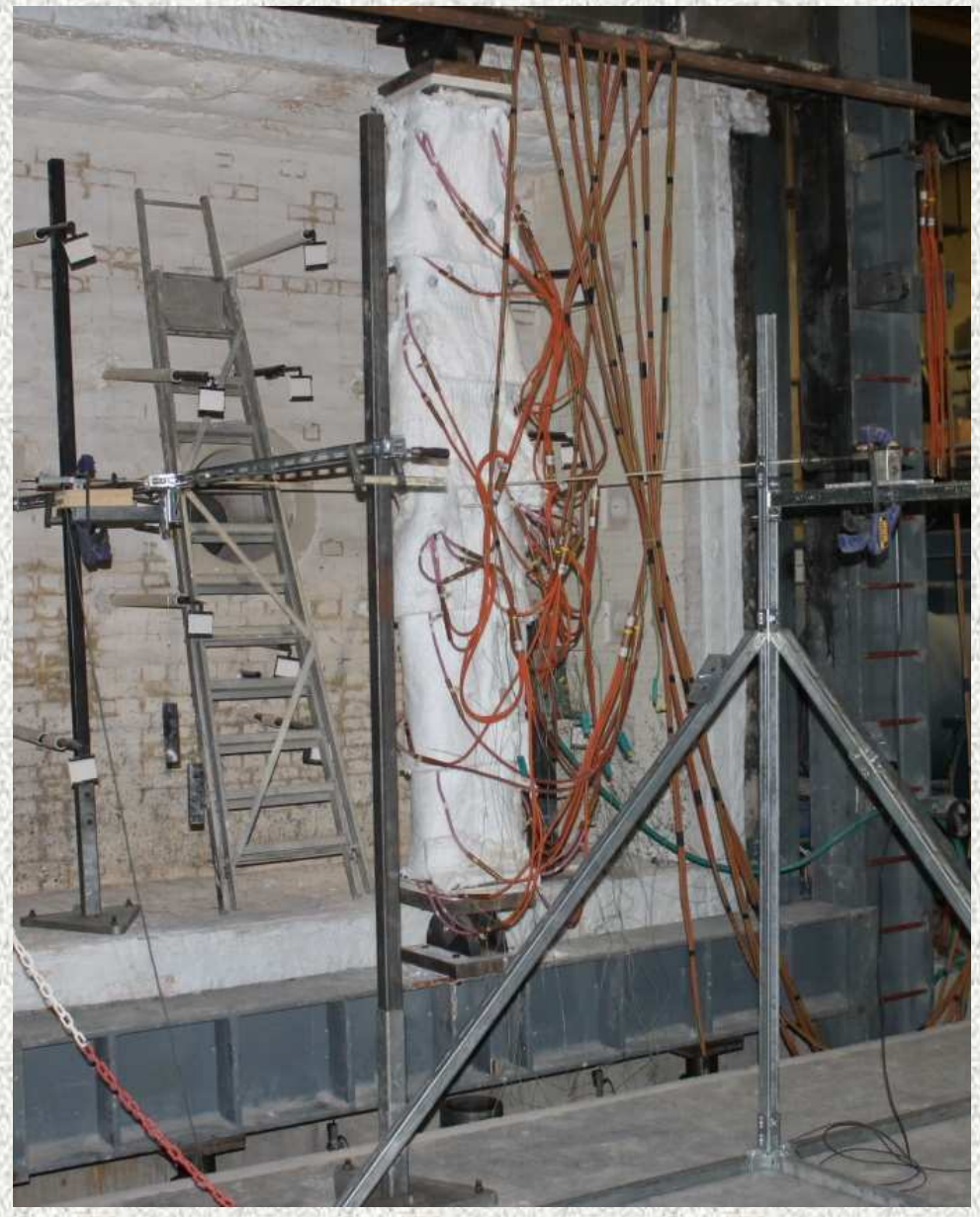
When warping is restrained near at the ends of the beam,
Lateral torsional buckling is prevented without the need to provide complex and expensive lateral supports in the span.

2) Verify that no undesirable failure mode will develop.

Example 2: a steel column that must not fail in the direction of the week axis



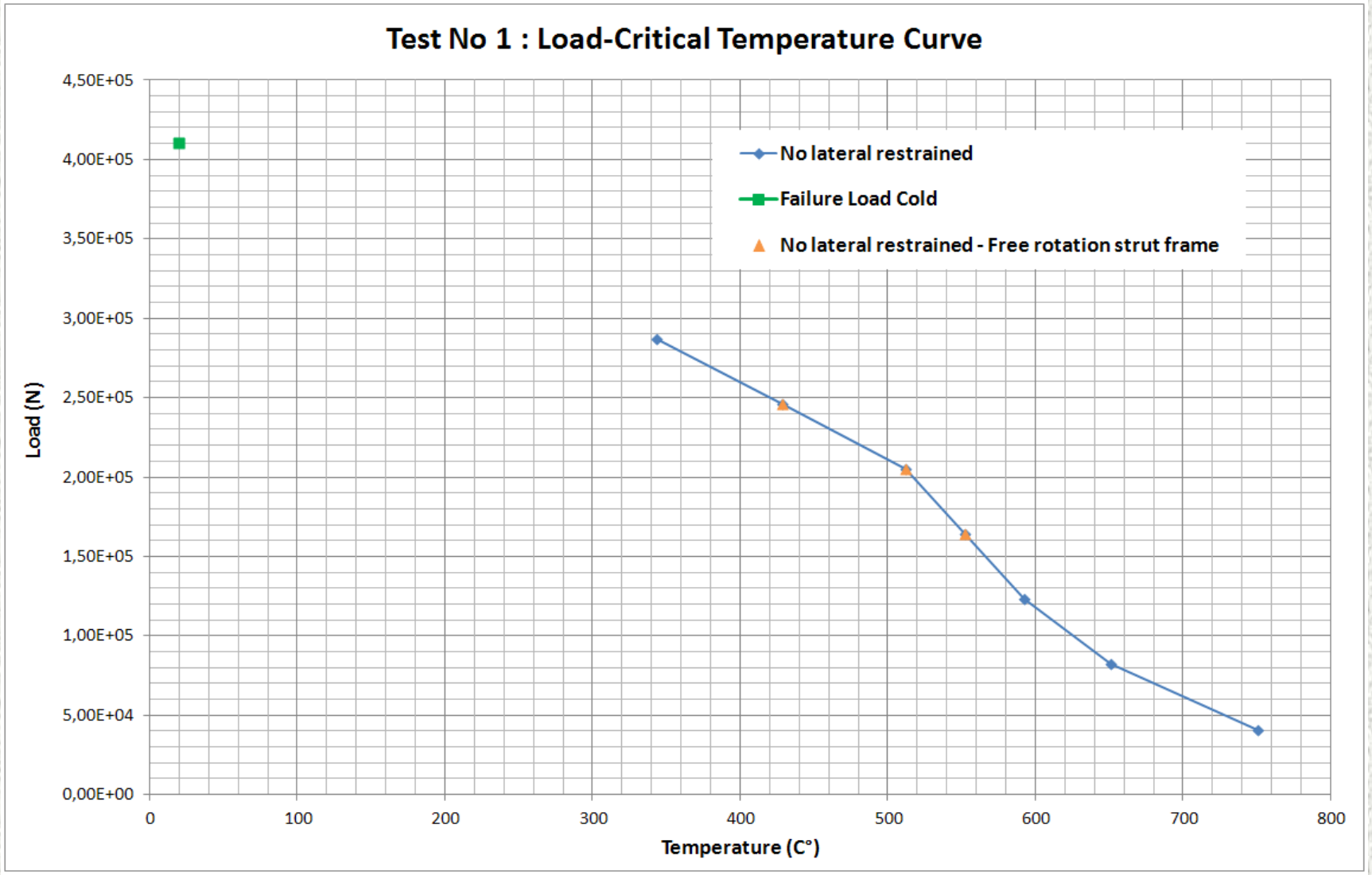
The numerical model



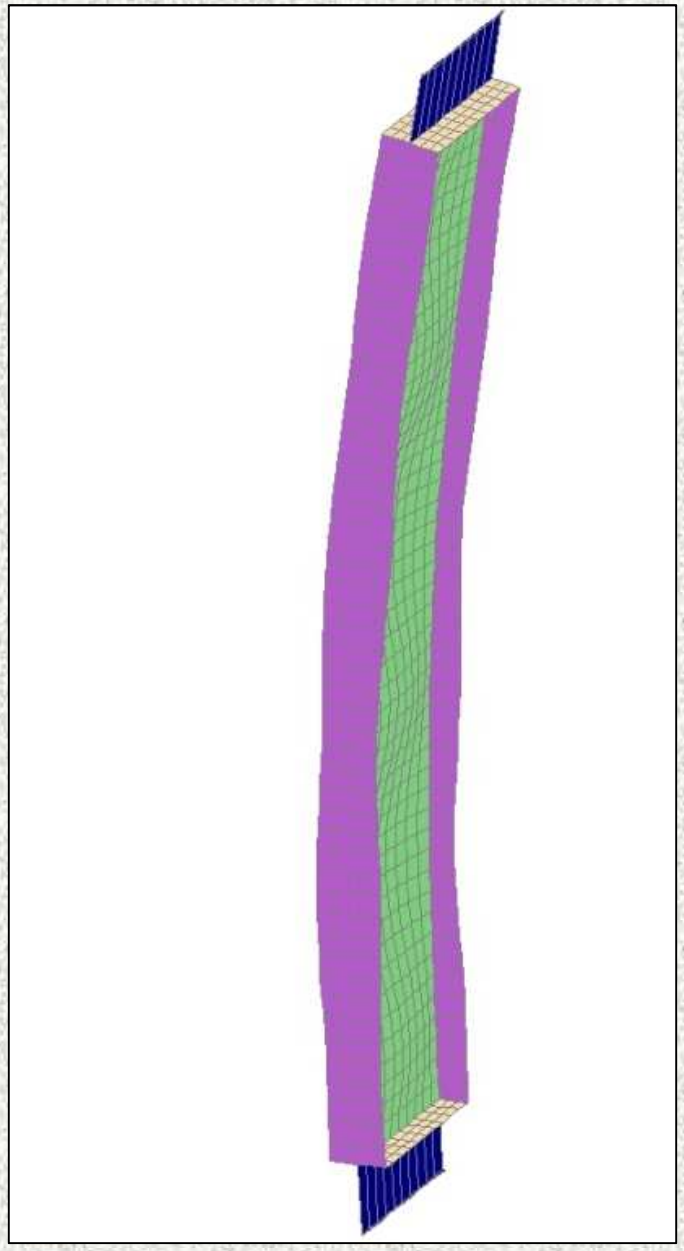
The column
before the test

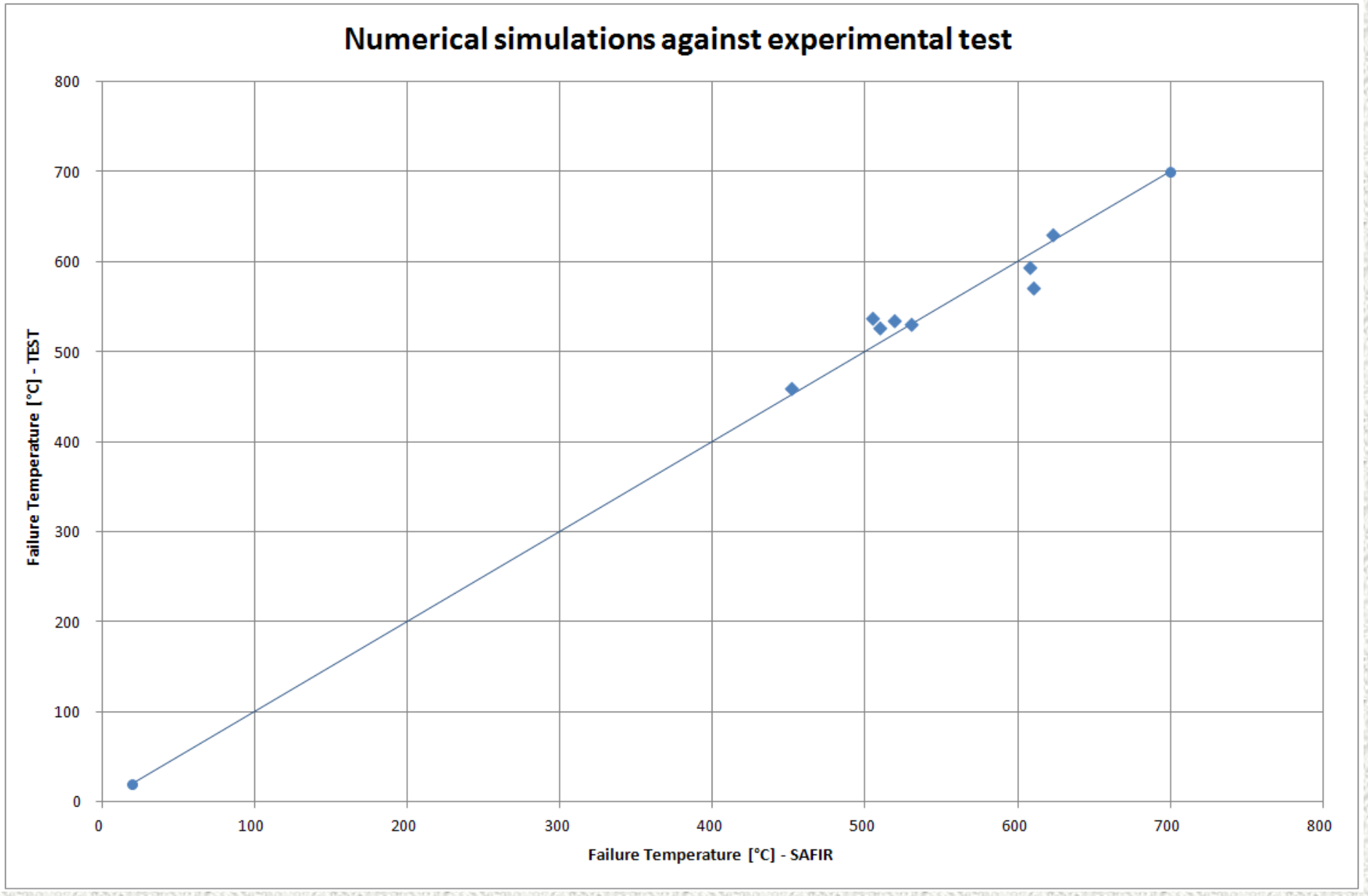
The column after the test

3) Choose the load to apply in order to reach a desired failure temperature.



A curve giving the failure temperature as a function of the applied load





Good correlation between the calculated and the experimental failure temperatures for 8 tests.

4) Estimate the influence of the real temperature distribution (gradient on the height of the column, cooling near the ends by conduction to the supports).

Three stainless steel columns

Theory and boundary conditions predict a failure mode with 3 plastic hinges.
The test showed only 2 clear hinges.
The vertical temperature gradient that was measured in the test was introduced in numerical simulation and could explain the oberved failure mode.

Additional advantages of being a university:

- ✓ Other laboratories are available to test other properties: structural lab, acoustic lab, material lab…
- ✓ High level of qualification of the staff, with long term experience.
- ✓ Scientific curiosity (gives you more than just a shear global result).
- ✓ No share holders to pay.