The development of Structural Fire Engineering over the past 25 years and issues for the future

Jean-Marc Franssen

The development of Structural Fire Engineering
over the past 25 years !
and issues for the future

=> Back to 1990…. Or 1982? Or earlier?

EUROPEAN CONVENTION FOR CONSTRUCTIONAL STEELWORK

INTERNATIONAL ASSOCIATION
FOR BRIDGE AND STRUCTURAL ENGINEERING

STABILITY OF STEEL STRUCTURES

PRELIMINARY REPORT

LIEGE

13 - 14 - 15
APRIL 1977

Second International Colloquium

IN CO-OPERATION WITH

STRUCTURAL STABILITY RESEARCH COUNCIL
COLUMN RESEARCH COMMITTEE OF JAPAN

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1) Behaviour of materials

A lot has been done already, at least on « traditional » materials

A lot has been lost (or ignored)

Sonderforschunsbereich 148

1) Behaviour of materials

A lot is still being done.

Please use published recommendations.

RILEM recommendations

1) Behaviour of materials

Old fashioned approach

- *Take material model at room temperature*
- *List the parameters of the model*
- *Measure these parameters at elevated temperature*

Better approach

- *Choose a material model at elevated temperature*
- *List the parameters of the model*
- *Measure these parameters at elevated temperature*

Material nehaviour has been « normalised » (in Eurocodes)

Is it a good thing?

Workshop on material properties at elevated temperatures
ECCS, Arnhem, The Netherland, June 12, 1986

2) Tests on structural members or structures

Tests on small scale structures?

Not for all materials (OK for metals)

Not so popular anymore

2) Tests on structural members or structures

Test on large structures (Cardington)

Very expensive

What to look for?

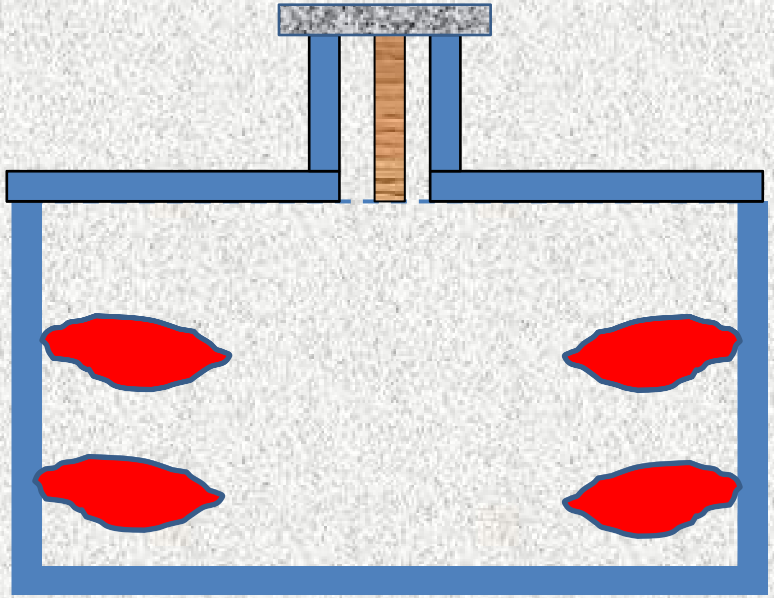
=> Not so common

2) Tests on structural members or structures

Test on elements?

- Q1: Do we need it or not?
- Q2: ISO fire or not?
- Use of plate thermometer
- ISO 17025?

"General requirements for the competence of testing … laboratories"



Make your tests in a laboratory that has accreditation ISO 17025

3) Tabulated data

- Have been there for a while
- No significant breakthrough

Résistance au feu normalisé	Dimensions minimales (mm) Largeur des poteaux b_{min}/ distance axe-parement a des barres principales			
	Poteau exposé sur plus d'un côté			Poteau exposé sur un seul côté
	[illegible]	μ_{fi} = 0.5	μ_{fi} = 0.7	μ_{fi} = 0.7
1	2	3	4	5
R 30	[illegible]	[illegible]	200/32 300/27	155/25
R 60	[illegible]	[illegible]	250/46 350/40	155/25
R 90	200/31 300/25	300/45 400/38	350/53 450/40**	155/25
R 120	250/40 350/35	350/45** 450/40**	350/57** 450/51**	175/35
R 180	350/45**	350/63**	450/70**	230/55
R 240	350/61**	450/75**	-	295/70

** Minimum 8 barres

Pour les poteaux en béton précontraint, il convient de noter l'augmentation de la distance de l'axe au parement selon 4.2.2. (4).

4) Simple calculation methods

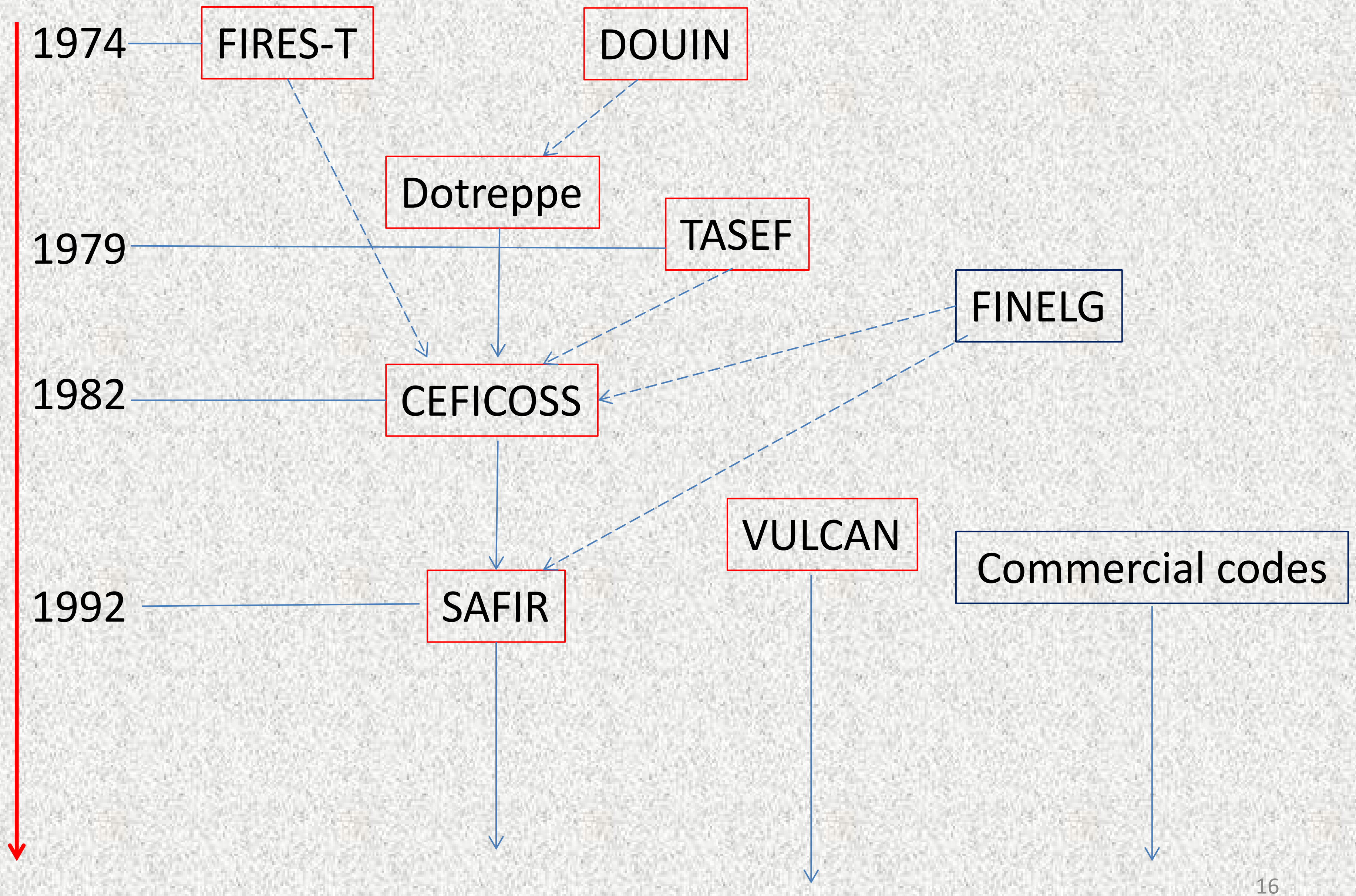
- Have been there for a while.

The little red book?

European Recommendation for the Fire Safety of Steel Structures, ECCS, 1983.

- No significant breakthrough

5) Advanced calculation models



Aims and capabilities of numerical modelling

- To reproduce a standard fire test (beam, then column)
- To analyse 2D frames (ISO curves, then other *increasing* curves)
- To represent 3D frames
- To combine different finite element types (beams, shells)
- Dynamic analyses
- Analyse local details (joints – volumic elements)

Failure mode <= Fire resistance time

Q1: Which materials can we use in simulations?

A priori all of them

BUT

on the condition that we know the properties of the model.

$\Rightarrow$ Know your model and its limits

Challenges for thermal calculation

- Contact resistance between two materials.
- Effects of large displacements (the structure moves to the fire).
- Moisture
- Behaviour during cooling
- Changes of geometry (charring, expansion, spalling)

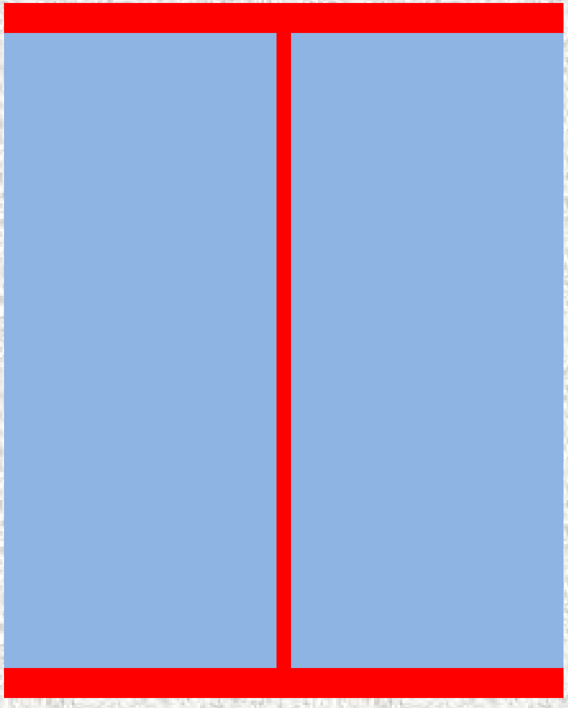
Q2: What kind of structure can we model?

Practically none

except if….

we tested a similar one before

One example: composite steel-concrete column.



The solution is easy:

Just model every possible physical phenomena.

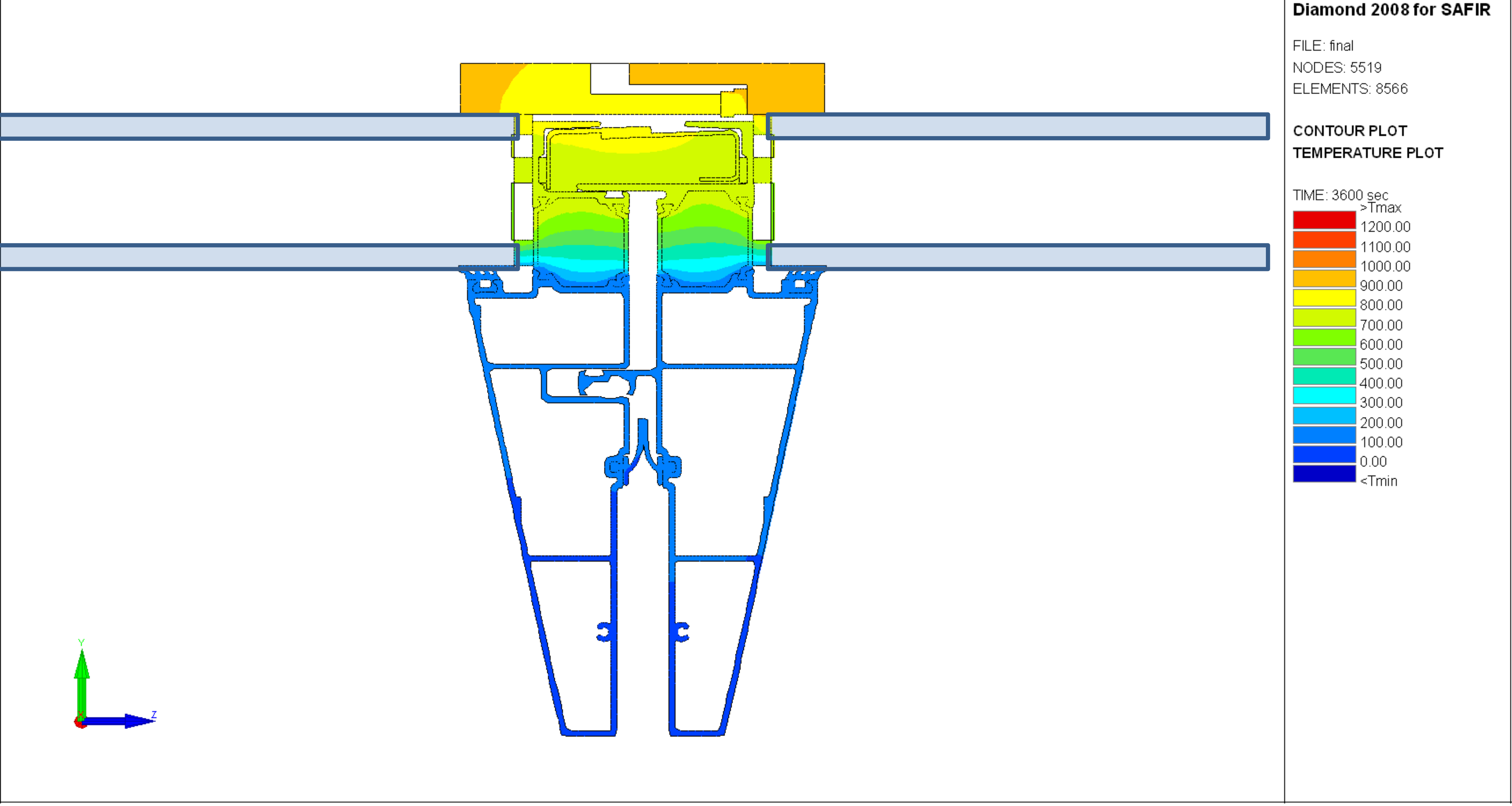
- ✓ 3D solid elements,
- ✓ changes of geometry,
- ✓ contacts,
- ✓ full thermo – hydro – visco – dynamic - mechanical coupling.
- ✓ ...

Good luck!

Have we made some progress in structural fire modelling?

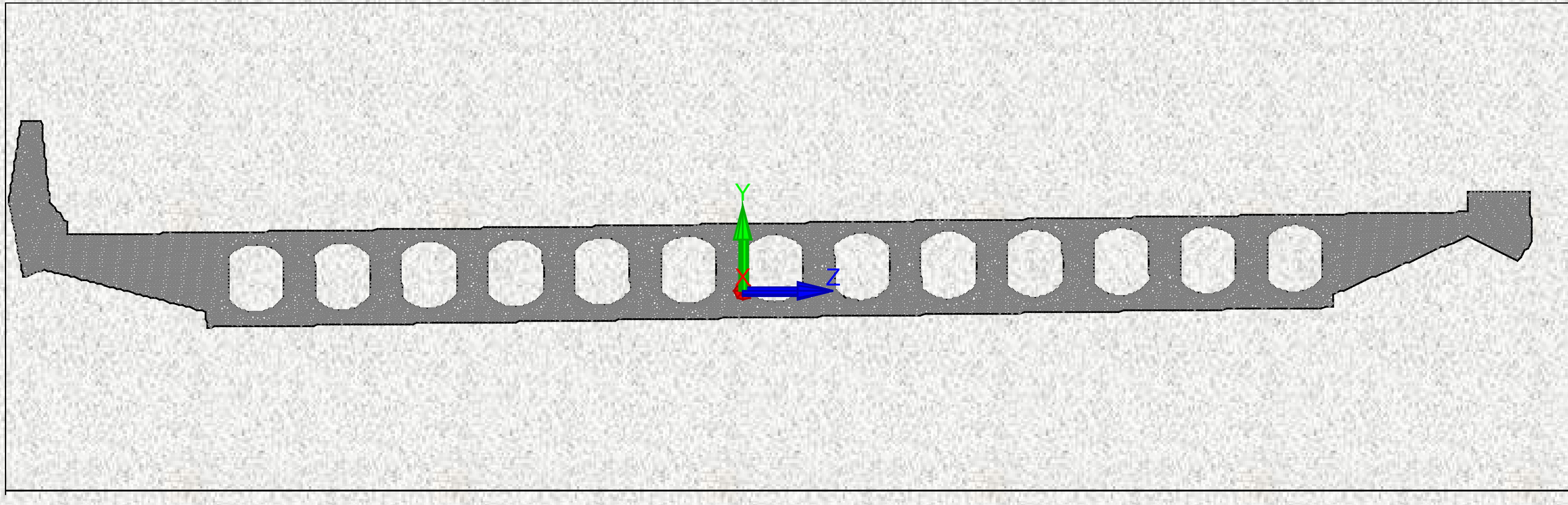
- ✓ Capabilities of the software
- ✓ What is the direction in the stress-strain plane for the next time step, loading or unloading?
- ✓ How are the residual stresses in steel sections influenced by a fire?

Some nice examples (made with SAFIR)

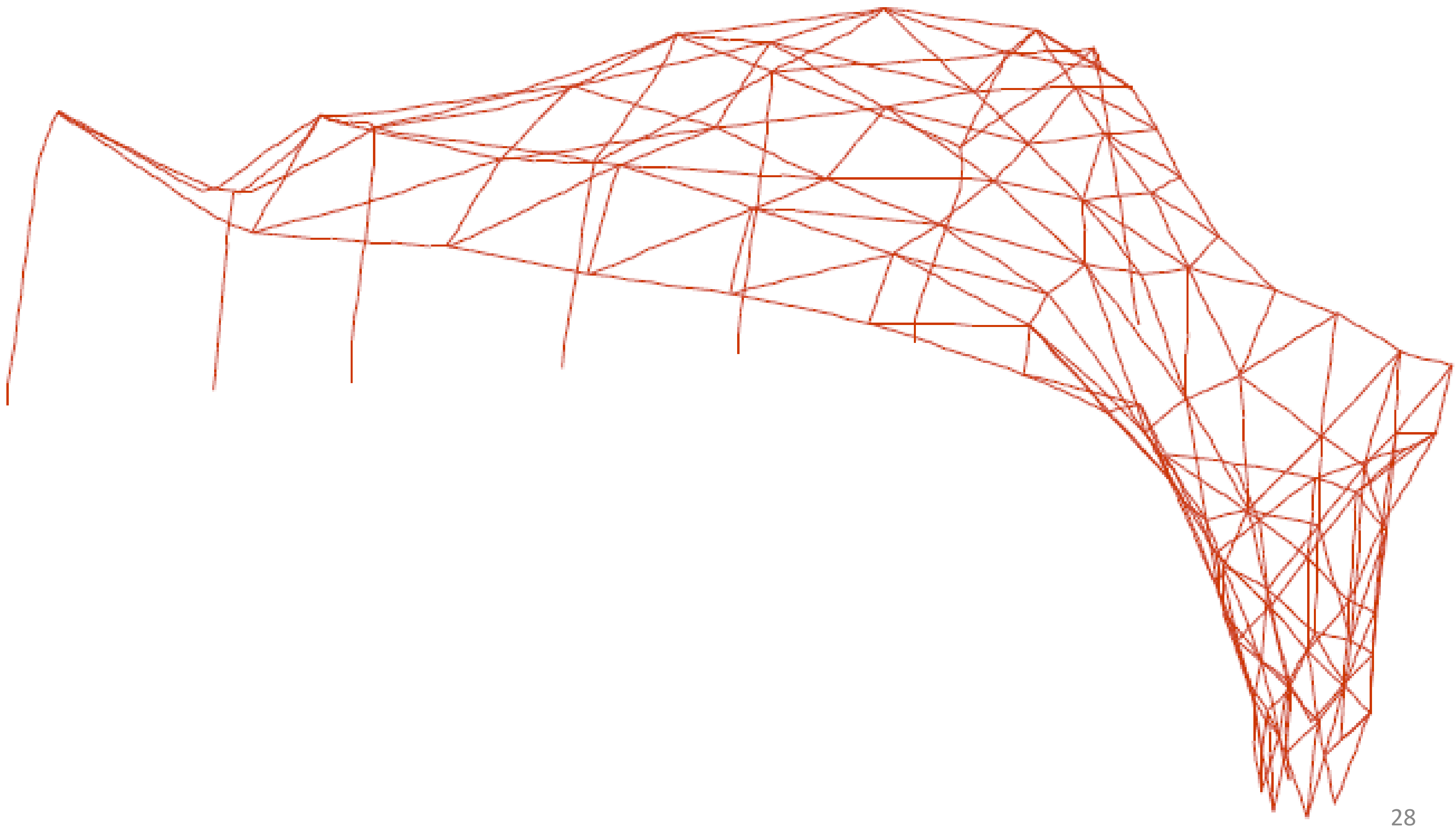


Window frame (courtesy: Permasteelisa)

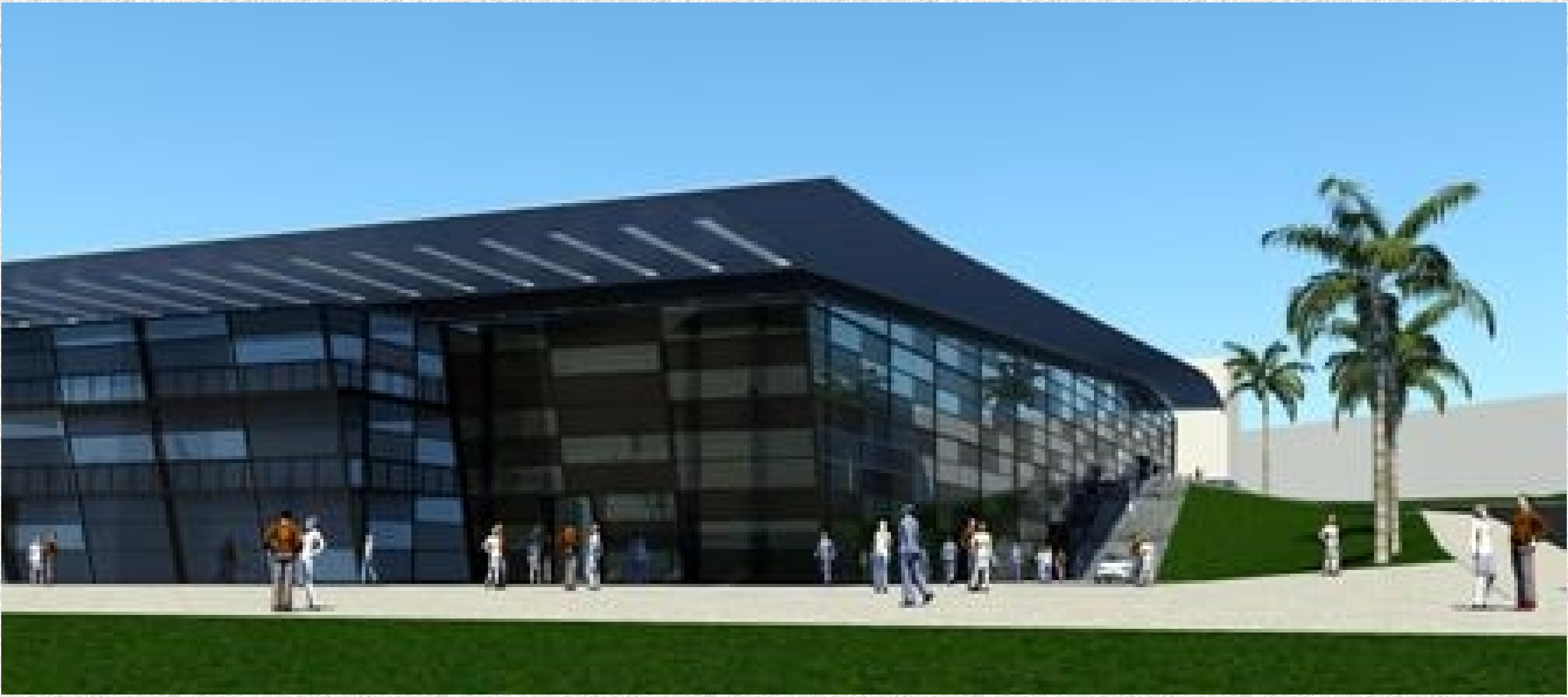
The deck of a concrete bridge (author unknown)



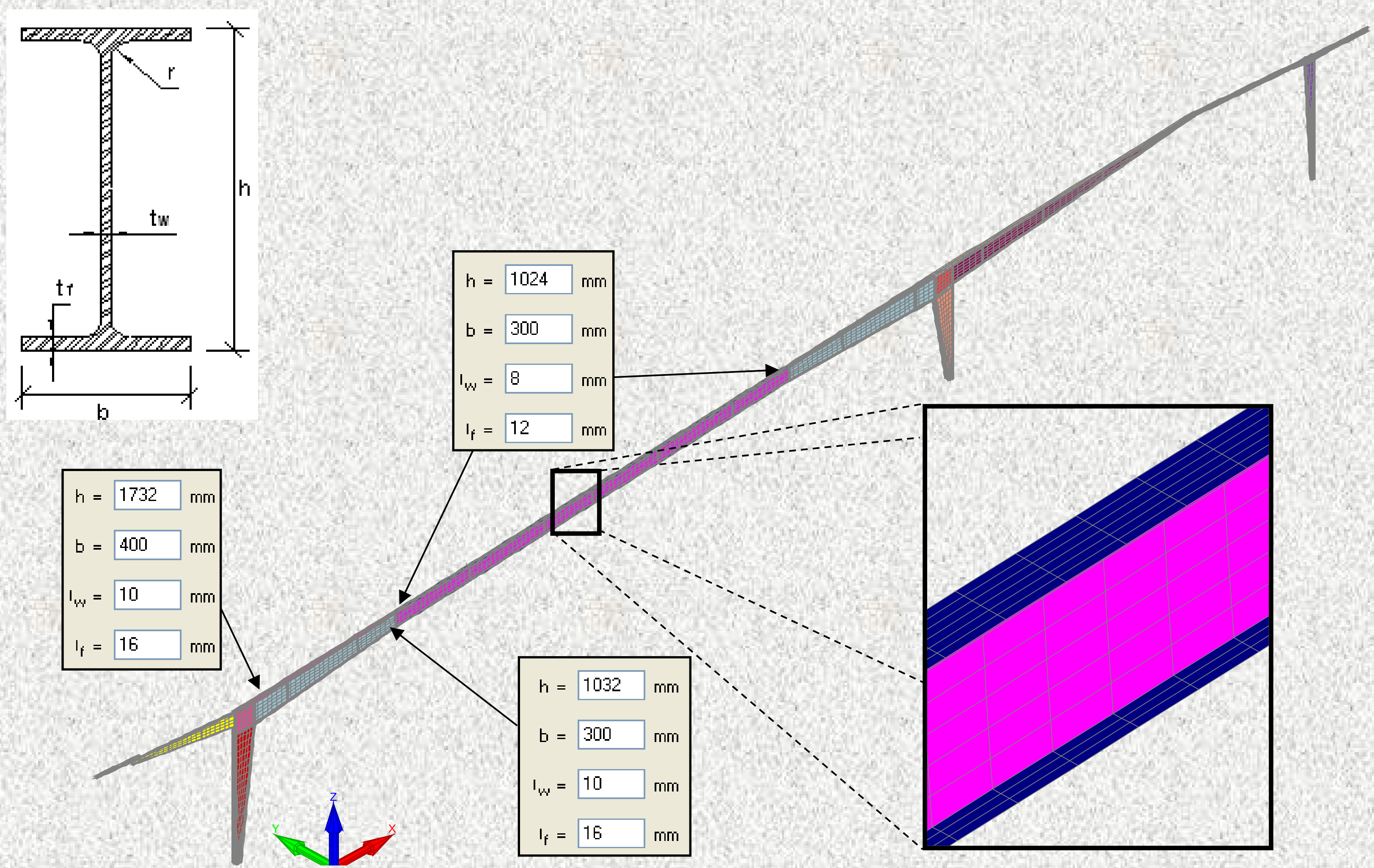
3D eye catcher, Brussels airport
Model: StuBeCo (courtesy Tom Molkens)

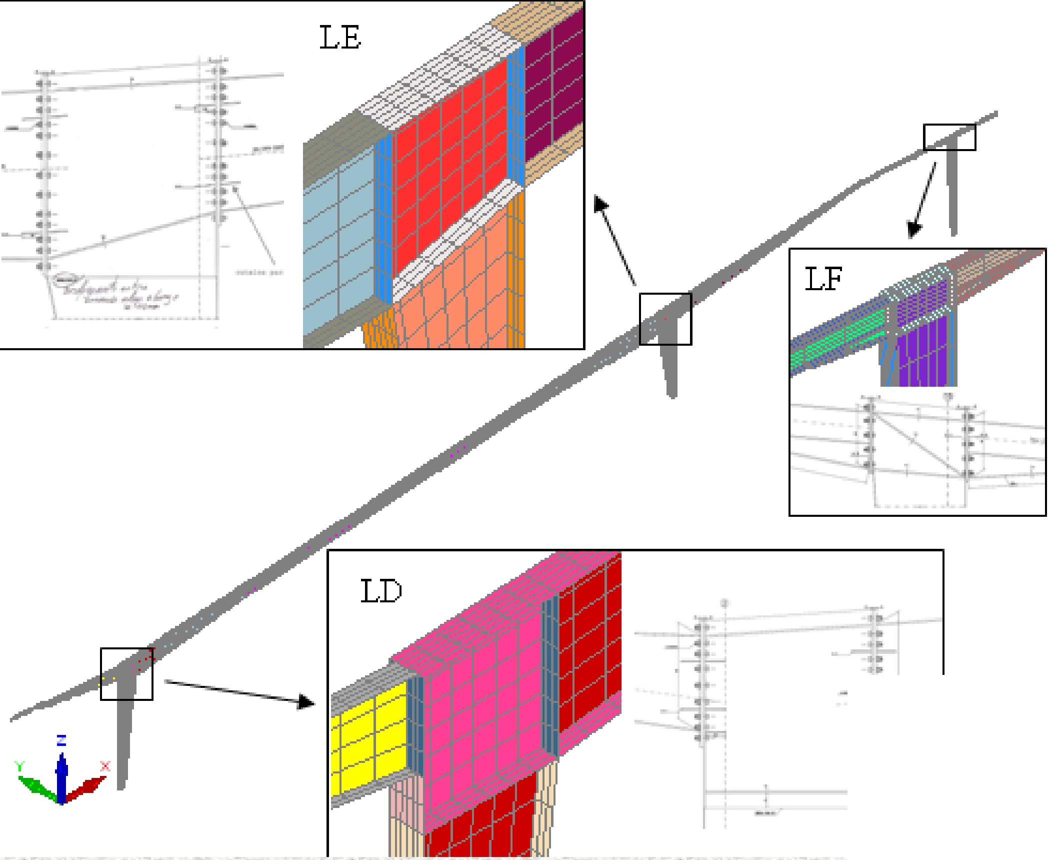


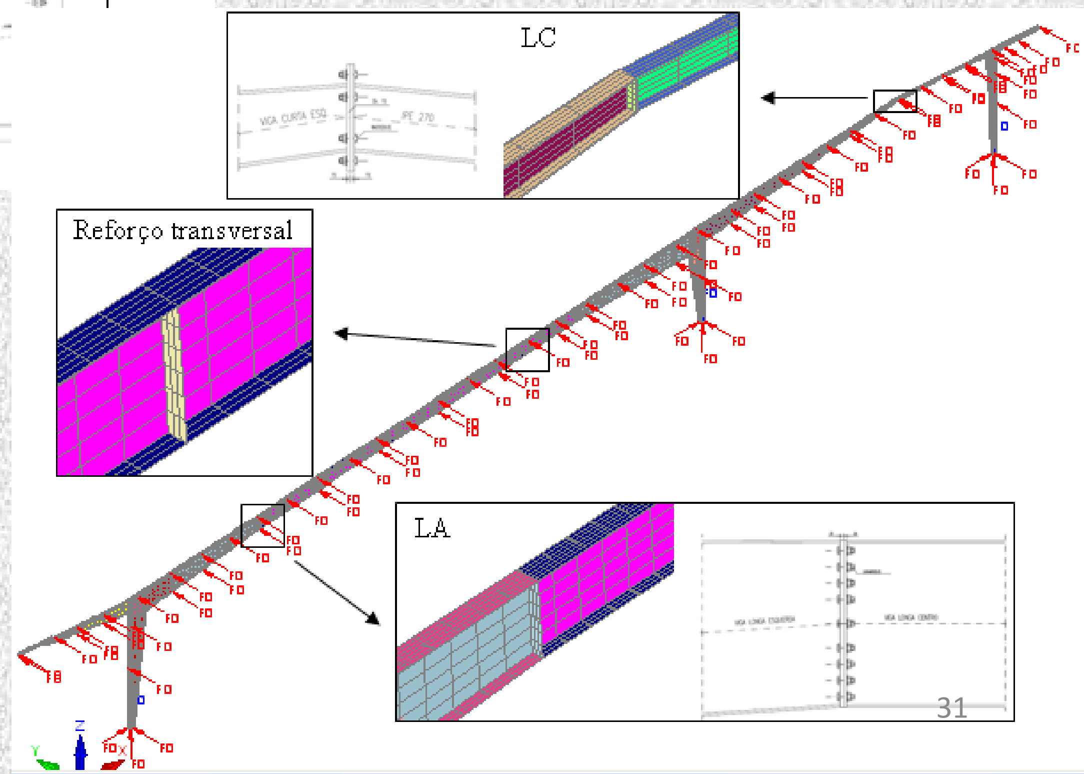
Oeiras Valley Convention Center, Oeiras PT
Luis Neto, arch.

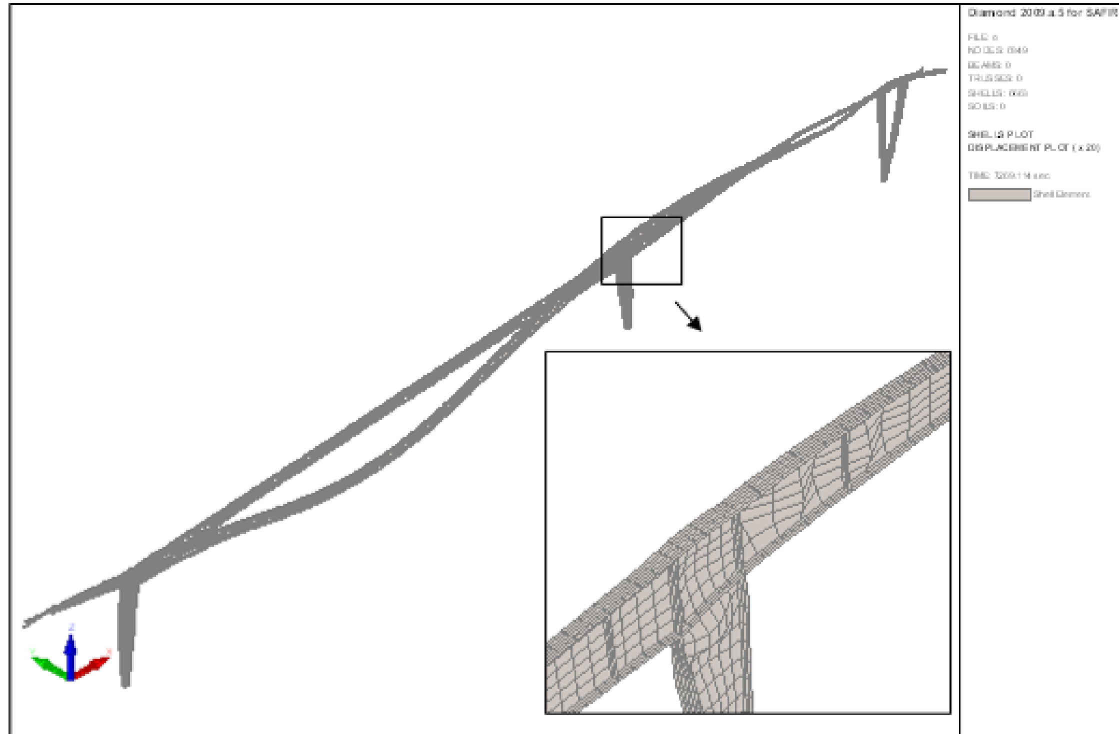


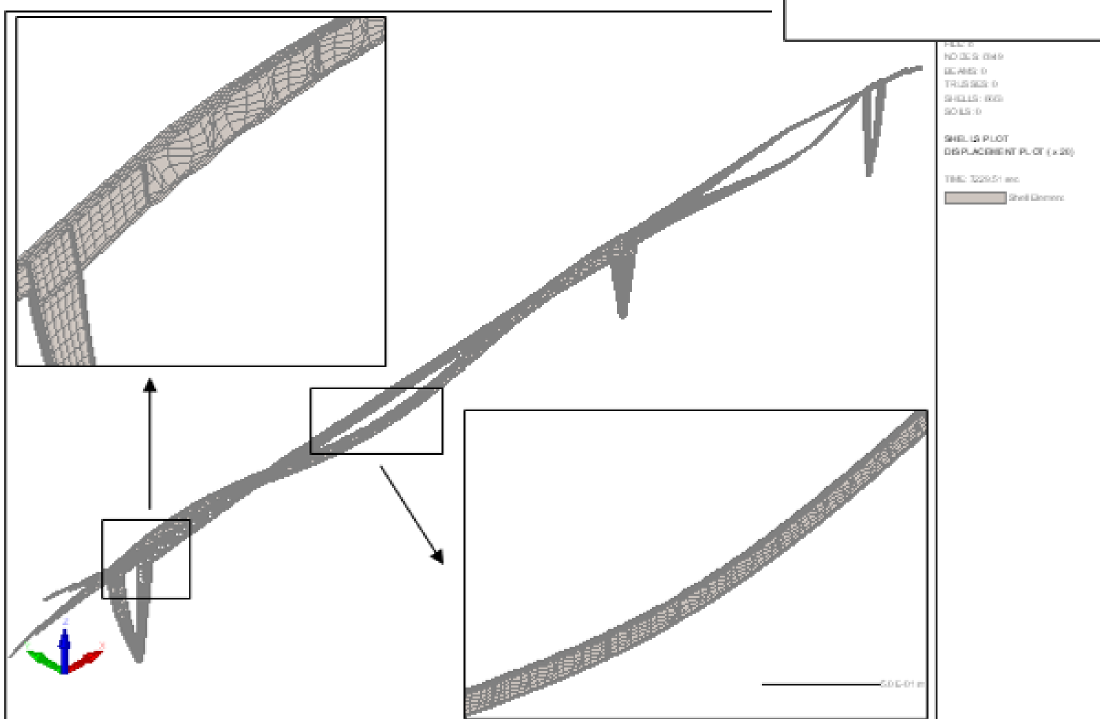
Model: Univ. of Aveiro (courtesy Paolo Vila Real & Nuno Lopes)



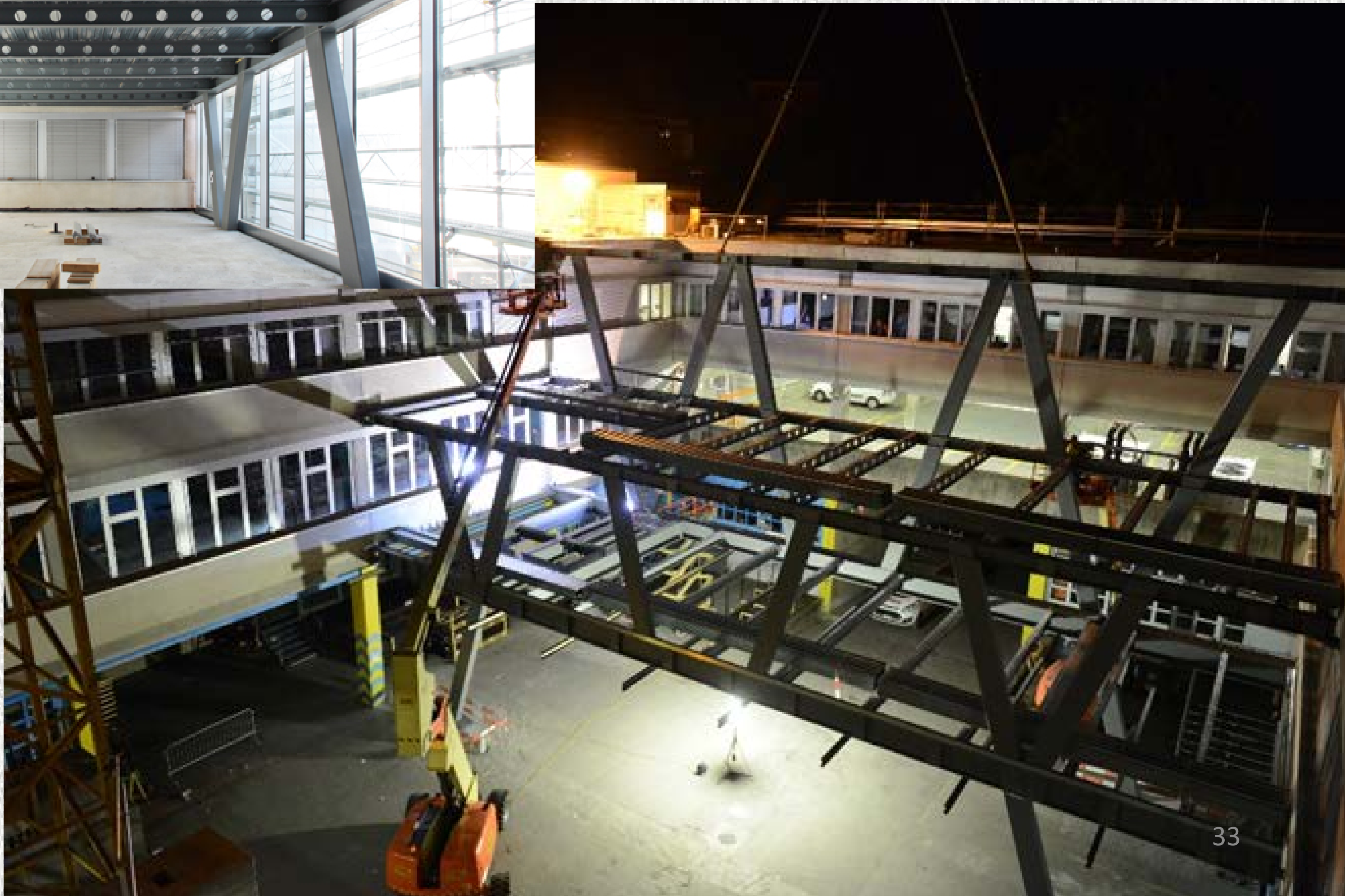

LE
LF
LD


LC
Reforço transversal
LA

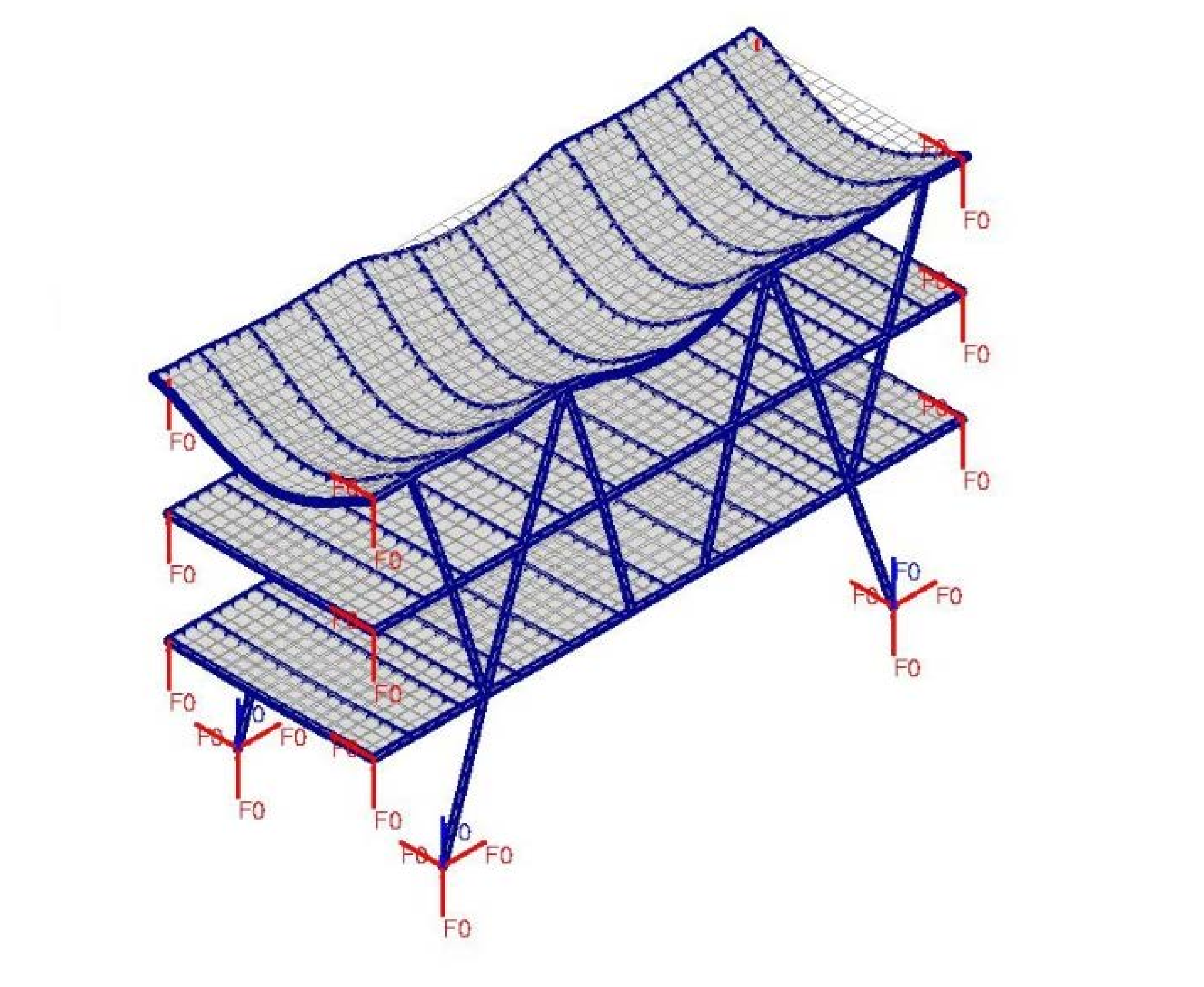

Diamond 2009.a.5 for SAFIR
BEAMS: 0
TRUSSES: 0
SOILS: 0
SHELLS PLOT
DISPLACEMENT PLOT (x 20)


BEAMS: 0
TRUSSES: 0
SOILS: 0
SHELLS PLOT
DISPLACEMENT PLOT (x 20)

Loterie romande, Lausanne CH
CHE architecture et Design Arch.

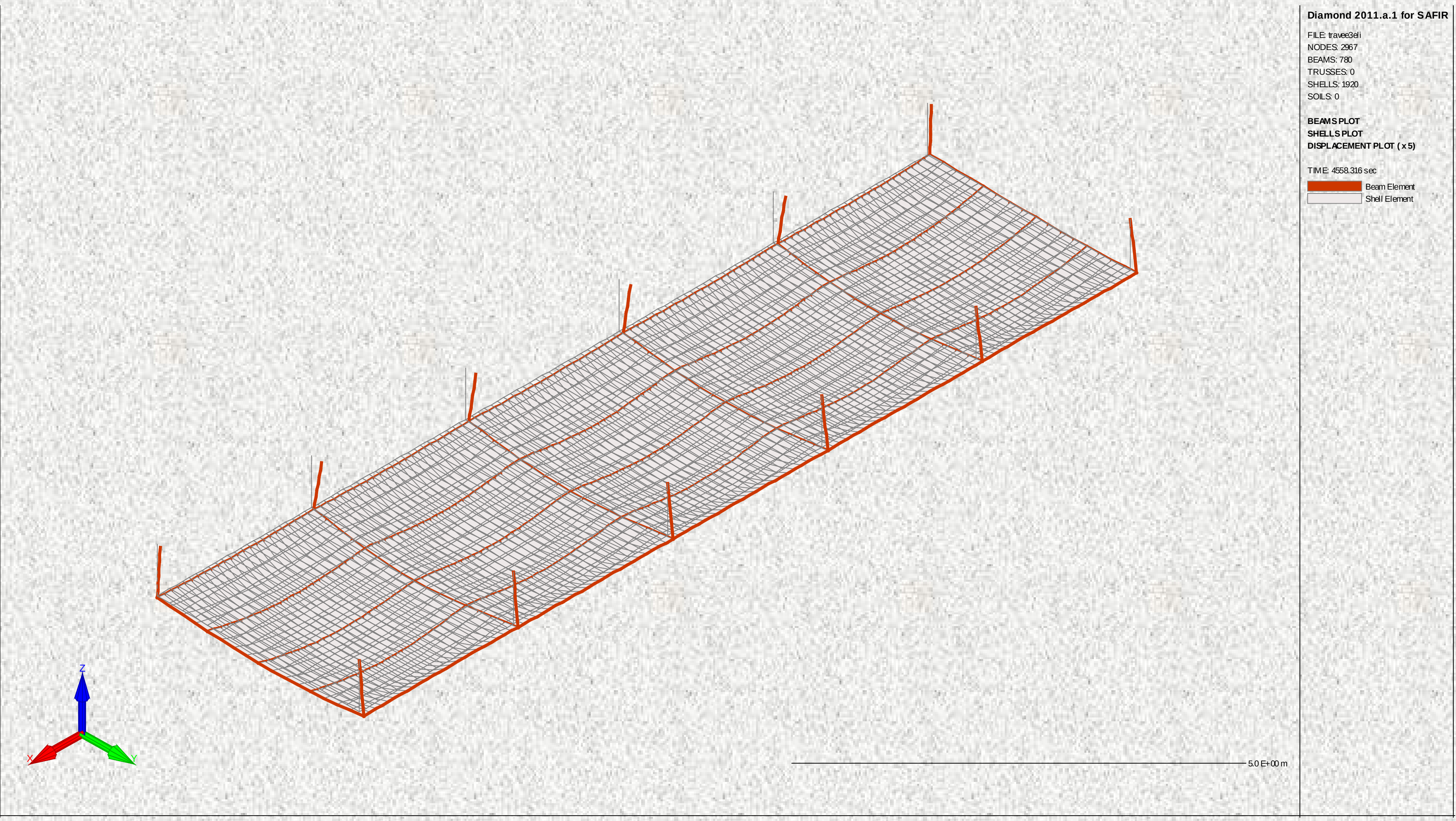


Model: Daniel Willi SA – Montreux CH (courtesy Olivier Burnier)

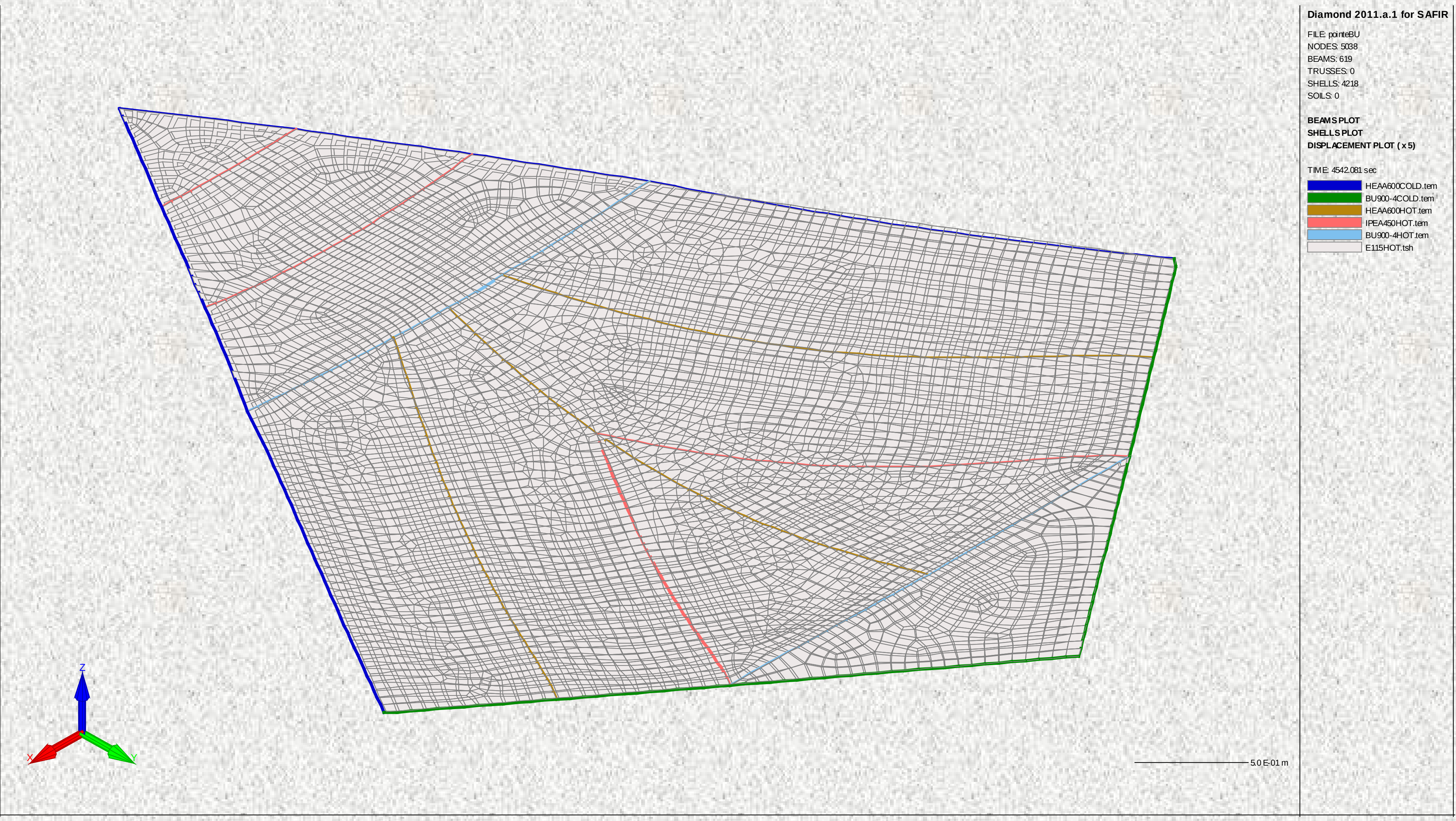


Japan Tobacco Intl, Geneva CH
SOM & Burckhardt Partner, Arch.

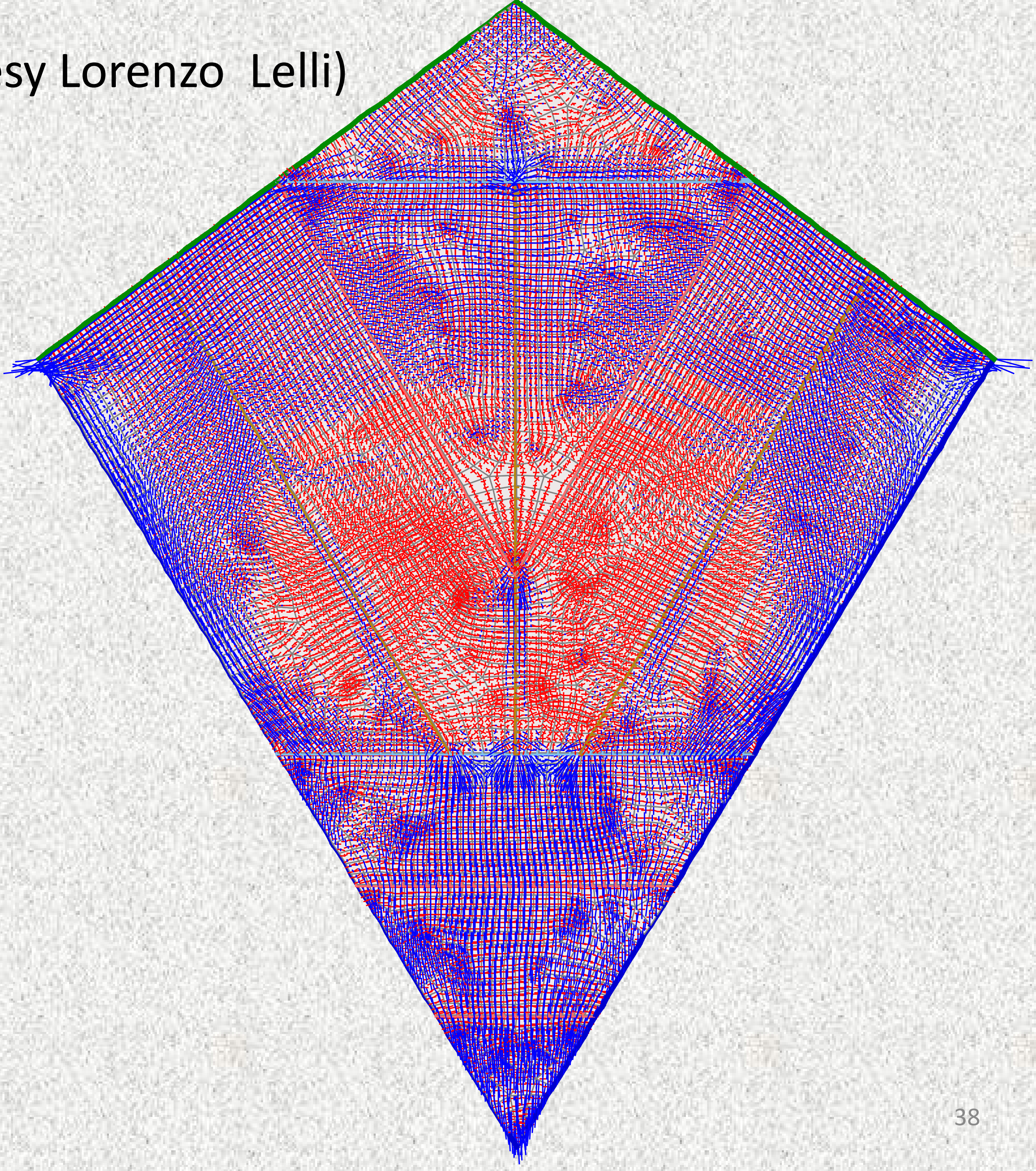
Model: Ingeni (courtesy Lorenzo Lelli)



Model: Ingeni (courtesy Lorenzo Lelli)



Model: Ingeni (courtesy Lorenzo Lelli)



Misuse of numerical modelling

Results of simulations are sometimes presented which show extremely ductile behaviour, typically for steel structures.
If several hypotheses which are at the base of the numerical model have been violated, such as Bernoulli hypothesis, small deformation, limited rotations, infinite strength of joints, interpenetration of adjacents elements, descanding branch in the stress-strain diagrams, etc, this is in our view a misuse of numerical modelling.

And the future?

I don’t know.

Probably:

- Simulation during the cooling phase
- New materials ans construction systems.
- Probabilistic aspects
- CFD-FE interaction
- Local fire models

I have some doubts

- Solid mechanics (3D finite elements)
- Prediction of spalling

9th intl Conf. Structures in Fire
8-10 June 2016, Princeton

Extended abstracts before December 14, 2015

[*https://sif2016.princeton.edu/*](https://sif2016.princeton.edu/)