Université de Liège

SAFIR®

SECURE WITH STEEL

ArcelorMittal, Esch-sur-Alzette

Annual meeting - October 27, 2016

New features in SAFIR® 2016

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1. Updated GiD-SAFIR interface
2. New SAFIR executable release
3. New DIAMOND release
4. Distribution and evolution policy
5. References

1. GiD

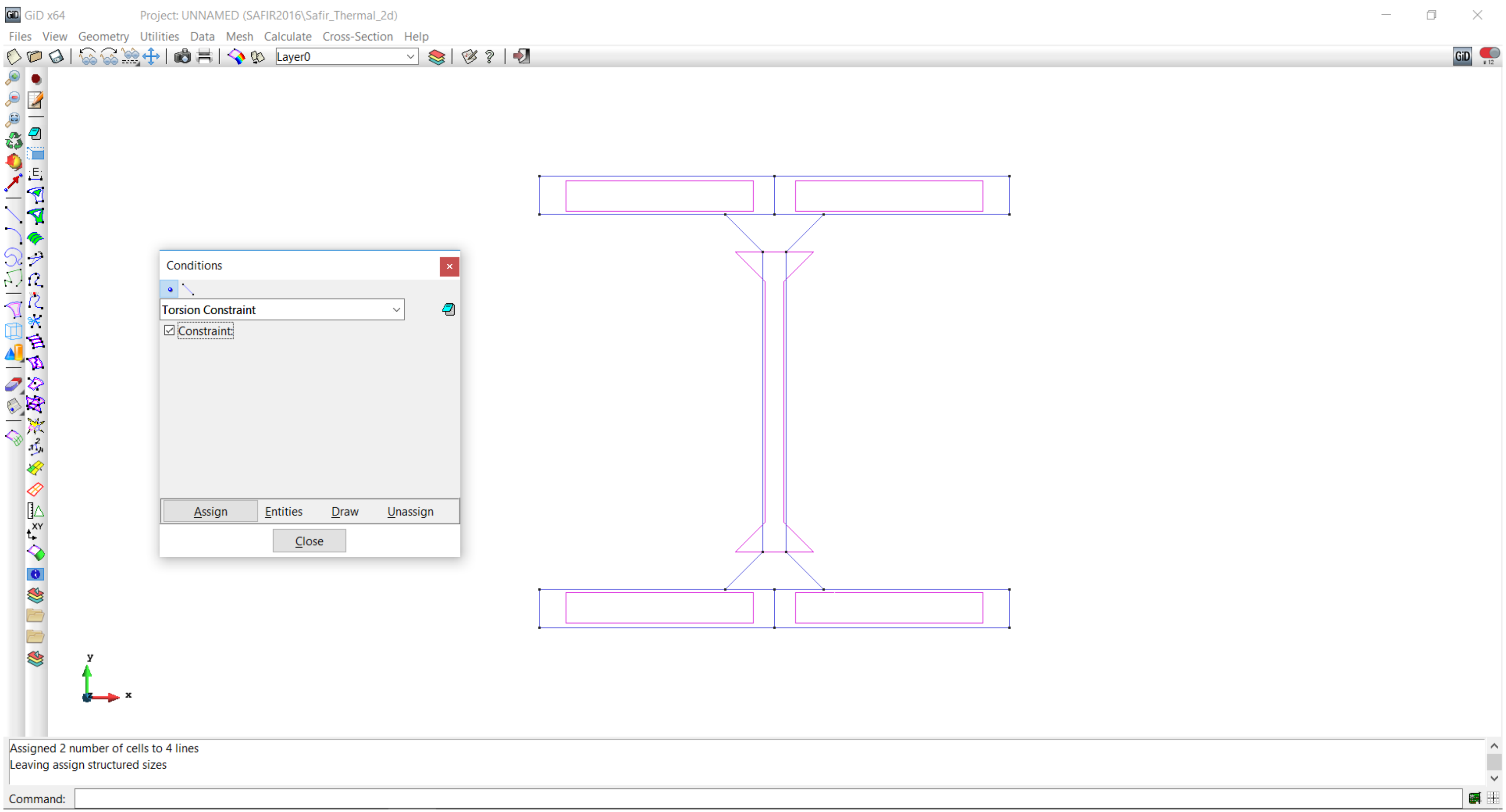
The problem types for creating SAFIR input files have been updated. They have been checked with **version 12 of GiD**.

- Some bugs have been fixed, namely:
  - Modification of the name of the SAFIR executable launched by GiD: the name of the file (to be included in the folder specified in the environment variable defined by the user) should now be “safir.exe” (see sections 4.2 and 4.3 in “SAFIR_installation_guide.pdf”);
  - Correction of a bug with Structural 3D cases that include beam elements and shell elements.

- New features have been added, namely:
  - Possibility to fix one node during the torsional analysis ;
  - Possibility to reduce the torsional stiffness by a chosen factor ;
  - Possibility to define tetrahedral elements in Structural 3D cases.

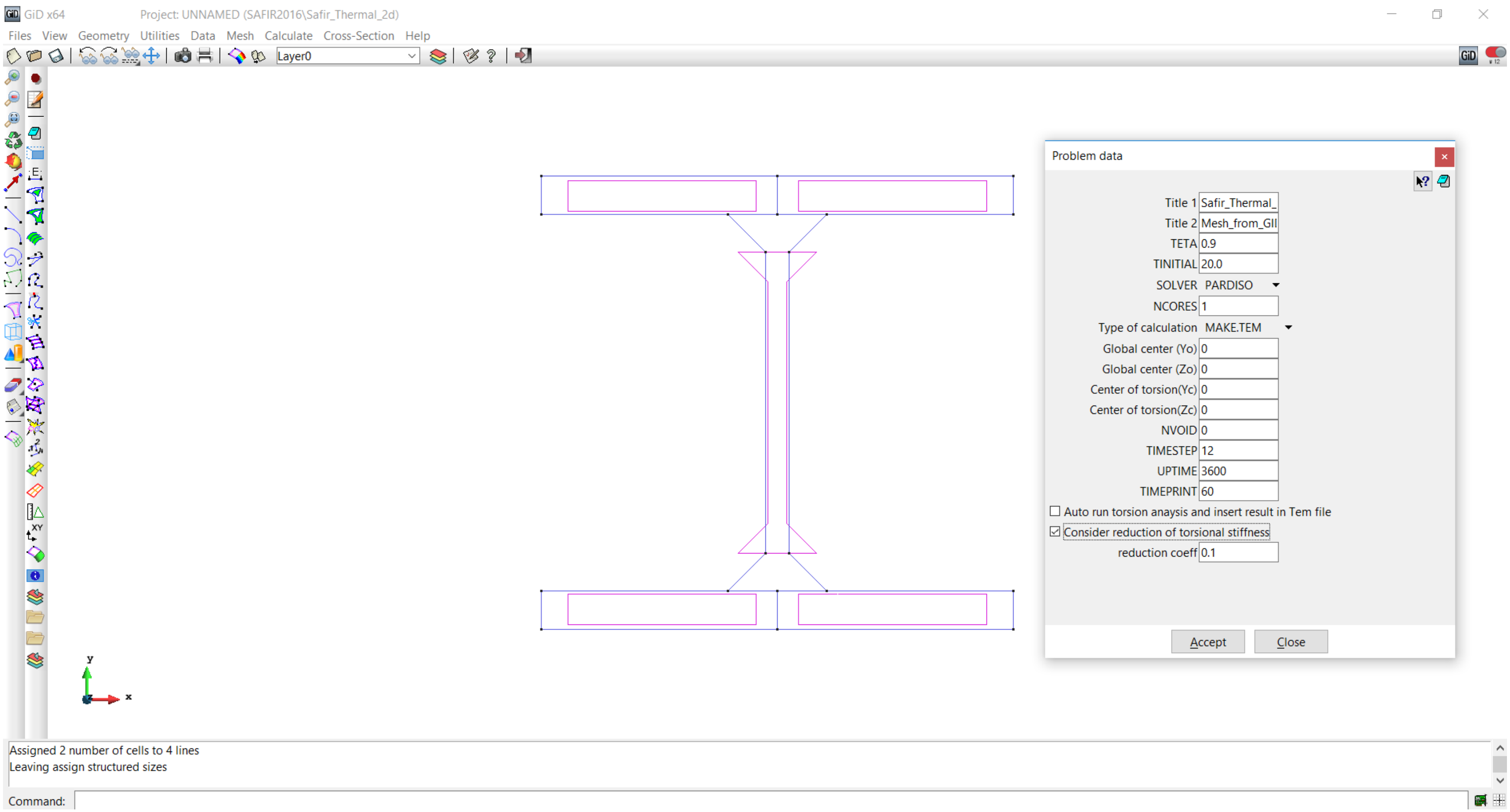
1. GiD

Possibility to fix one node during the torsional analysis



1. GiD

Possibility to reduce the torsional stiffness by a chosen factor (take into account temperature)



2. SAFIR

New developments in:

- Capabilities for thermal analysis
- Capabilities for mechanical analysis
- Finite elements
- Material laws
- Solver
- Output files

2. SAFIR

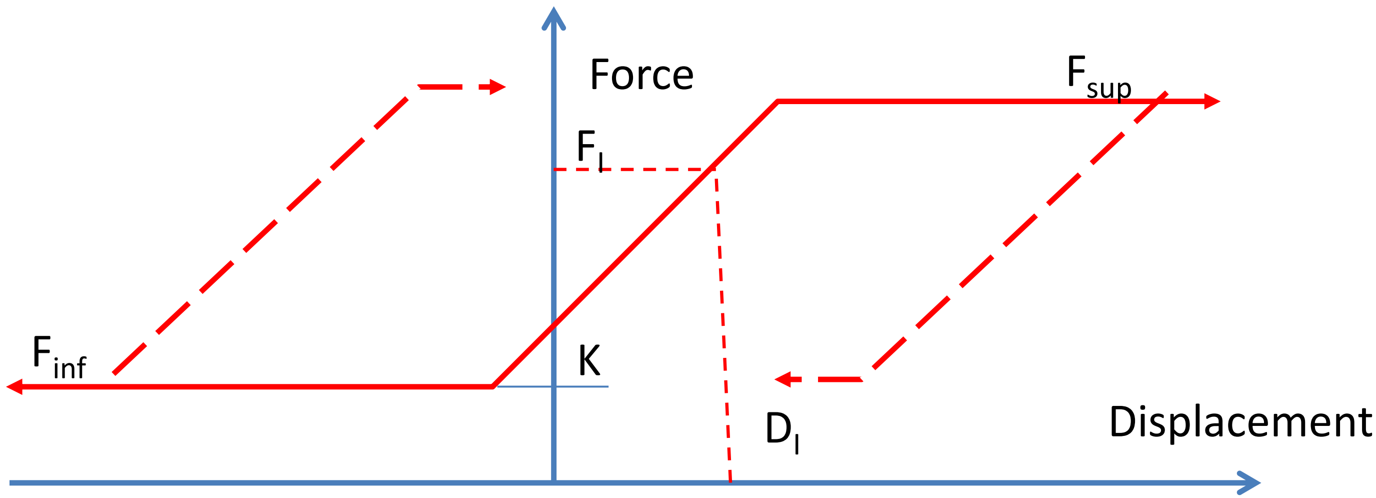
- Capabilities for thermal analysis
  - New method to heat structural beam finite elements by a localized fire, see **LOCAFI** in the Users manual - thermal.

2. SAFIR

- Capabilities for mechanical analysis:
  - **Trapezoidal distributed loads** on beams, in local (for wind loads) or in global (for gravity loads) system of coordinates, see **TRAPLOCBM** and subsequent commands
  - **Pressure from water table**, following the large displacements of the structure, see **NHYDROST** and **WATERTABLE**.
  - Possibility to **print the strains** that **exceed a certain value** in the bars of shell finite elements, see **PRNSTRAIN**.
  - Possibility to specify a **maximum value** admitted for the **displacements**, see **MAX_DISPL**.

2. SAFIR

- Finite elements:
  - New type of finite element **SPRING** to link the structure to the foundation, with elasto-plastic behaviour. Allows a more precise representation of the pressure from the ground than a constant pressure.



Input parameters are:

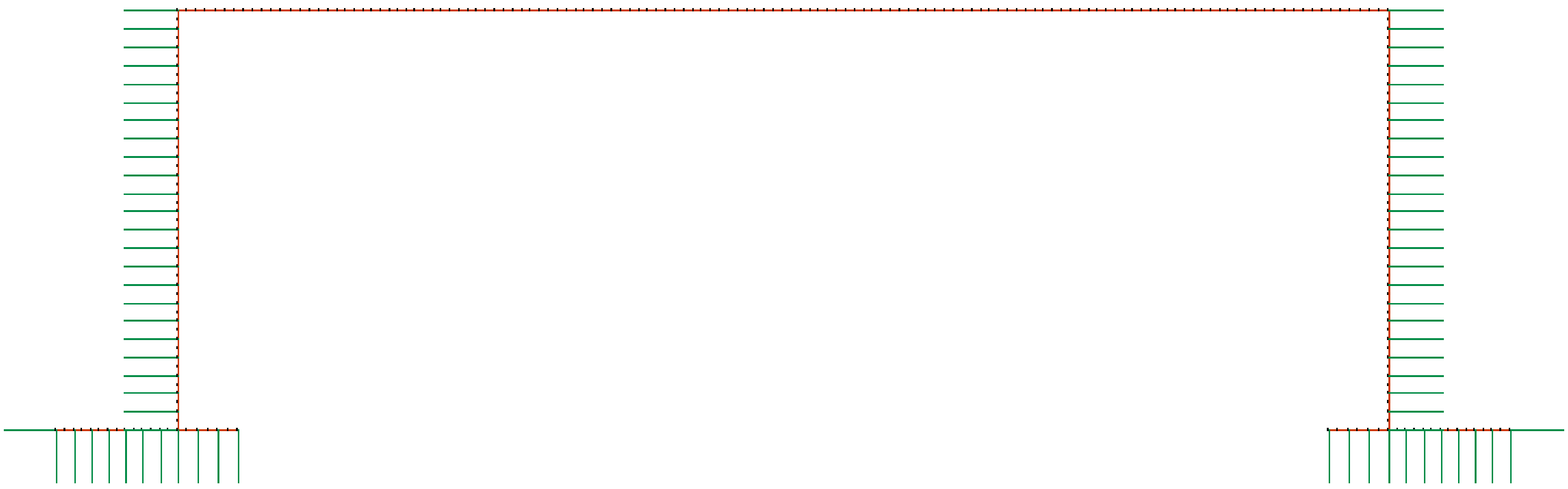
NSPR:	Number of the element.
NNODE:	Node where this element is attached.
CX:	Cos of the angle between X axis and this element
CY:	Cos of the angle between Y axis and this element
CZ:	Cos of the angle between Z axis and this element

F_s	Superior limit of the load.
F_{inf}	Inferior limit of the load.
K	Stiffness of the element (elastic loading/unloading)
A	Area of influence (all forces are multiplied by A)
D_i	Displacement in the configuration of reference (t = 0).
F_i	Force in the configuration of reference (t = 0).

2. SAFIR

- Finite elements: example with springs

2D model with beam F.E. and spring F.E.



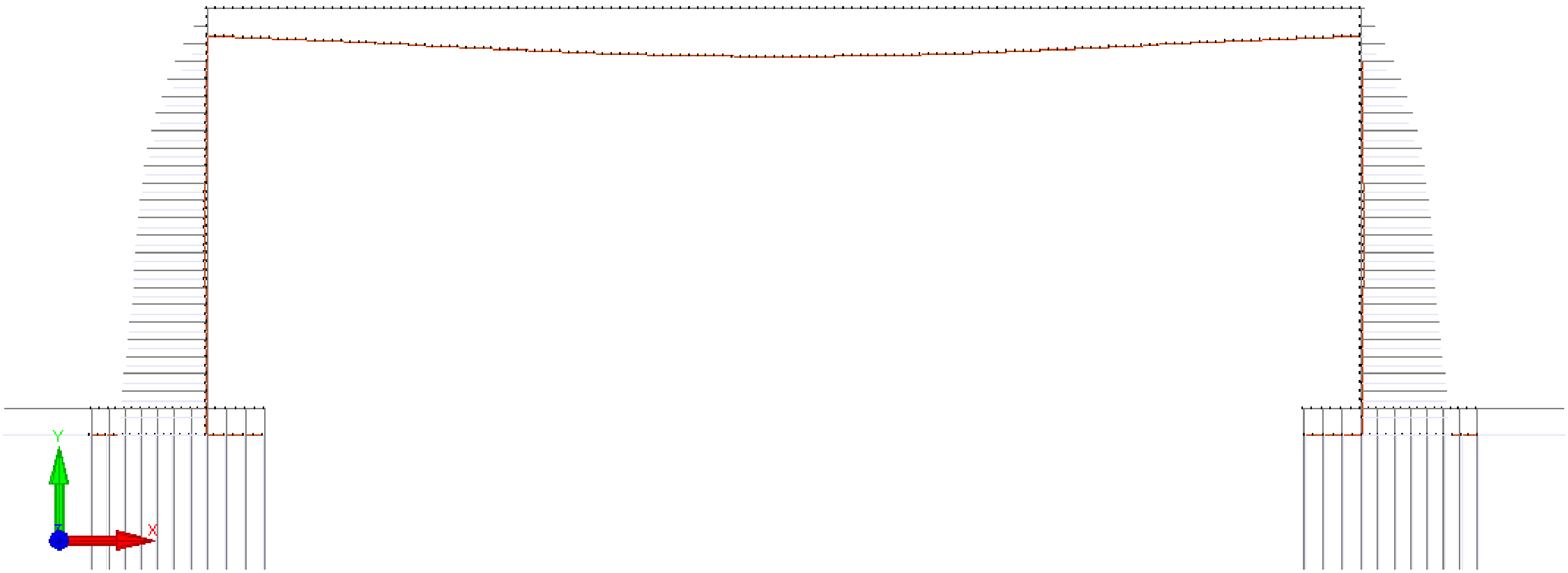
- No restrain
- Trapezoidal loads on the walls replaced by spring F.E.

2. SAFIR

- Finite elements: example with springs

Deformed shape and soil pressures at t = 60 s

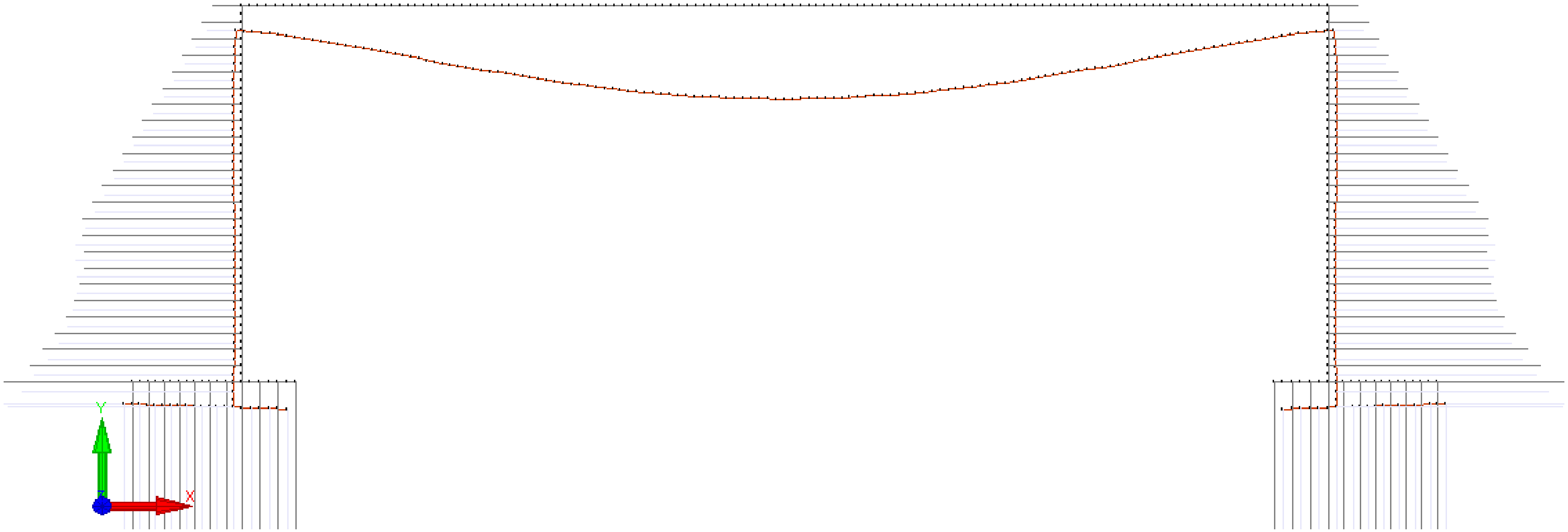
Note: Diamond can plot the loads *F* or the pressure *F/A* in the spring elements



2. SAFIR

- Finite elements: example with springs

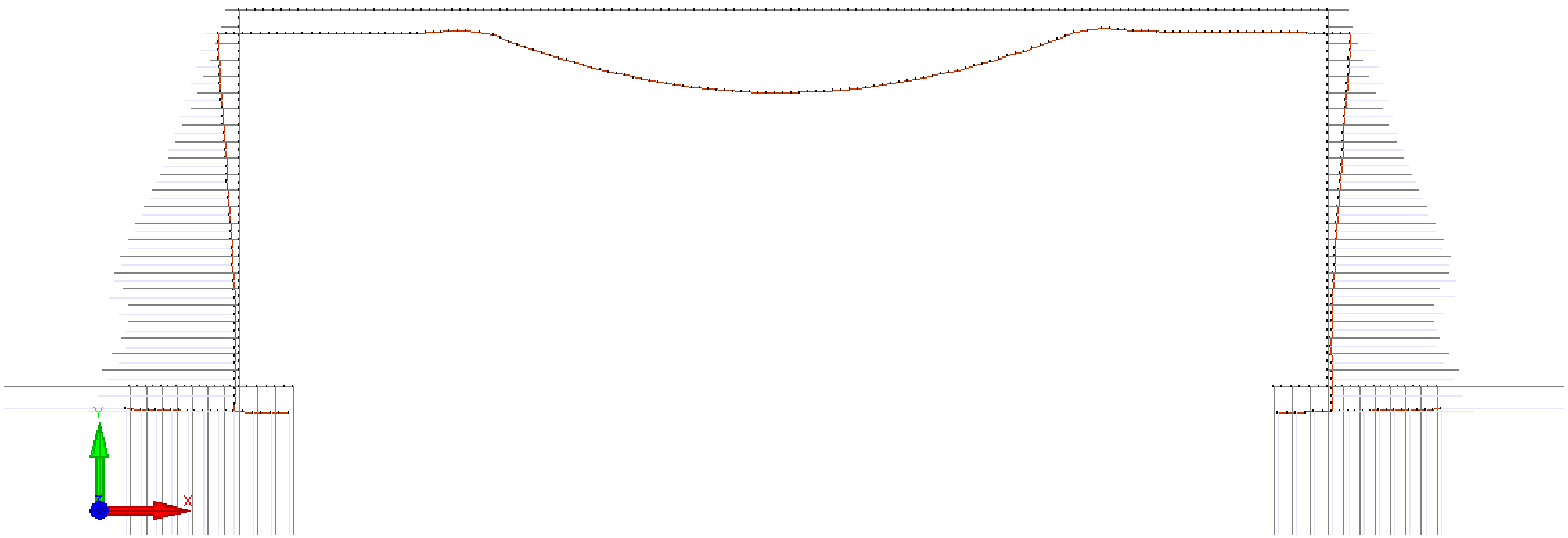
Deformed shape and soil pressures at *t* = 3 720 s
(just before plastic hinges appear)



2. SAFIR

- Finite elements: example with springs

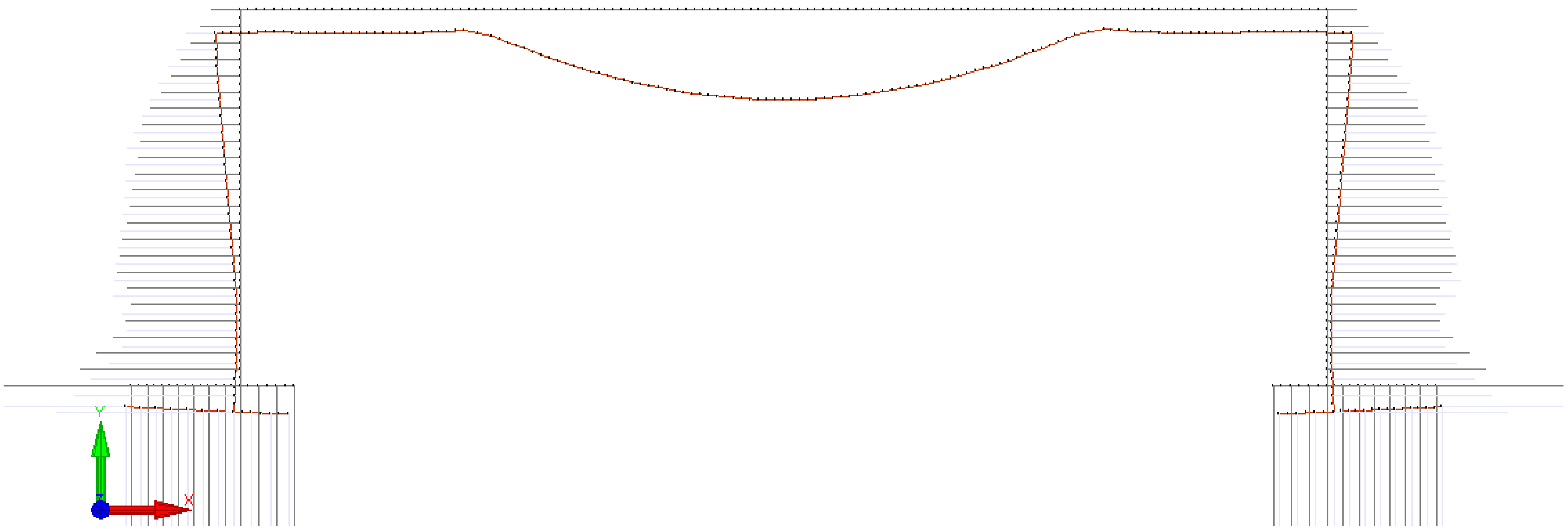
Deformed shape and soil pressures at *t* = 3 800 s
(just after plastic hinges appear)



2. SAFIR

- Finite elements: example with springs

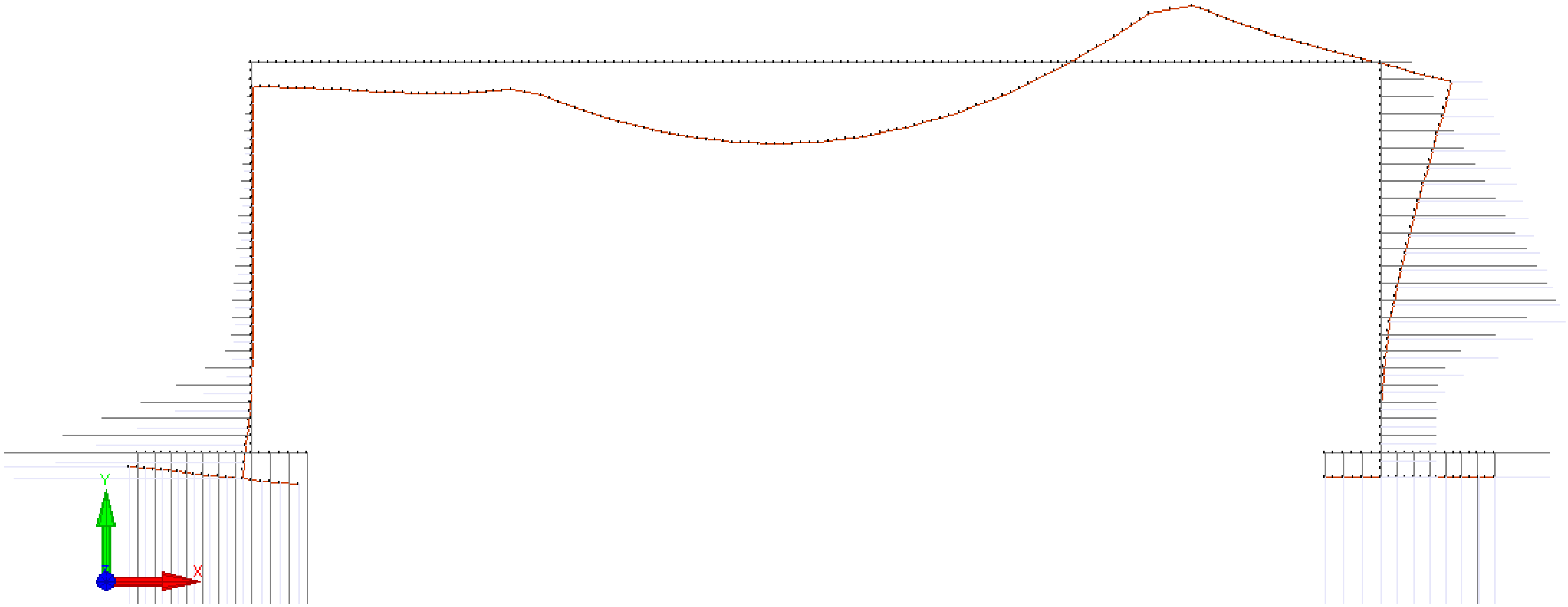
Deformed shape and soil pressures at *t* = 5 135 s
(just before failure)



2. SAFIR

- Finite elements: example with springs

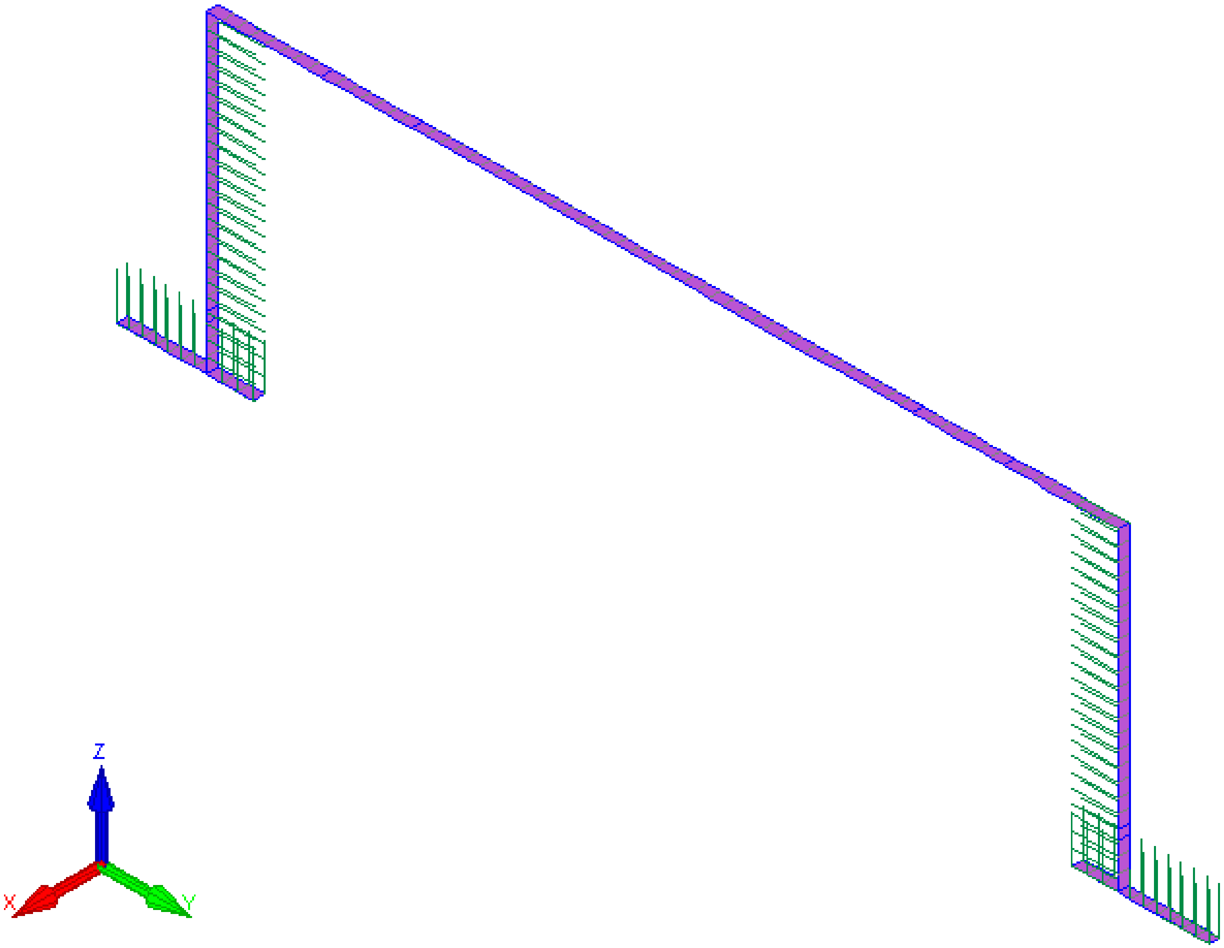
Deformed shape and soil pressures after failure



2. SAFIR

- Finite elements: example with springs

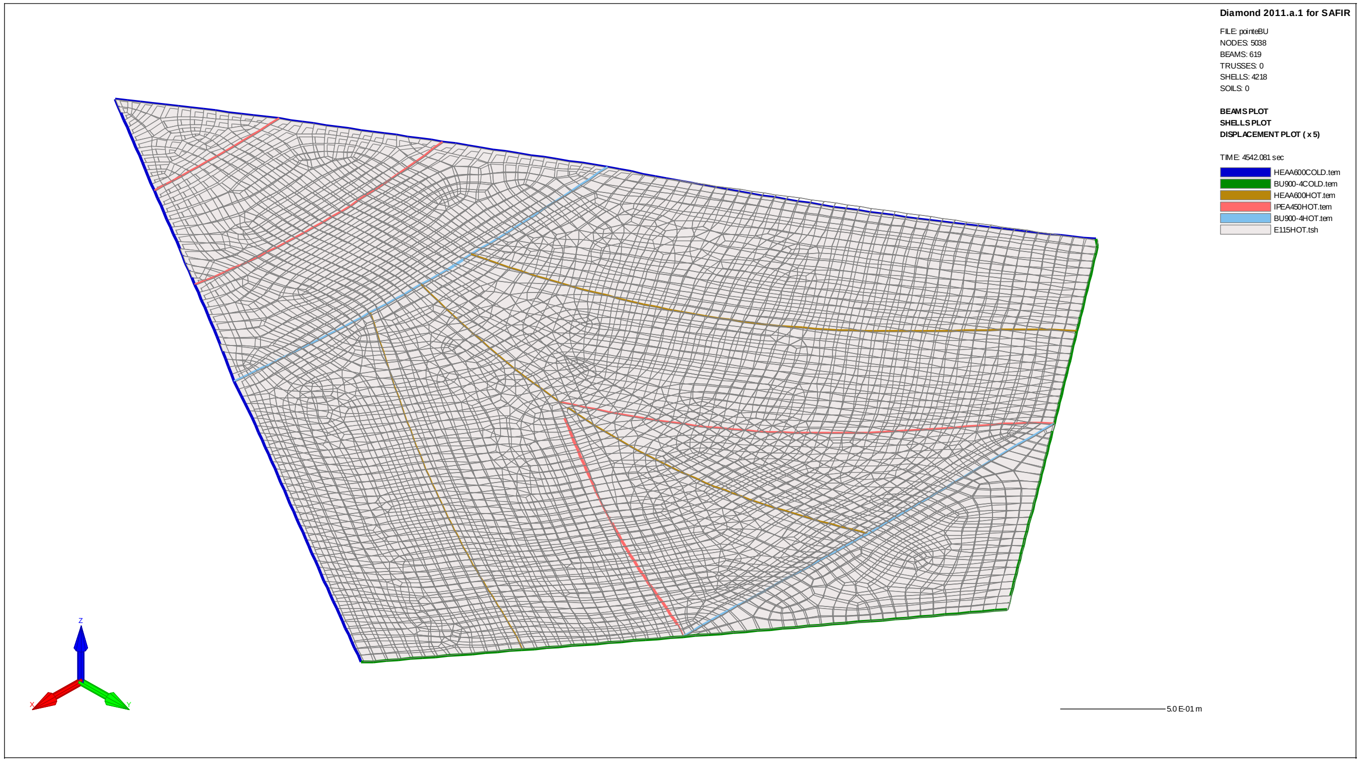
3D model



2. SAFIR

- Finite elements:

  – **Reinforcing bar** layers oriented with respect to the **global system of coordinates** in shell finite elements (very useful in unstructured meshes).



Japan Tobacco Intl, Geneva

Model: Ingeni (courtesy Lorenzo Lelli)

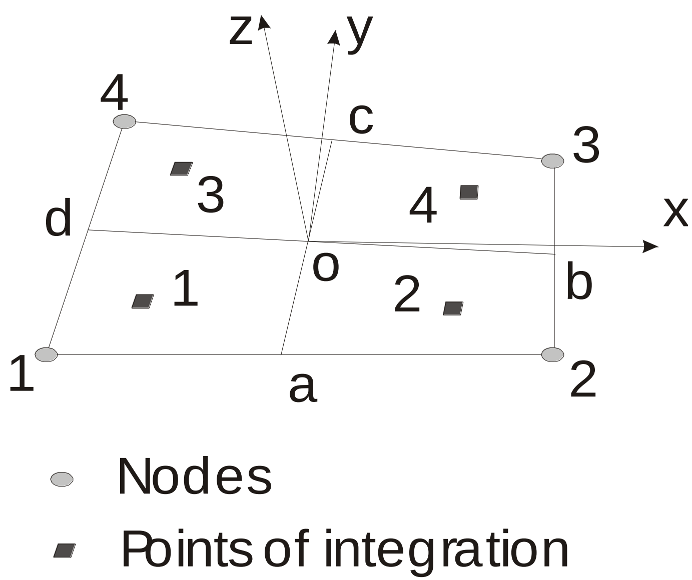
2. SAFIR

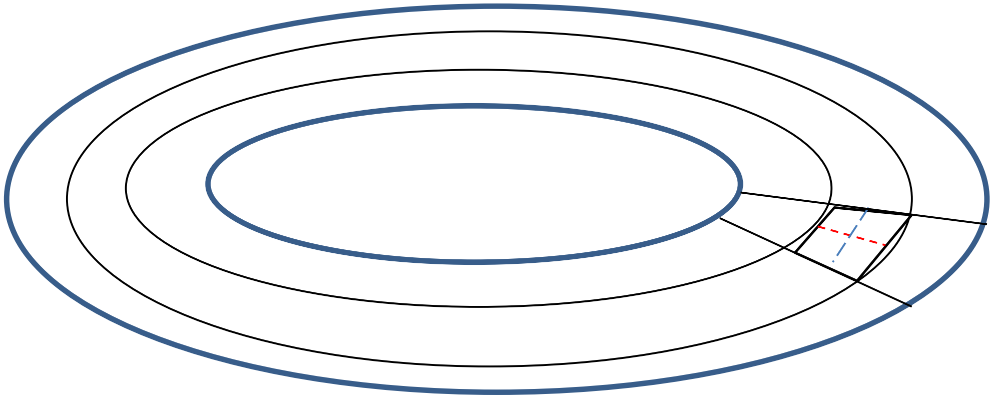
- Finite elements: reinforcing bars in shell

For each bar layer, there are 2 methods to give the orientation of the bars in the plane of the element.

<u>Method 1</u>: with respect to the <u>local</u> system of coordinates of each element.

1 card.
- "ANGLE"
- **angle** Angle in degrees between the local x axis and the layer of rebars, see Figure in which the bars of the layer are represented by doted lines. This angle cannot be smaller than -180°.





Bars in a circular ring

Method 1

2. SAFIR

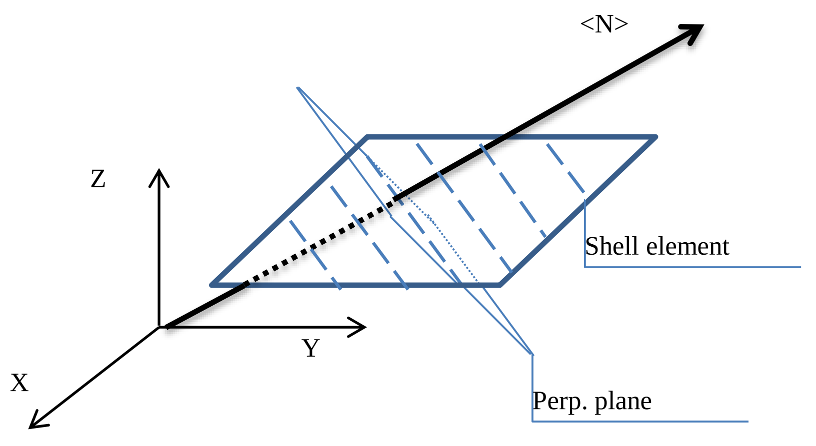
- Finite elements: reinforcing bars in shell

<u>Method 2</u>: with respect to the <u>global</u> system of coordinates of the structure.
1 card.

- "NORMAL"
- N_1
- N_2
- N_3

< N_1 ; N_2 ; N_3 > is a vector in the global system of coordinates of the structure. The norm of the vector does not have to be 1.

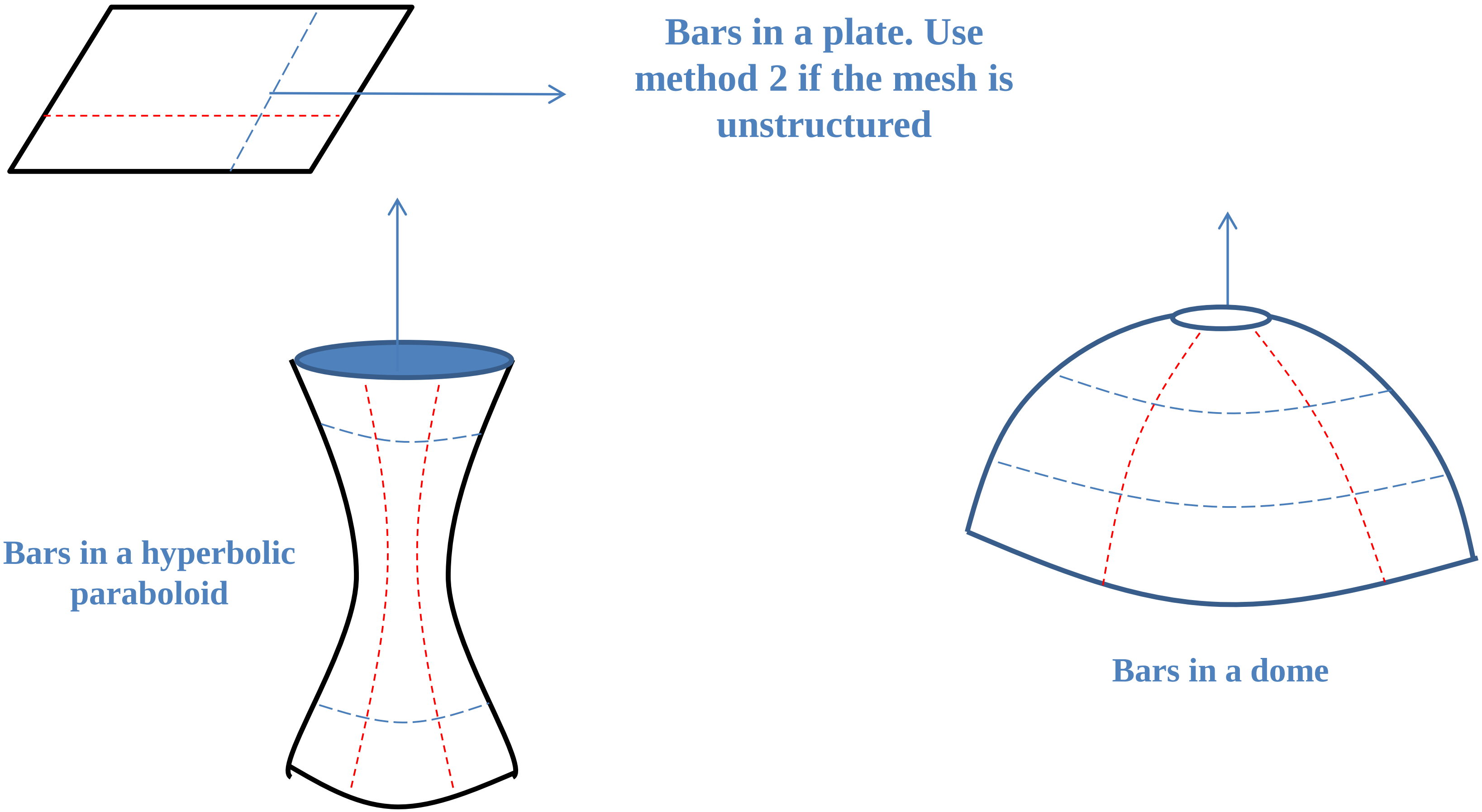
This vector is used to define the position of the bar layers in the shell elements with respect to the global system of coordinates according to the following technique, see Figure.



The bars have the orientation of the line which is the intersection between the shell element and a plane that is perpendicular to the normal.
If the norm of the vector is 0, then the orientation of this bar layer is perpendicular, in each element, to the previous bar layer (not possible for bar layer 1).

2. SAFIR

- Finite elements: reinforcing bars in shell



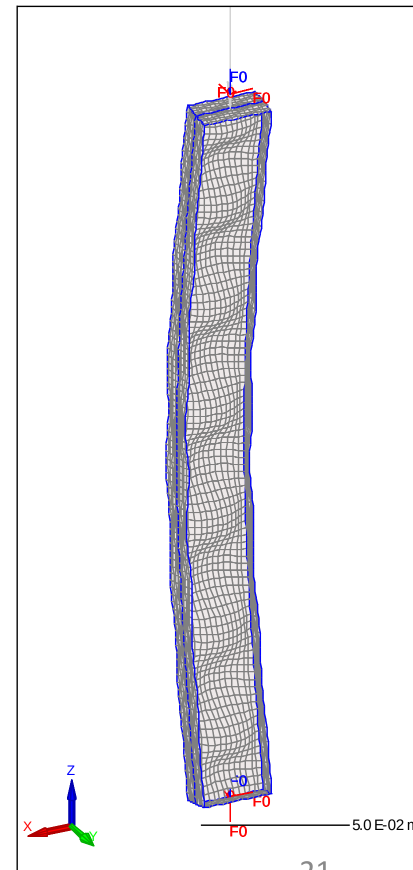
ACKNOWLEDGEMENT
DEVELOPMENT OF THE SECOND METHOD HAS BEEN SUPPORTED BY « HOLMES FIRE »

2. SAFIR

- Material laws:

  – New type of material « STEELSL » to take **local buckling** into account **in beam finite elements**.

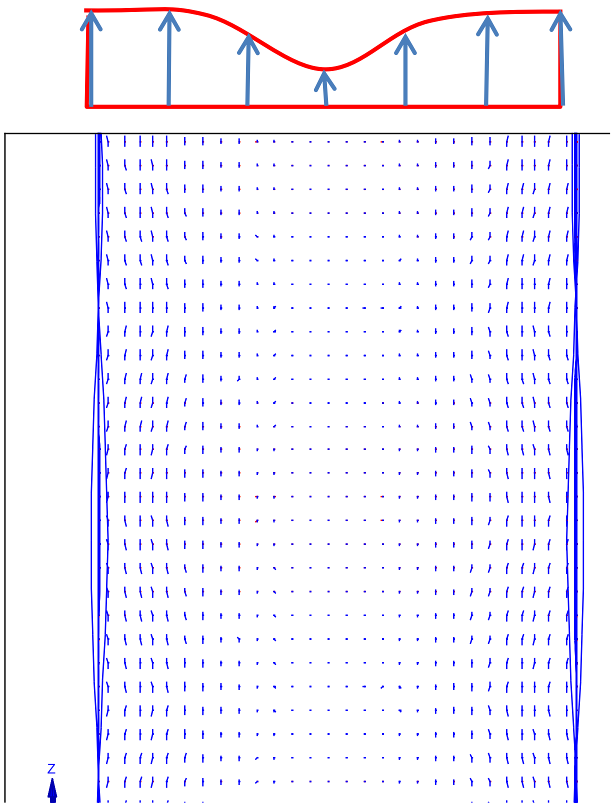
Steel sections made of slender plates may deform locally (local buckling)



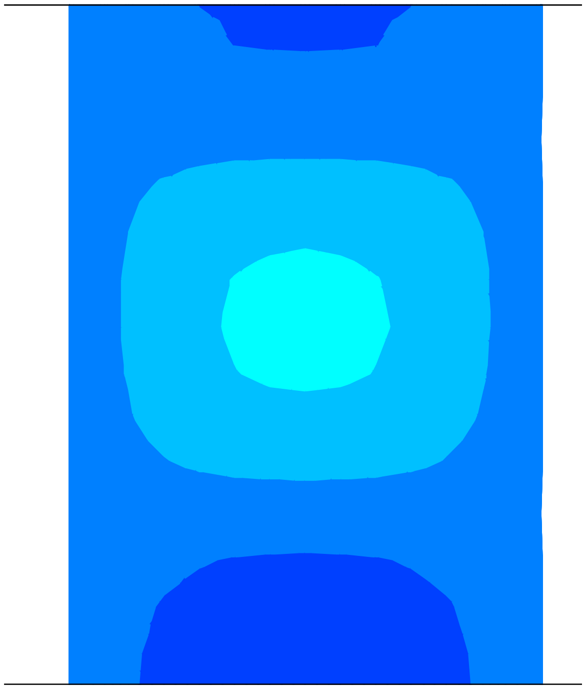
=> They cannot be modelled with beam finite elements

2. SAFIR

- Material laws: STEELSL



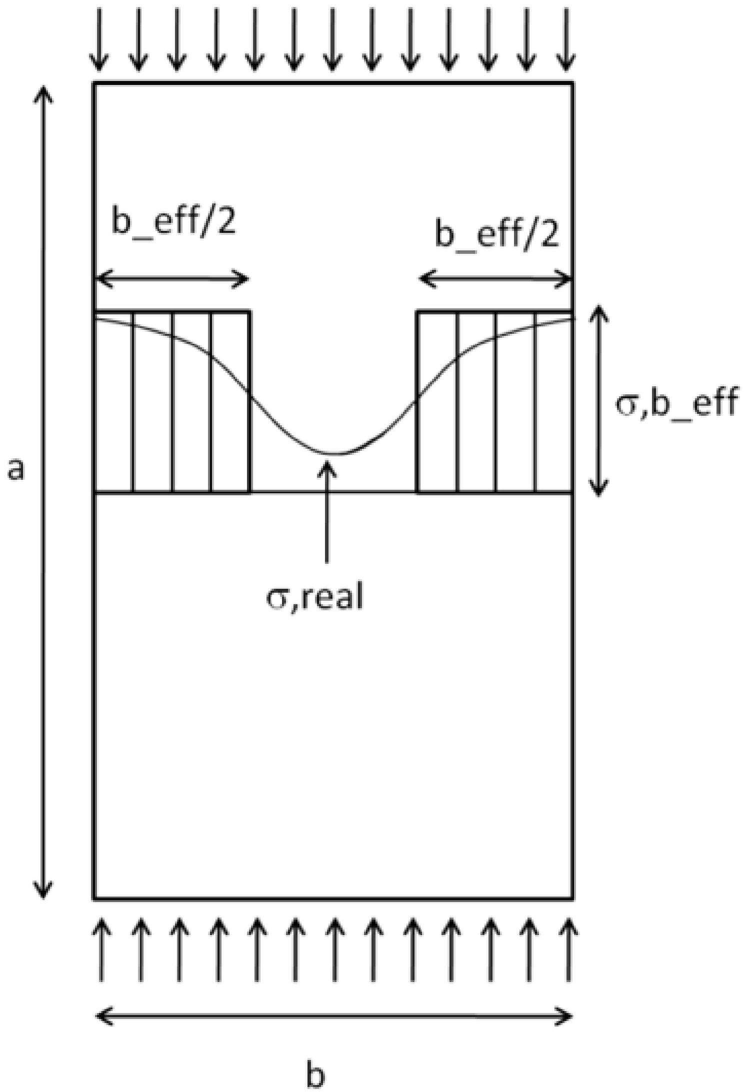
Membrane forces
In the web



Perpendicular displacement
In the web

2. SAFIR

- Material laws: STEELSL



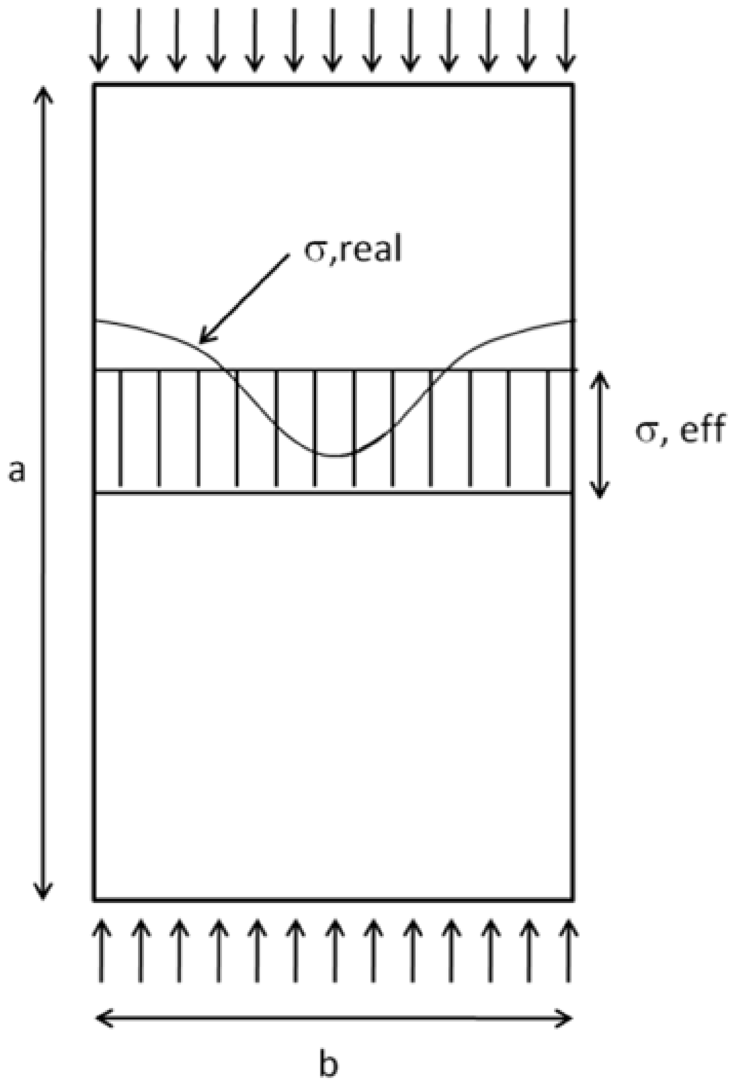
Effective width: b_{eff}

$b_{eff} = f(\sigma_{max})$ $\sigma_{max} = f(b_{eff})$

If used in F.E, it must be introduced **<u>at the element level</u>**

2. SAFIR

- Material laws: STEELSL



Effective stress: σ_{eff}

$\sigma_{eff} = f(\varepsilon)|_{\text{support conditions, slenderness, temperature}}$

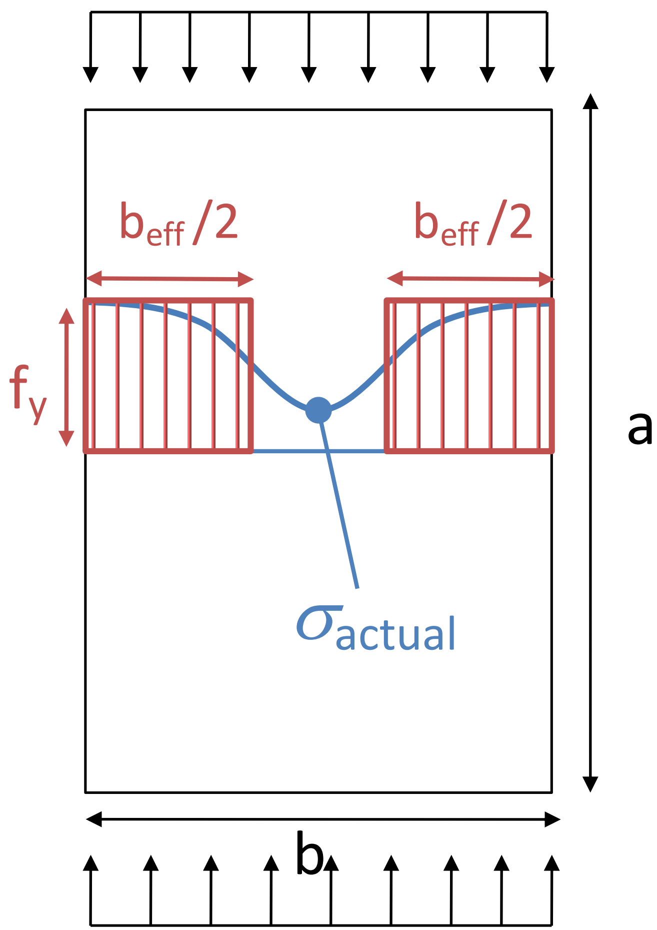
If used in F.E, it can be introduced **at the material level**

2. SAFIR

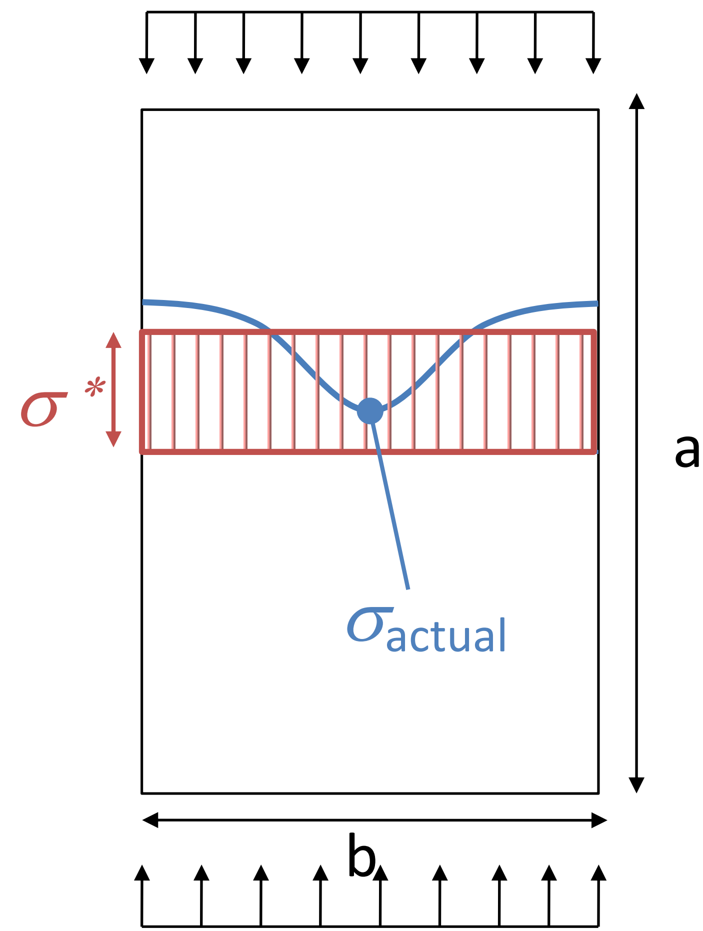
- Material laws: STEELSL

New proposal:

Effective width



Effective stress



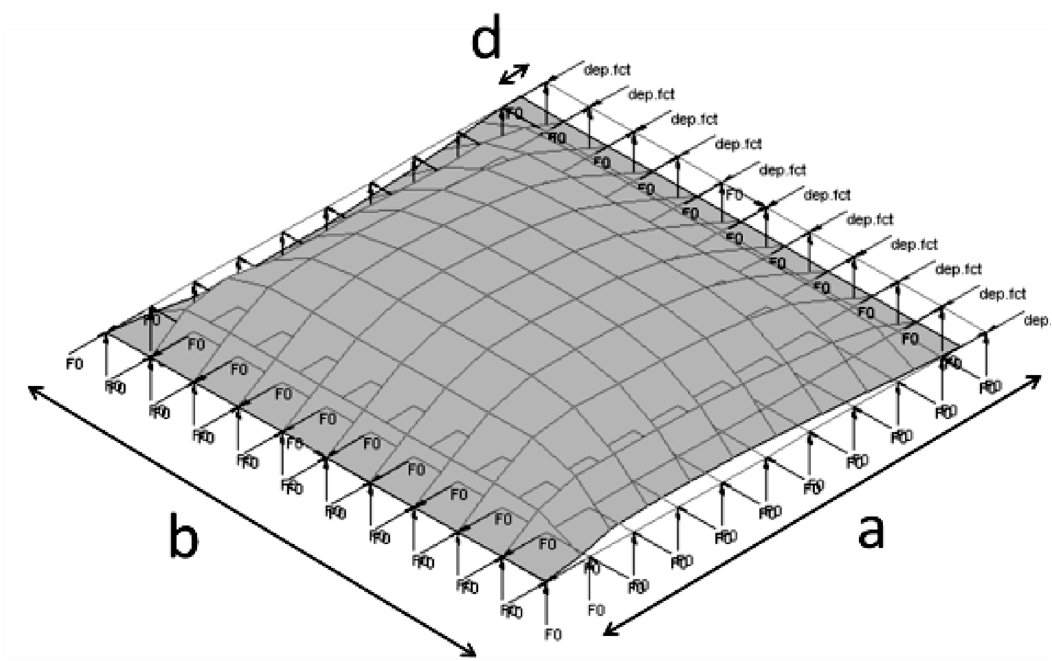
2. SAFIR

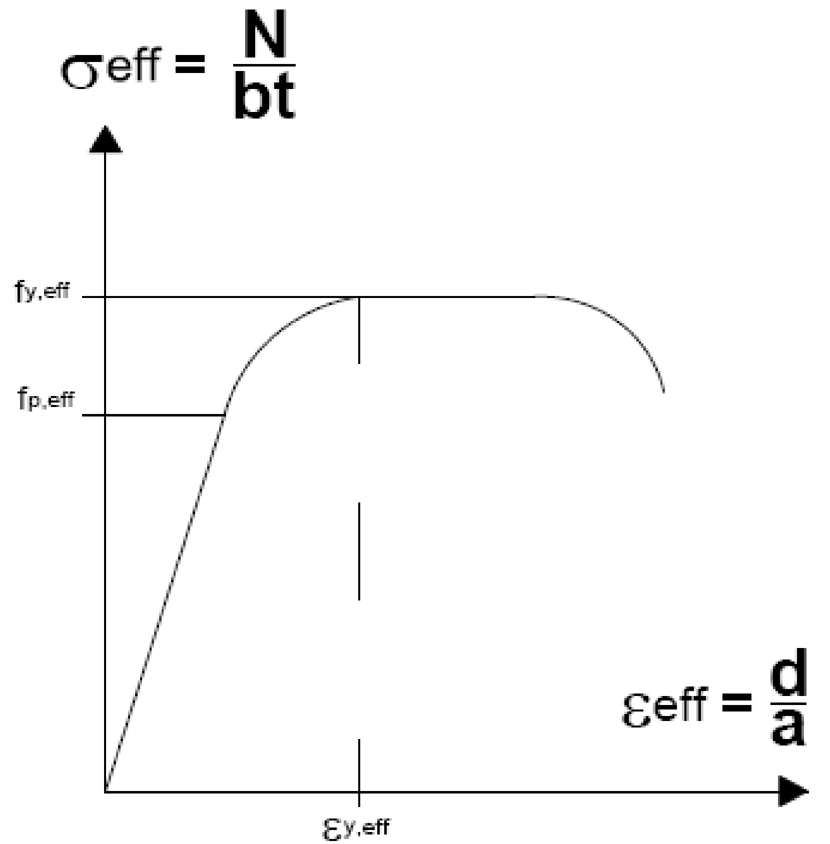
- Material laws: STEELSL

How do we determine $\sigma_{eff} = f(\varepsilon)$?

By a series of numerical push-over tests made for different:

- Support conditions
- Plate slendernes
- Temperatures





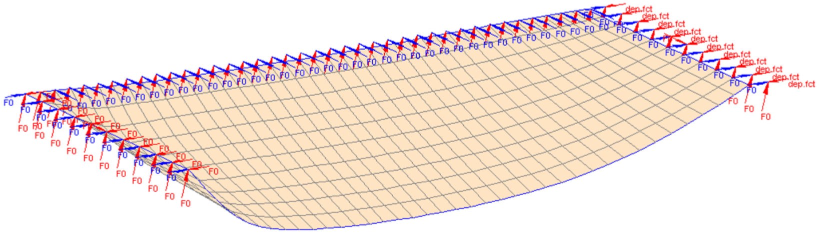
2. SAFIR

- Material laws: STEELSL

Various support conditions

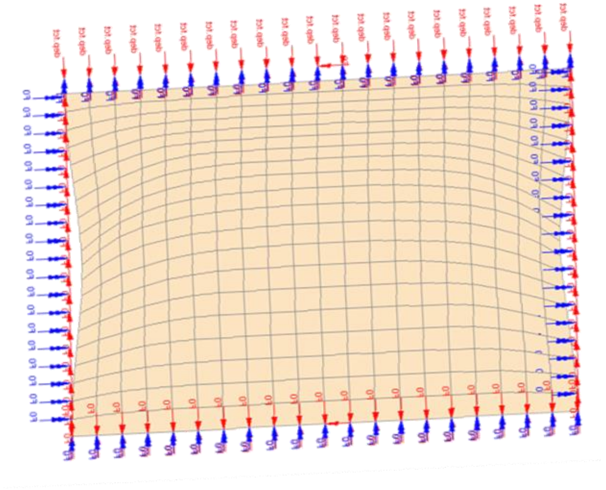
Flange

Simply supported on 3 sides



Web

Simply supported on 4 sides

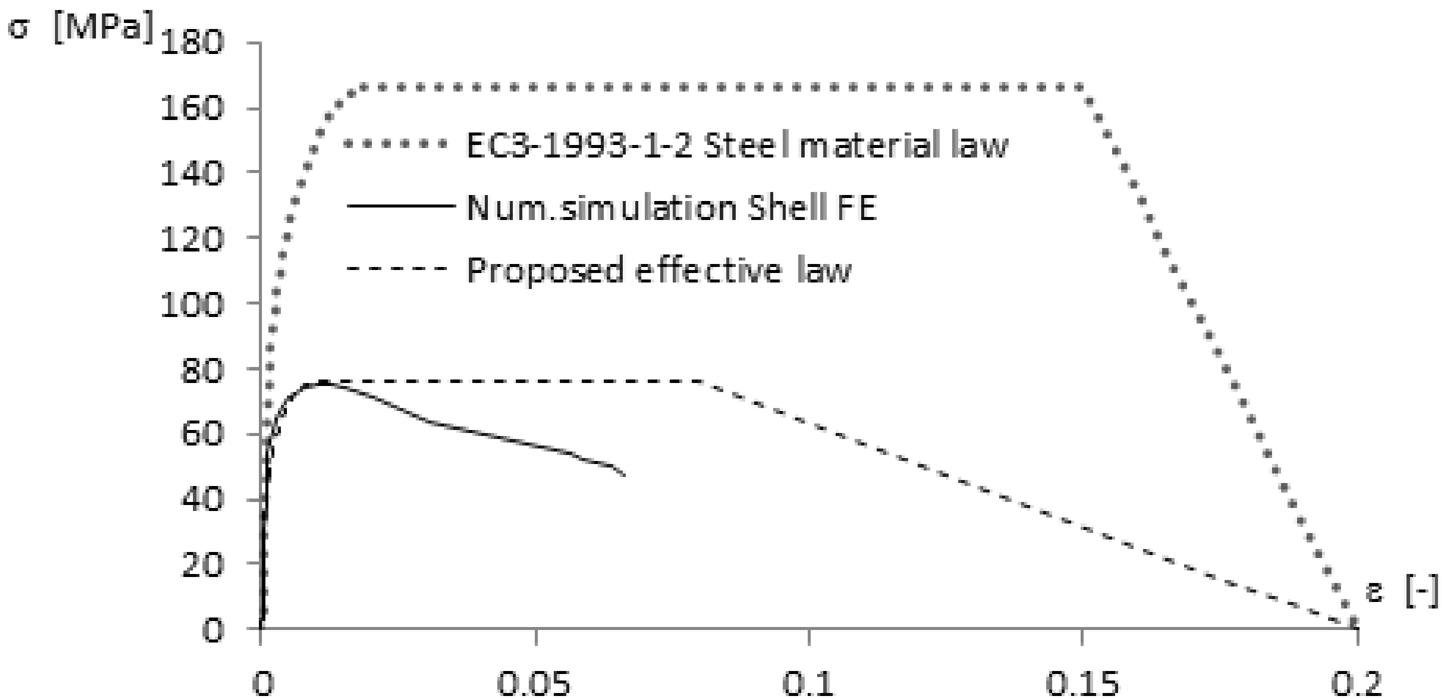


2. SAFIR

- Material laws: STEELSL

The stress-strain relationship is the one of Eurocode 3.

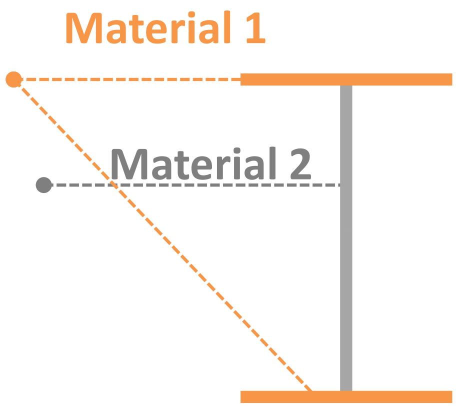
For each combinaison of Temperature – Slenderness - support condition, the values of $f_{p,eff}$ and $f_{y,eff}$ in compression are modified in the material law (E and ε_u remain unchanged, as well as all parameters in tension)



2. SAFIR

- Material laws: STEELSL

The user gives in the input file f_y, b/t and the support condition for the web and the flange



In the members, every point of integration follows its own σ_{eff}-ε relationship

2. SAFIR

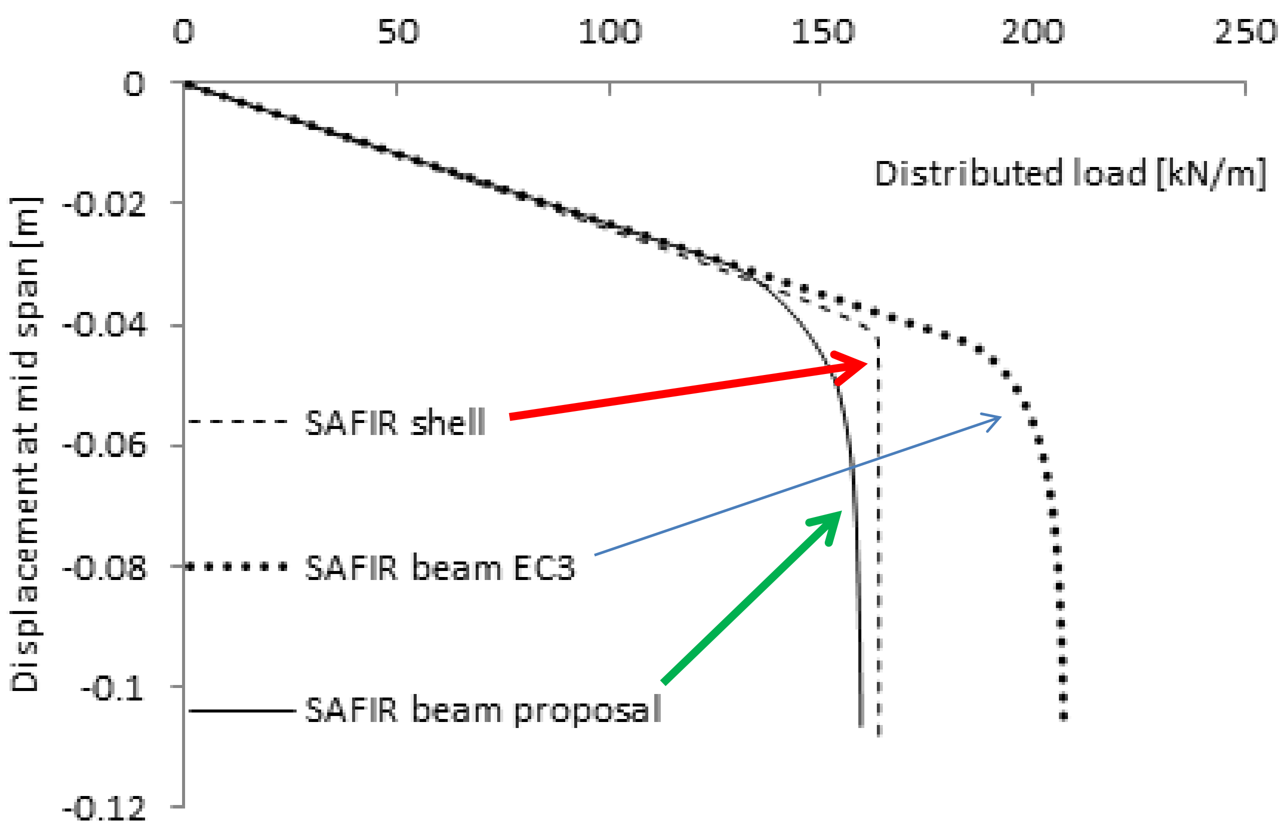
- Material laws: STEELSL – Validation against shell FE

Simply suported beam with UDL

L = 6 meters

Section: H = 300x4, B = 150x4

T = 20°C



2. SAFIR

- Material laws: STEELSL – Conclusion

✓ The proposed technique is extremely CPU efficient compared to shell F.E.

✓ It reasonably well accounts for local buckling arising from longitudinal stresses

✓ Sometimes too severe – further research in progress

2. SAFIR

- Material laws:
  - New laws for **reinforcing steel “STEELEC2EN”**. Hot rolled or cold formed bars can be chosen (see Table 3.2a of EN 1992-1-2); class A, B or C can be chosen (see Fig. 3.3 of EN 1992-1-2).
    Note: in previous versions, cold worked, class B or C was used.
  - New types of material for **high strength concrete** (table 6.1N of EN 1992-1-2 for the reduction of strength with temperature): “SILHSC1ETC”, “SILHSC2ETC”, “SILHSC3ETC”, “CALHSC1ETC”, “CALHSC2ETC”, “CALHSC3ETC”.

2. SAFIR

- Solver, algorithms and CPU time
  - Structural calculations continue even with negative values on the main diagonal of the stiffness matrix, which gives a better insight into the **failure mode**.
  - **Reduction of CPU time** by approximately a factor 2 for simulations with **HASEMI** fires.

2. SAFIR

- Output files
  - Results written in an **XML file** in order to facilitate post-processing (see the Section about DIAMOND).

3. DIAMOND

- Completely **re-written in C++**
- Based on the **XML file** produced by SAFIR (from versions 2016).

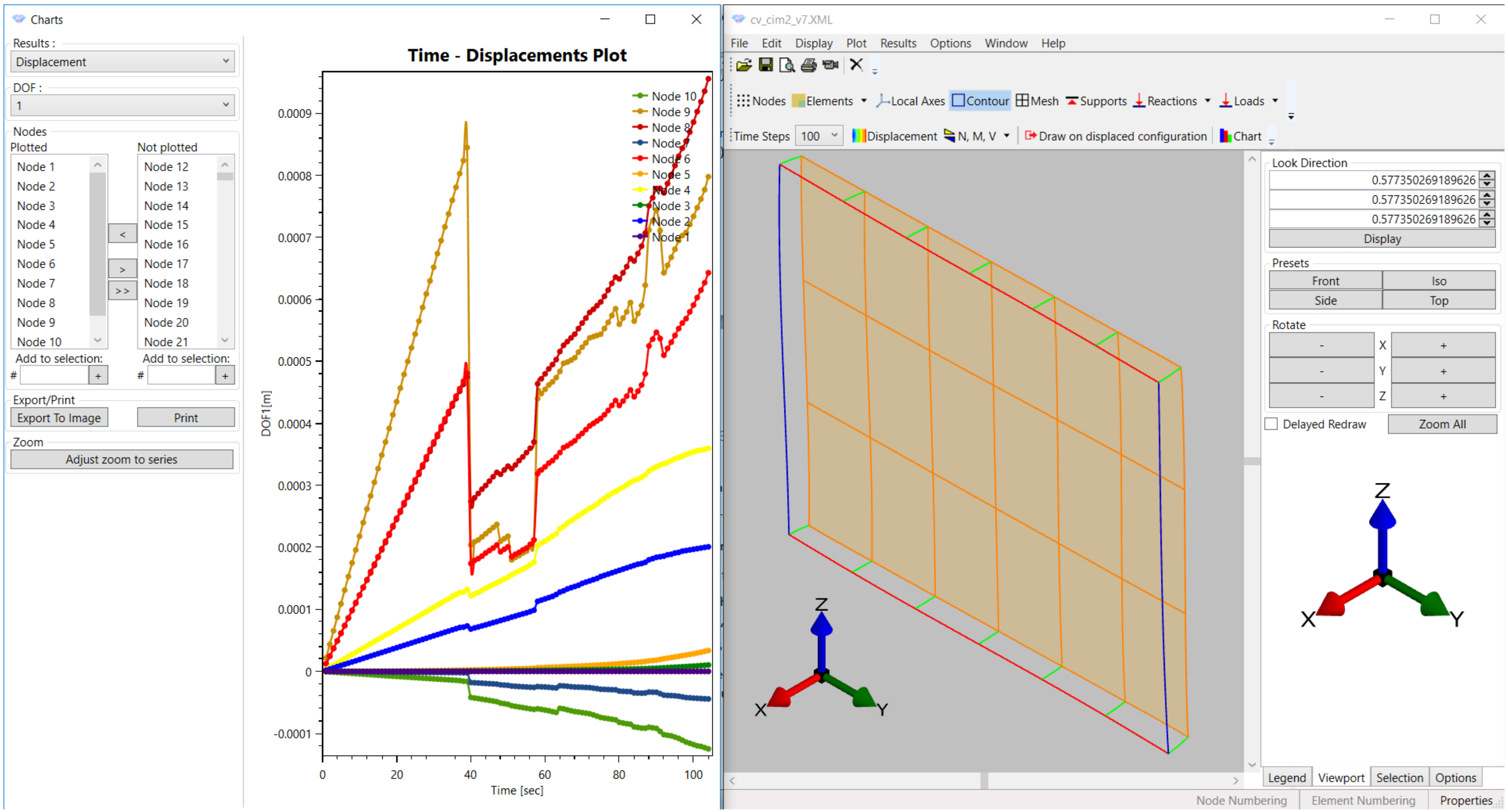
The results of this are:

- Possibility to treat **larger files** (was limited to 2 Gb previously);
- Much **faster** opening of the program and initial reading of the file;
- Allows to keeps **several “chart” windows** opened, with an unlimited number of curves in each window (was limited to 5 curves previously);
- Possibility to **paint the results** (M, N, V diagrams on beams, membrane or bending forces on shells, displacement colours in shells) **on the displaced structure**.
- Possibility to **add values on the M, N, V diagrams**

⇒ Work in progress, further developments planned (happy to hear your feedbacks)

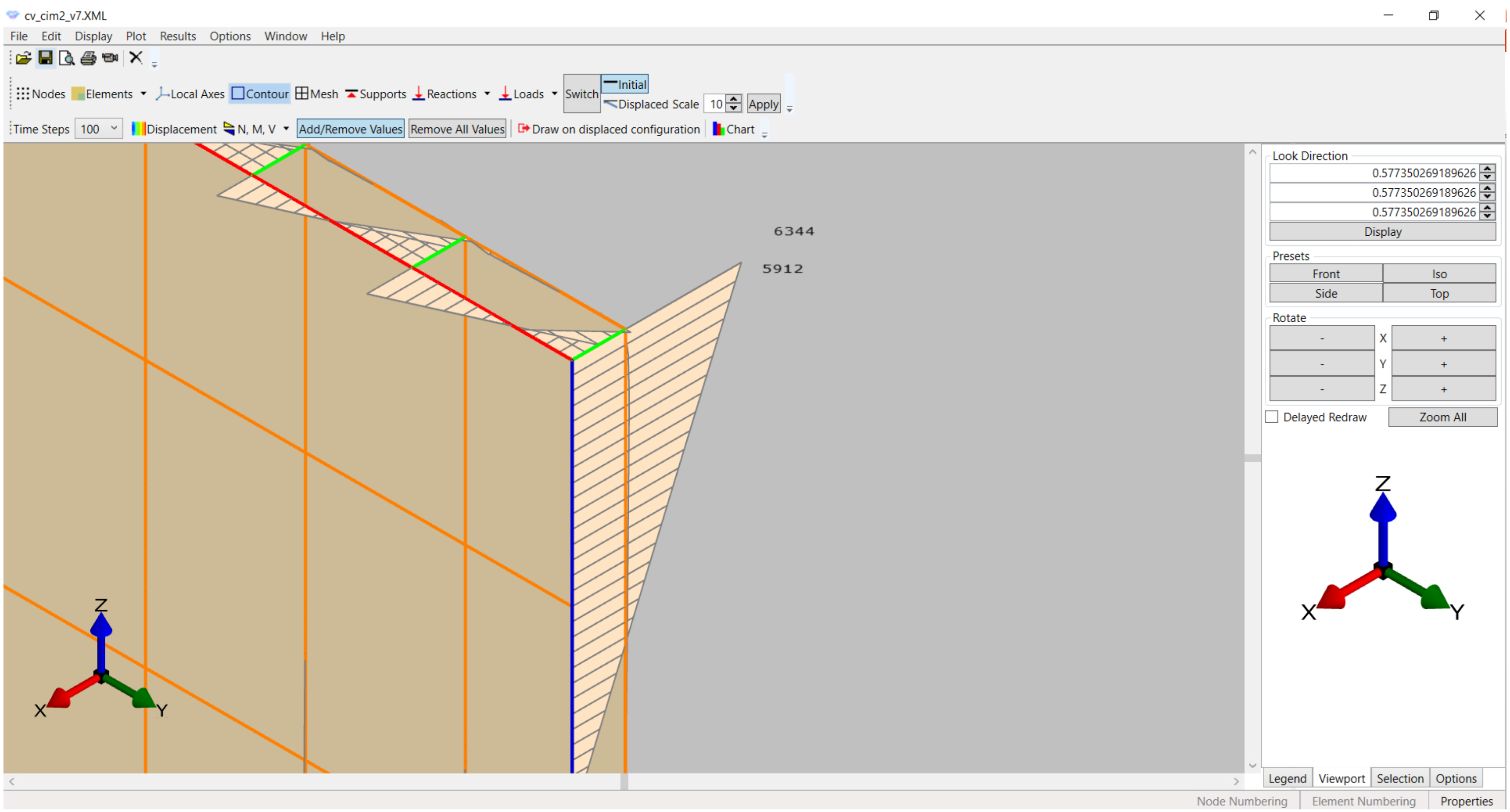
3. DIAMOND

Multiple charts / curves



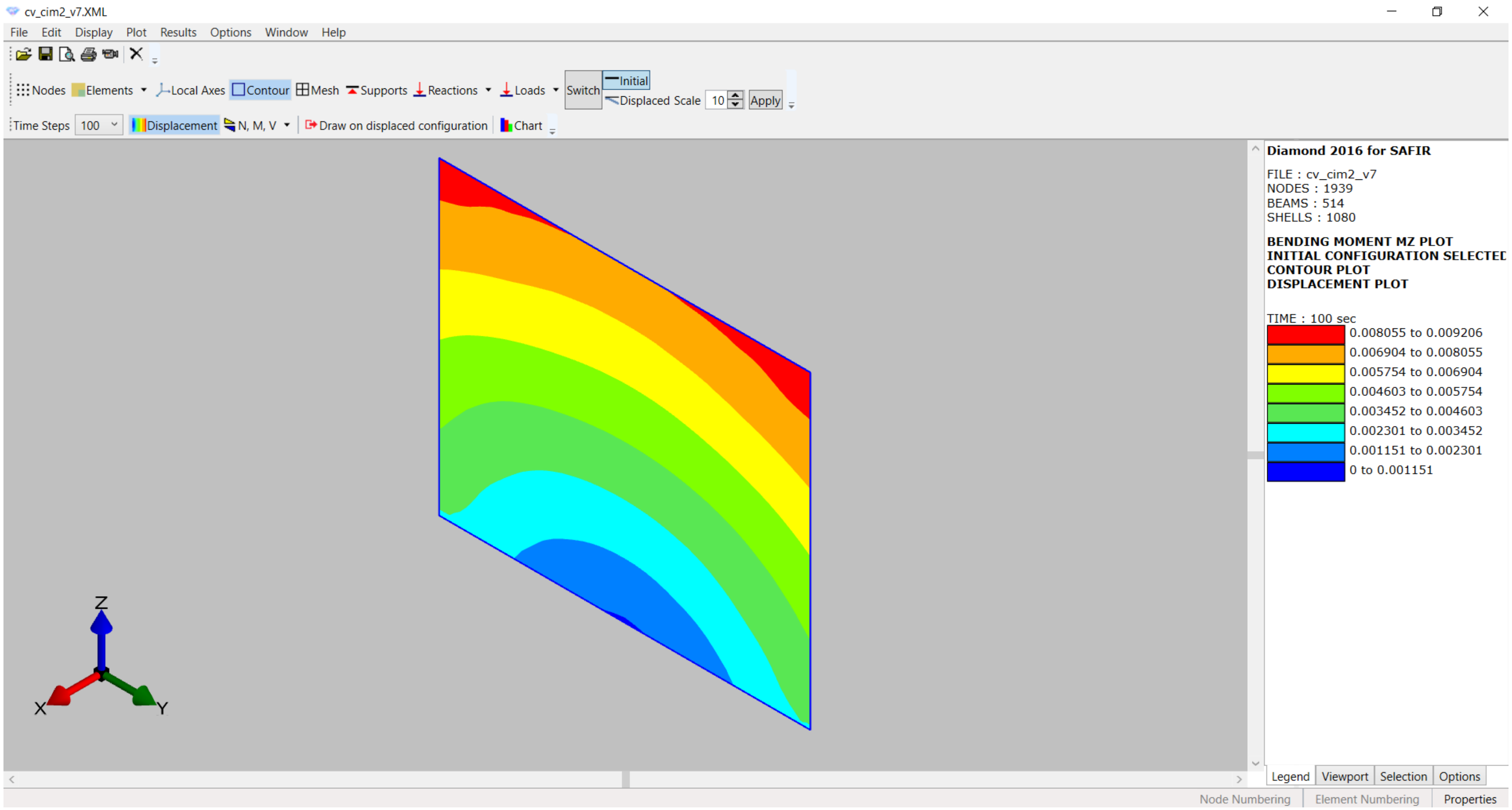
3. DIAMOND

Peak values plotted on the M diagram



ACKNOWLEDGEMENT
DEVELOPMENT OF THIS CAPABILITY SUPPORTED BY « Lenz Weber Ingenieure GmbH »

3. DIAMOND


cv_cim2_v7.XML
File Edit Display Plot Results Options Window Help
Nodes Elements Local Axes Contour Mesh Supports Reactions Loads Switch Initial Displaced Scale 10 Apply
Time Steps 100 Displacement N, M, V Draw on displaced configuration Chart
Diamond 2016 for SAFIR
FILE : cv_cim2_v7
NODES : 1939
BEAMS : 514
SHELLS : 1080
BENDING MOMENT MZ PLOT
INITIAL CONFIGURATION SELECTED
CONTOUR PLOT
DISPLACEMENT PLOT
TIME : 100 sec
0.008055 to 0.009206
0.006904 to 0.008055
0.005754 to 0.006904
0.004603 to 0.005754
0.003452 to 0.004603
0.002301 to 0.003452
0.001151 to 0.002301
0 to 0.001151
Z
X
Y
Legend Viewport Selection Options
Node Numbering Element Numbering Properties

4. DISTRIBUTION AND EVOLUTION POLICY

- The problem types for GID-SAFIR interface can be downloaded for free from the SAFIR website http://www.facsa.ulg.ac.be/cms/c_1629716/en/safir-free-downloads ; updates will be posted regularly on the website.
- The version 2016 of Diamond can be downloaded for free from the SAFIR website http://www.facsa.ulg.ac.be/cms/c_1629716/en/safir-free-downloads ; updates will be posted regularly on the website. Note that it requires the version of SAFIR 2016 or later to work, because it needs the XML output file produced by these versions.
- The previous version of Diamond, the one that reads the .OUT file will still be available for download on the SAFIR website, but it will not be developed nor maintained in the future.
- The new versions of SAFIR will still produce an .OUT file in parallel to the XML file, but this .OUT file is for your eyes utilisation. It is not anymore intended to be used by Diamond 2016.
- Free updates are normally granted for one year after acquisition of a licence. The new version of the SAFIR executable will be delivered for free to any user who acquired a licence on or later than January 1rst, 2015.
- Users who acquired their licence before 2015 can acquire an update for 1 000 € (commercial licence) or 250 € (academic licence). If interested, please contact safir@ulg.ac.be to obtain a coupon that will allow buying at a discount price on http://www.gesval.be/en/catalogue/safir-commercial (commercial) or http://www.gesval.be/en/catalogue/safir-academic (academic).

5. REFERENCES

The references to be quoted when using SAFIR are:

- Franssen, J.M., Gernay, T. (in press). “Modeling Structures in Fire with SAFIR®: Theoretical Background and Capabilities”, *Journal of Structural Fire Engineering*.
- Franssen, J.M. (2005). “SAFIR. A Thermal/Structural Program Modelling Structures under Fire”, *Engineering Journal, A.I.S.C.*, Vol 42, No. 3, 143-158. http://hdl.handle.net/2268/2928

- Please also quote the adequate references when using the material models CALCON_ETC, SILCON_ETC, STEELSL, CALCOETC2D, CALCOETC3D, etc. (references specified in the Users manual of SAFIR 2016 – mechanical).

QUESTIONS

For questions about the SAFIR suite, please write us as at safir@ulg.ac.be with copy to:

- Installation of the software and administrative questions: a.scifo@ulg.ac.be
- GiD and DIAMOND: jdferreira@ulg.ac.be
- SAFIR: jm.franssen@ulg.ac.be and thomas.gernay@ulg.ac.be