SAFIR
A software for modelling the behaviour of structure subjected to the fire

Jean-Marc Franssen

jm.franssen@uliege.ac.be

University of Liege

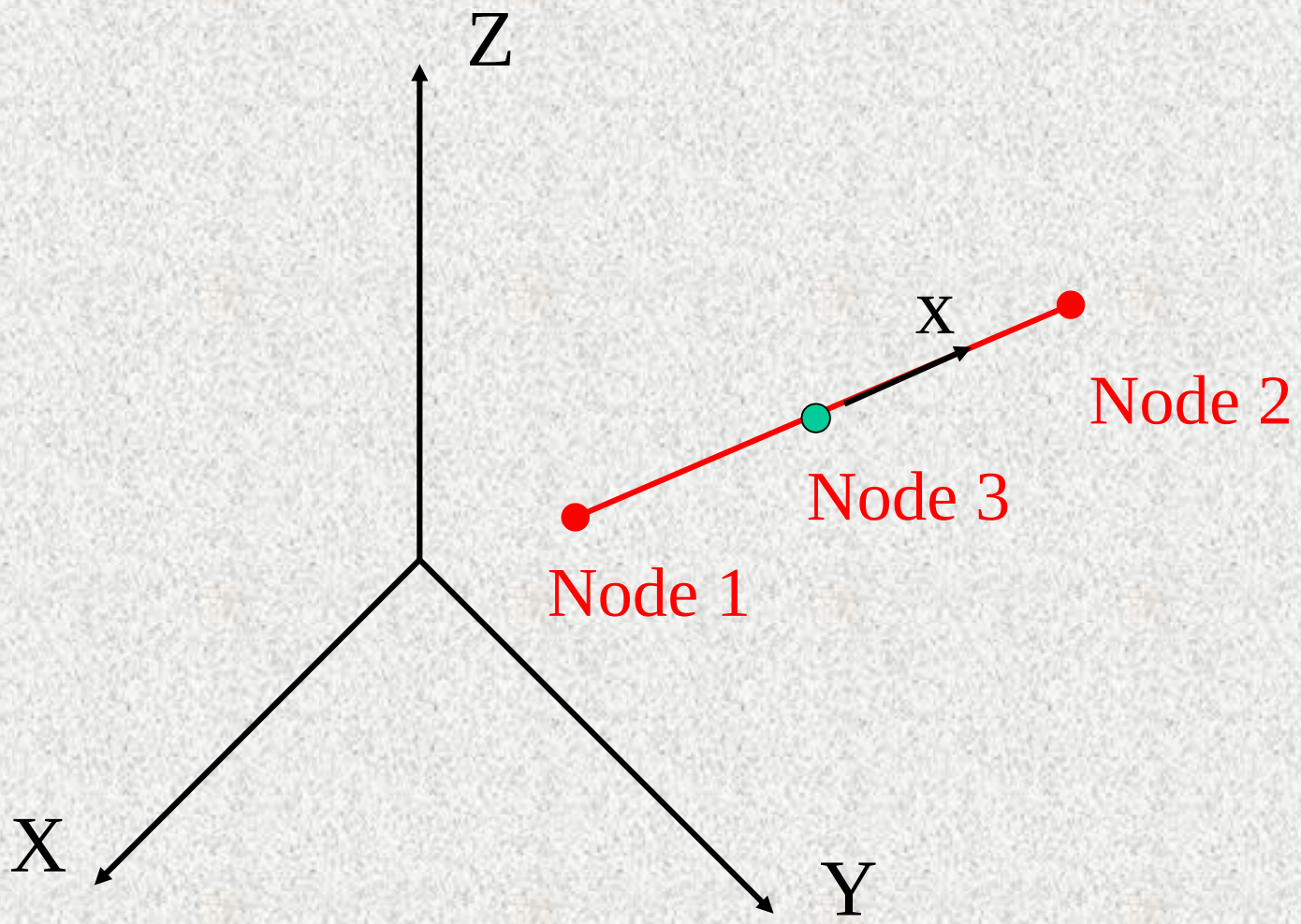
SAFIR

Basic theory of 3D beam F.E.

Three steps in the structural fire design:

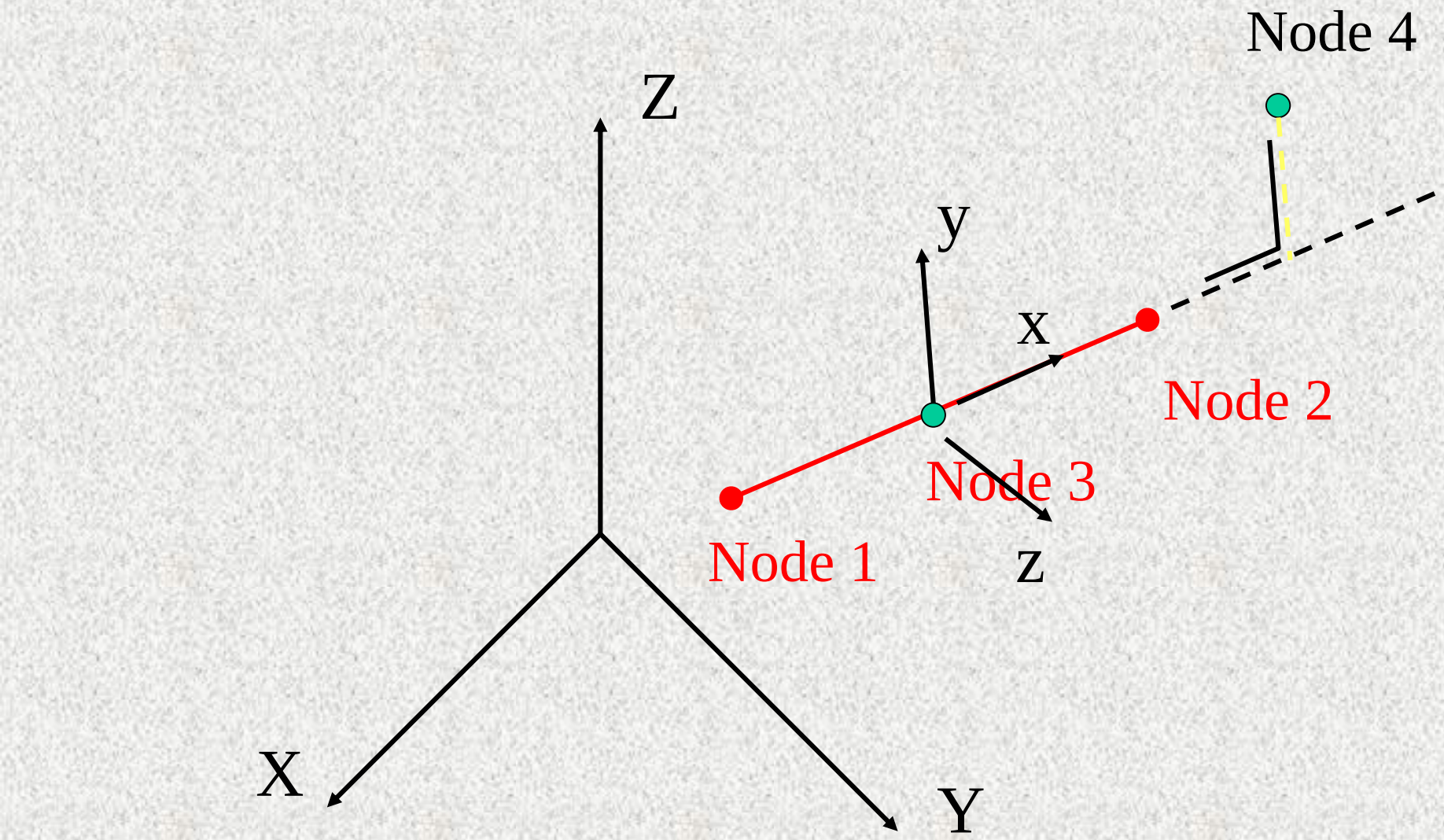
1. *Define the fire (not made by SAFIR).*
2. *Calculate the temperatures in the structure.*
3. *Calculate the mechanical behaviour.*

Discretisation of the 3D beam



In which direction is pointing "y" ?

Discretisation of the 3D beam



"y" is perp. to "x", in the plane 1-2-4

Degrees of freedom at the nodes:

End nodes

- 3 displacements
- 3 rotations
- 1 warping

Central node

- 1 non linear part of the axial displacement

Results at the Gausian integration points:

- N, M_y, M_z, M_t, V_y, V_z
- EA, ES, EI (`PRNEIBEAM`)
- + at each fiber: σ, E_t, ε_m (optional)

Transmission of warping?

In continuous elements: yes

At joints: no

=> either fix the warping to 0.

=> or use 2 nodes with same displ. (and rot.)
but different warping.

The 3D beam finite element needs the stiffness in torsion of the section.
SAFIR can calculate this stiffness.

PRINCIPLE

Use the same discretisation as for the thermal analysis.
No fire curves.
Introduce appropriate material properties and fixations.
Introduce the result of the torsional analysis in the .TEM file.

Note: the calculated stiffness GJ is elastic, at room temperature. It is kept constant during the simulation.
$\Rightarrow$ possibility to reduce GJ arbitrarily.
$\Rightarrow$ not valid if torsion is the main load path.

The detailled procedure is described in the file "*How to go to 3D.doc*"

File "How to go to 3D.doc"

1) Copy and rename the .IN file, for example FRAME.IN into FRAME3D.IN
2) If needed, add some additional nodes in order to define the position of the local system of coordinates of the beam elements.
3) `NDIM` goes from 2 to 3.
4) `NDOFMAX` goes from 3 to 7.
5) The nodes which had 3 DoF have now 7 DoF, see the `FROM` command.
6) Add a `FROM` command which says that the nodes that you may have added under point 2, have 0 DoF.
7) The number of fibres has to be adapted in the `NFIBERS` command (probably multiply it by 2 if you previously used an `YSYM` command in the thermal calculation).
8) The nodes which were previously present have to be given a third coordinate. In order to have a traditional view with DIAMOND, it is preferable that the new co-ordinate be the Y co-ordinate, see table below. Giving 0 to all these Y coordinates means no initial imperfection in this direction.

2D	=>	3D
X	=>	X
-	=>	Y
Y	=>	Z

9) Give the coordinates to the nodes that you have added under point 2.

10) Modify the `BLOCK` commands taking into account the new DoF's. they go in the order: X, Y, Z, θ_X, θ_Y, θ_Z, warping.

11) Add the fourth node to every beam finite element.

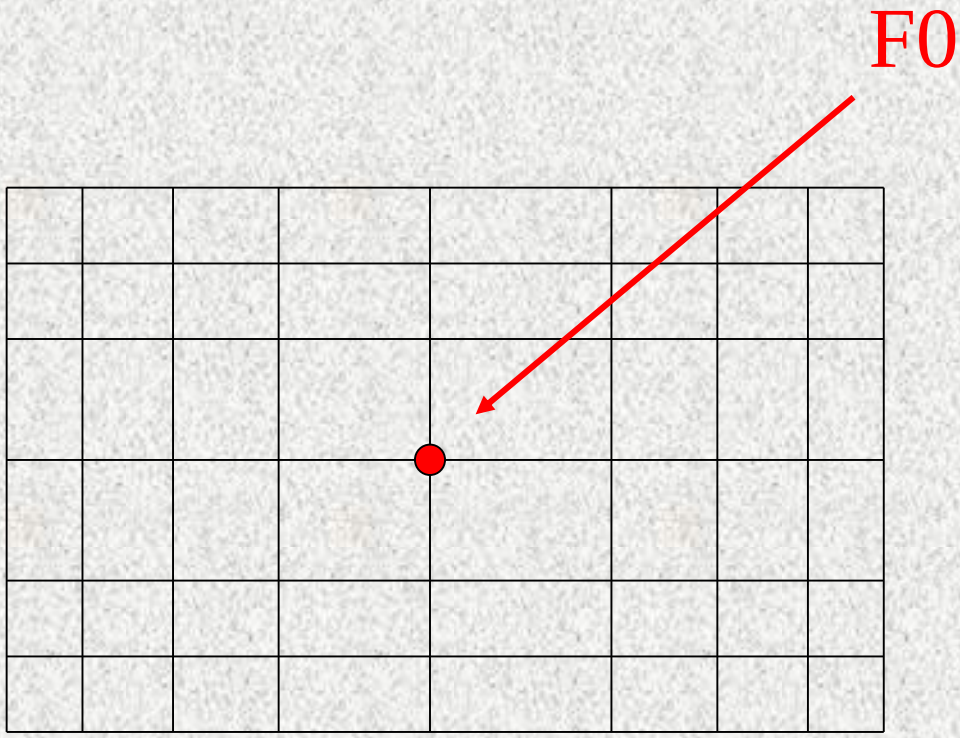
12) Modify the loads in order to reflect the new DoF's. Note that DISTRBEAM have now 3 components, p_X, p_Y and p_Z. NODELOAD have 6 components, F_X, F_Y, F_Z, M_X, M_Y, M_Z.

Note: GID (with the SAFIR/GID interface) can do this automatically (thick the appropriate box when meshing the section for the thermal calculation)

Basic principle:SAFIR calculates the value of the warping function ω at the nodes

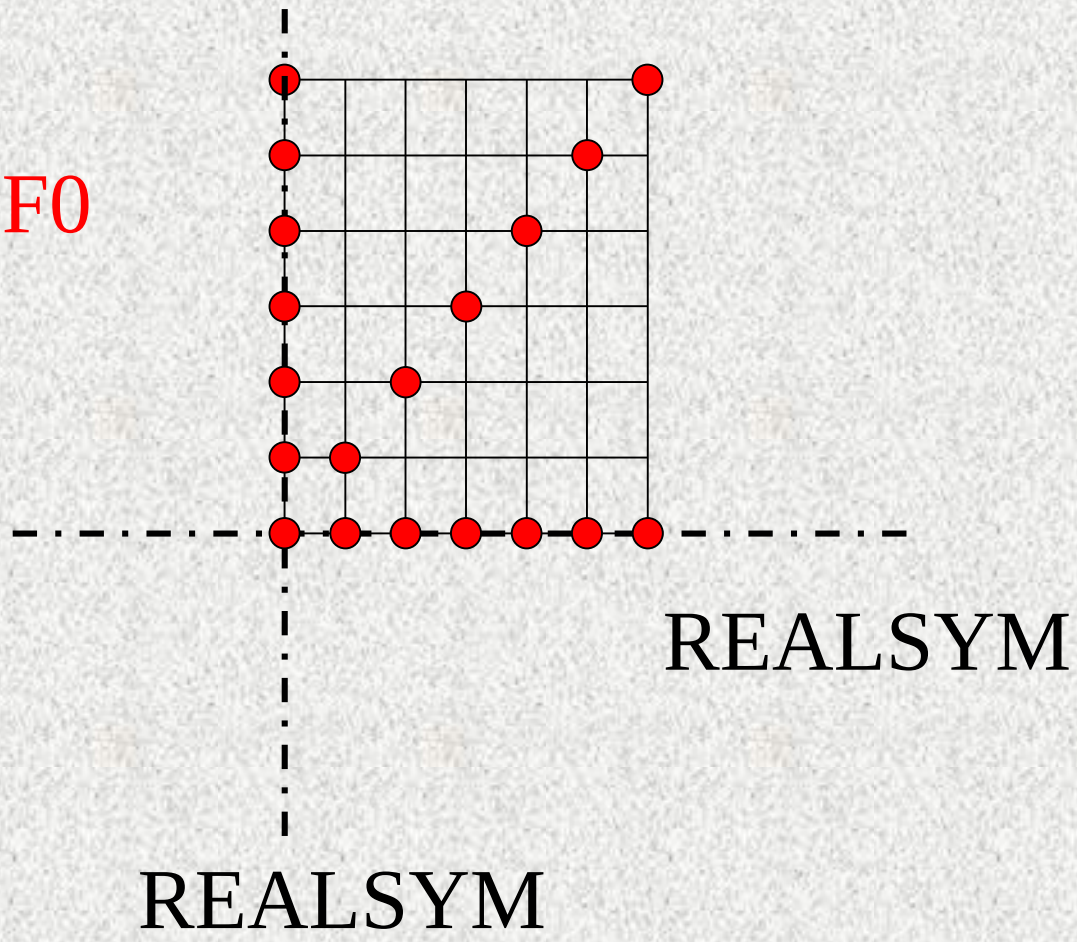
The derivatives of the warping function dω/dy and dω/dz are used to compute the stiffness in torsion GJ.

=> The solution can vary by a constant and GJ remains the same.

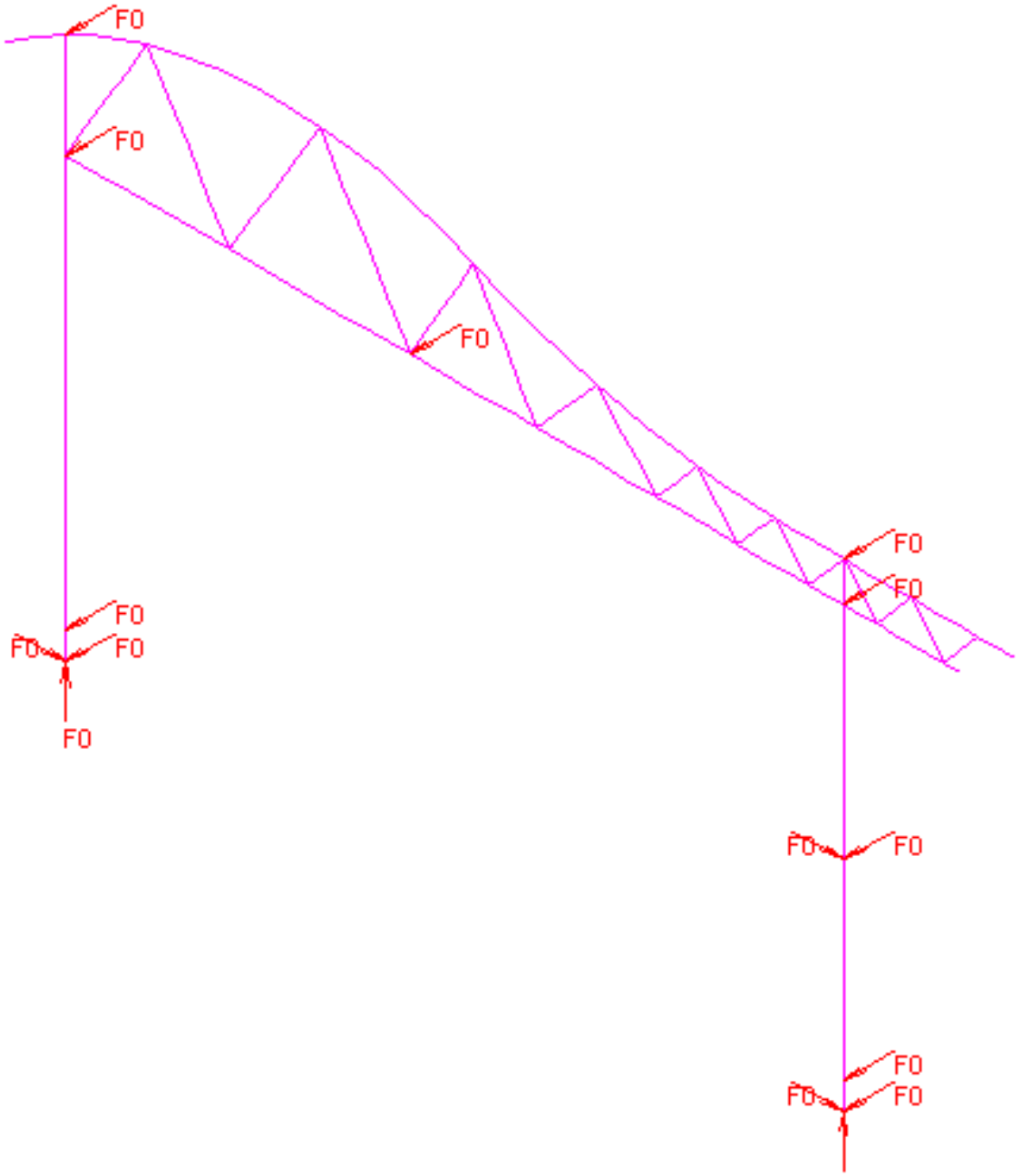


But, in order to have to correct behaviour, it is NECESSARY to fix the solution to 0 on the center of rotation.

YSYM cannot be used in a 3D analysis



Tip: if the section has insulating material,
with no stiffness,
=> use in the torsional analysis, ELASTIC material
with very low value of E.



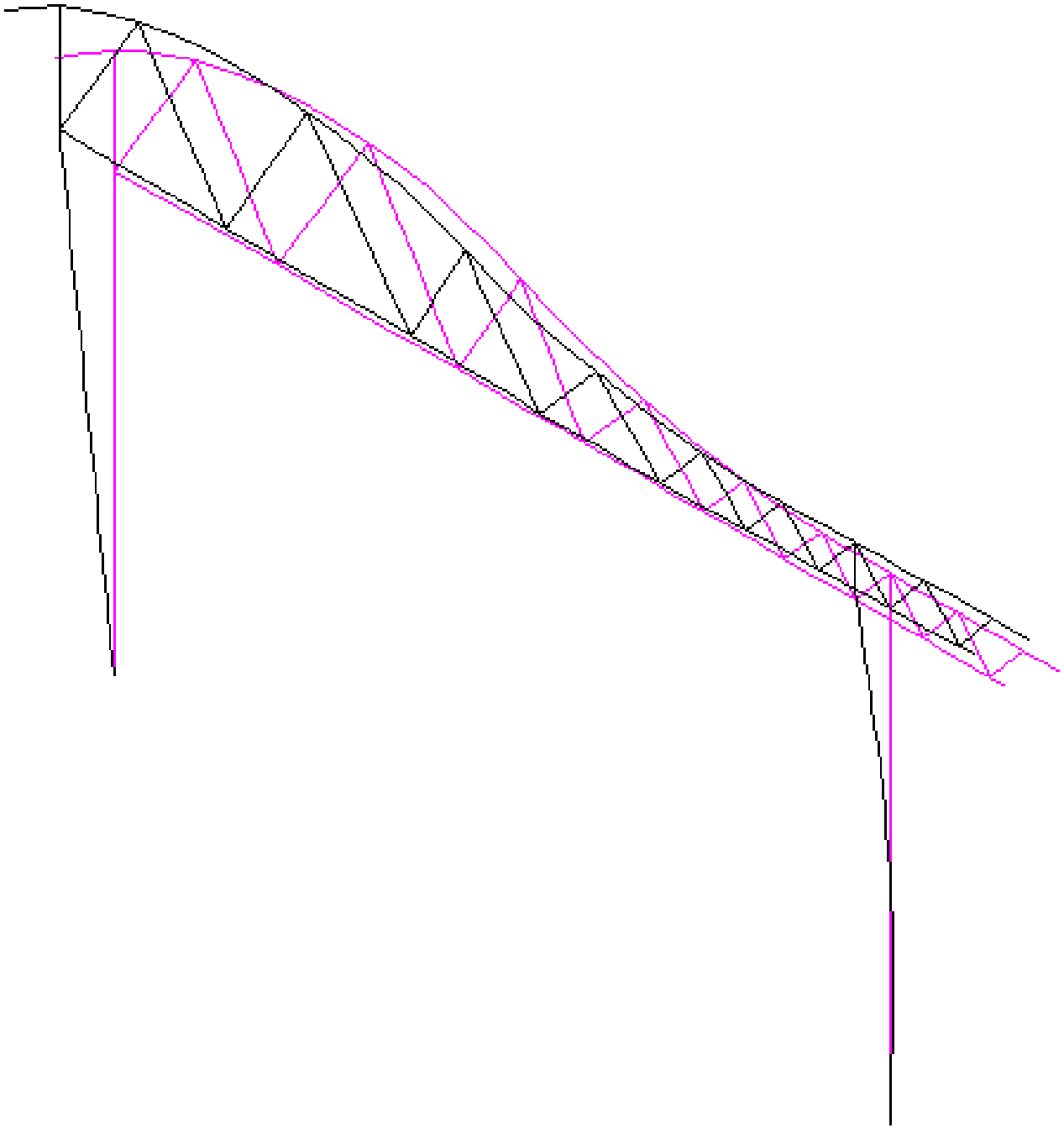
Diamond 2001

FILE: portique4.OUT

NODES: 356

ELEMENTS: 185

IMPOSED DOF PLOT



Diamond 2001

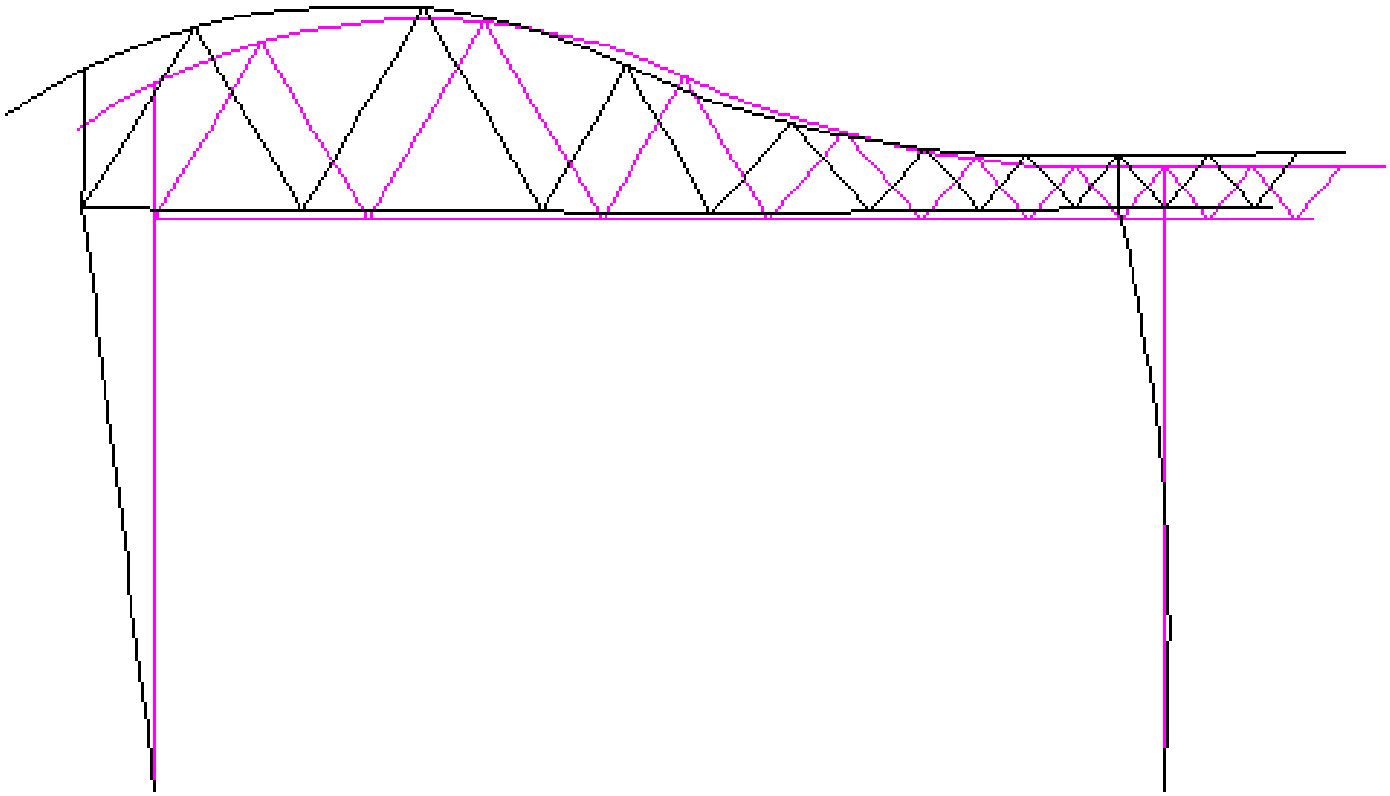
FILE: portique4.OUT

NODES: 356

ELEMENTS: 185

TIME: 752

DISPLACEMENT PLOT



Diamond 2001

FILE: portique4.OUT

NODES: 356

ELEMENTS: 185

TIME: 752

DISPLACEMENT PLOT

Diamond 2001

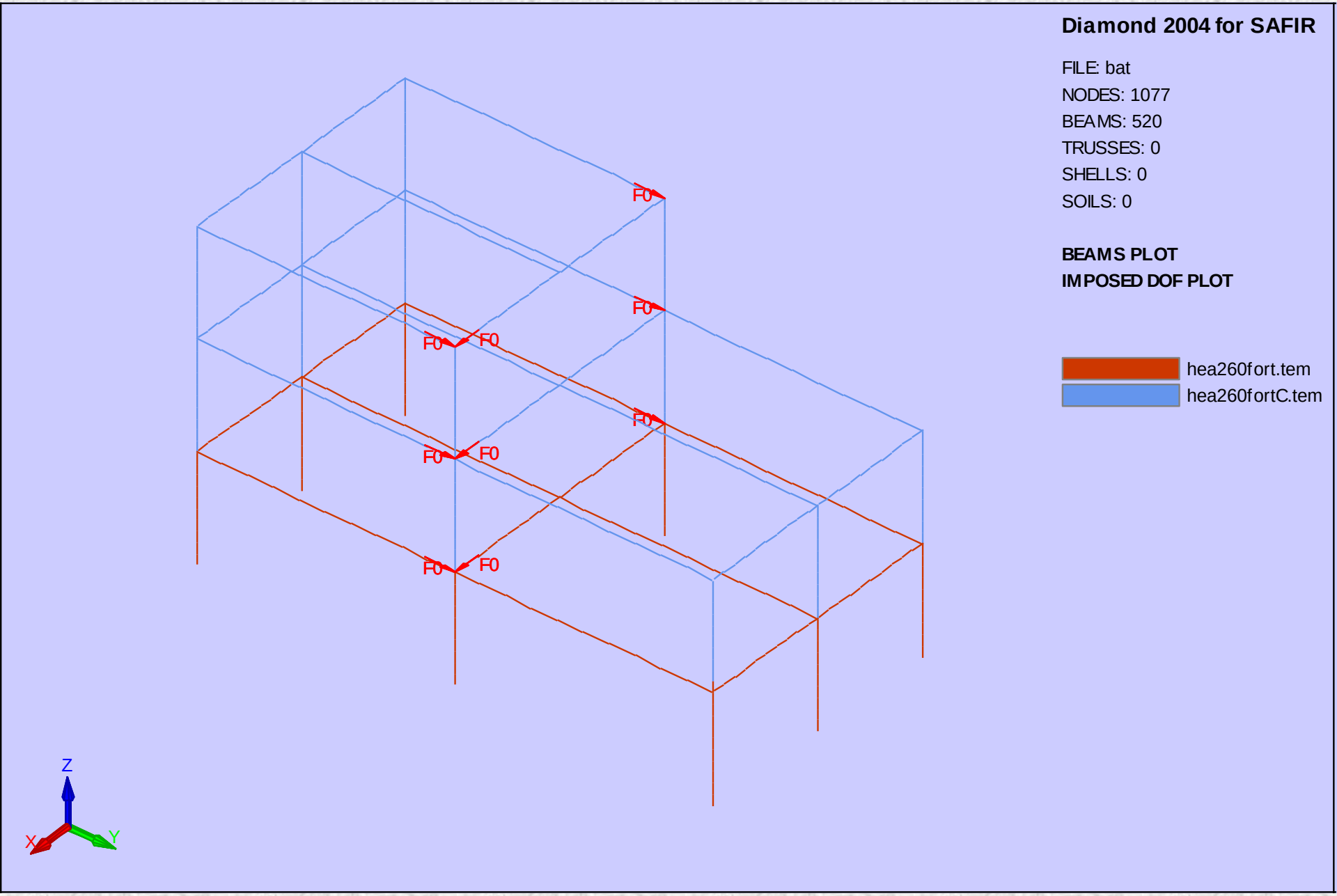
FILE: portique4.OUT

NODES: 356

ELEMENTS: 185

TIME: 752

DISPLACEMENT PLOT

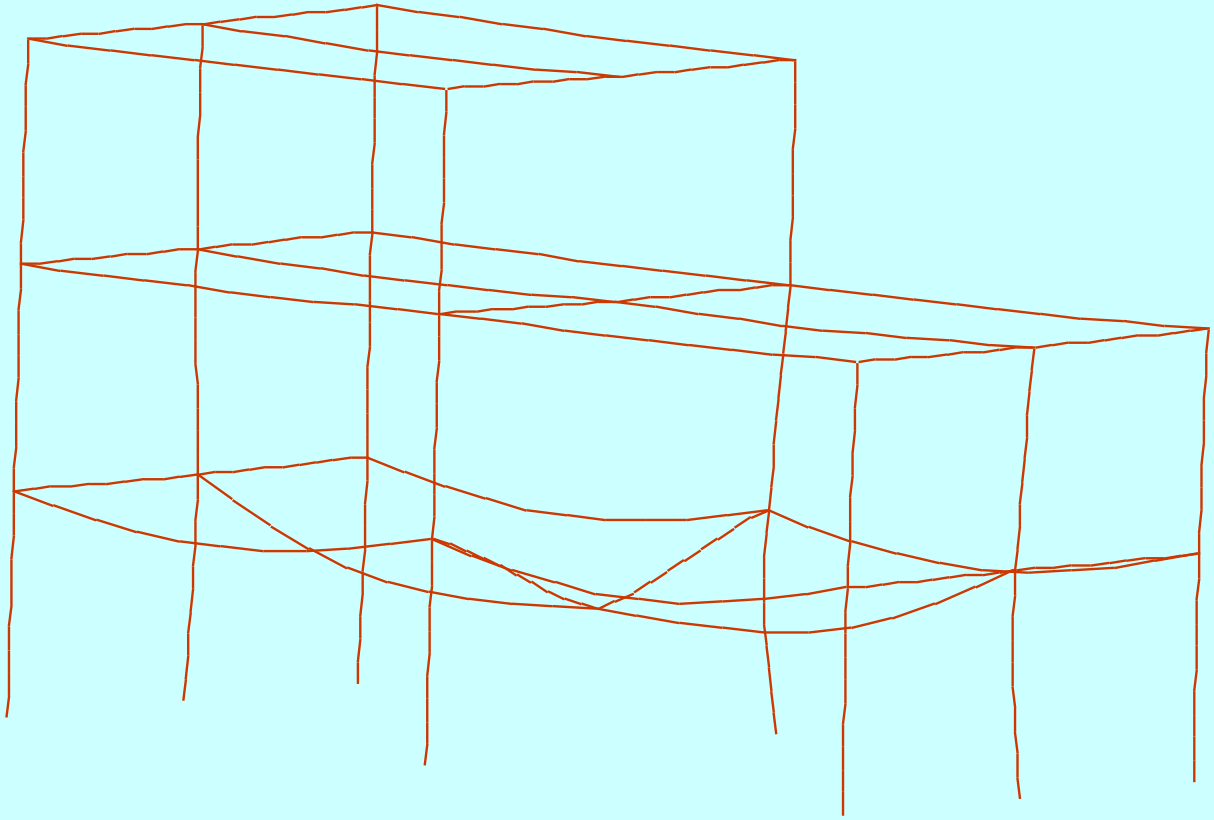

Diamond 2004 for SAFIR
FILE: bat
NODES: 1077
BEAMS: 520
TRUSSES: 0
SHELLS: 0
SOILS: 0
BEAMS PLOT
IMPOSED DOF PLOT
hea260fort.tem
hea260fortC.tem
F0
Z
X
Y

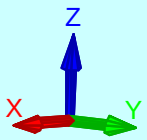
Diamond 2004 for SAFIR

FILE: bat
NODES: 1077
BEAMS: 520
TRUSSES: 0
SHELLS: 0
SOILS: 0

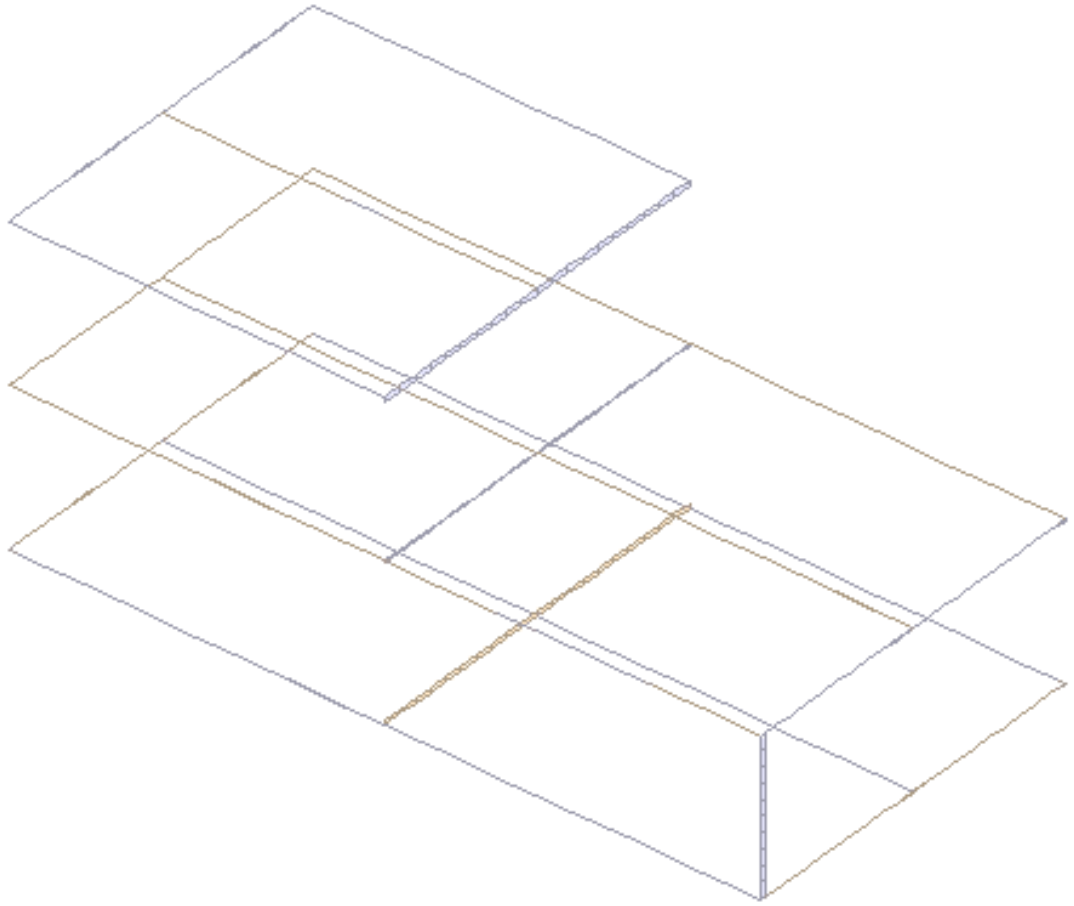
DISPLACEMENT PLOT (x 1)

TIME: 3129.25 sec





5.0 E+00 m



Diamond 2004 for SAFIR

FILE: bat
NODES: 1077
BEAMS: 520
TRUSSES: 0
SHELLS: 0
SOILS: 0

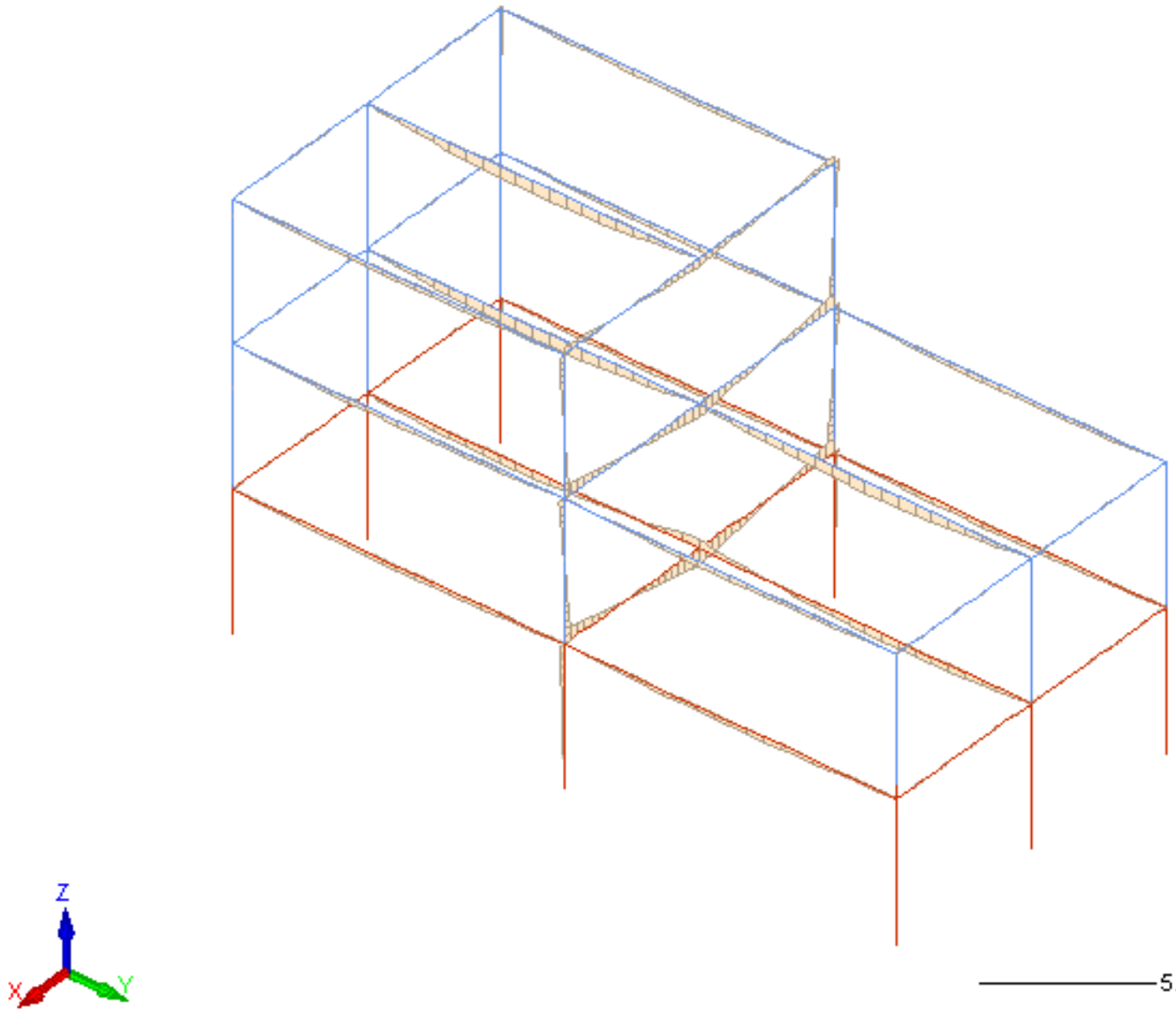
AXIAL FORCE PLOT

TIME: 4 sec

N < 0
N > 0

Z
X
Y

5.0 E+05 N

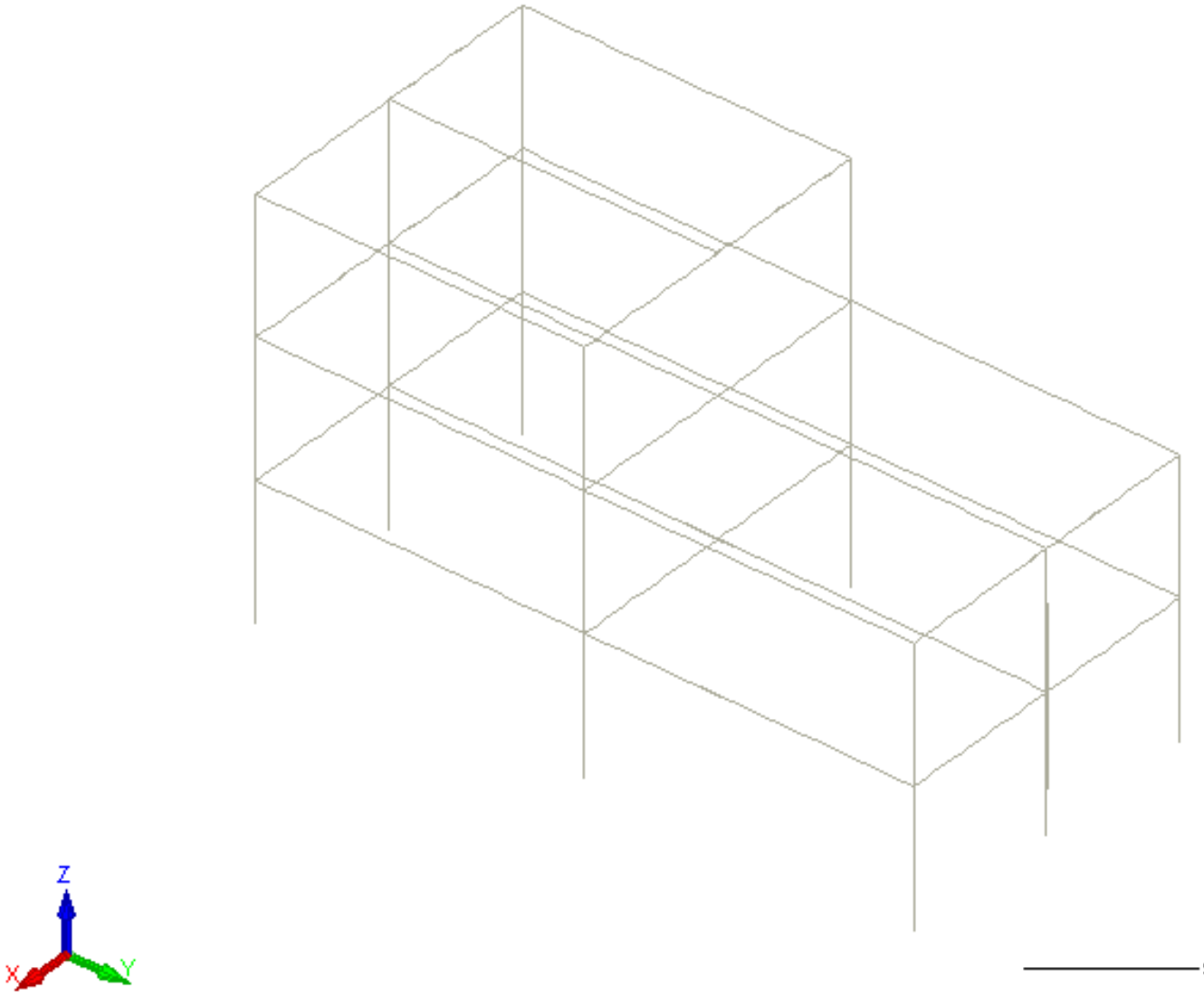


Diamond 2004 for SAFIR

FILE: bat
NODES: 1077
BEAMS: 520
TRUSSES: 0
SHELLS: 0
SOILS: 0

BEAMS PLOT
My BENDING MOMENT PLOT

TIME: 4 sec

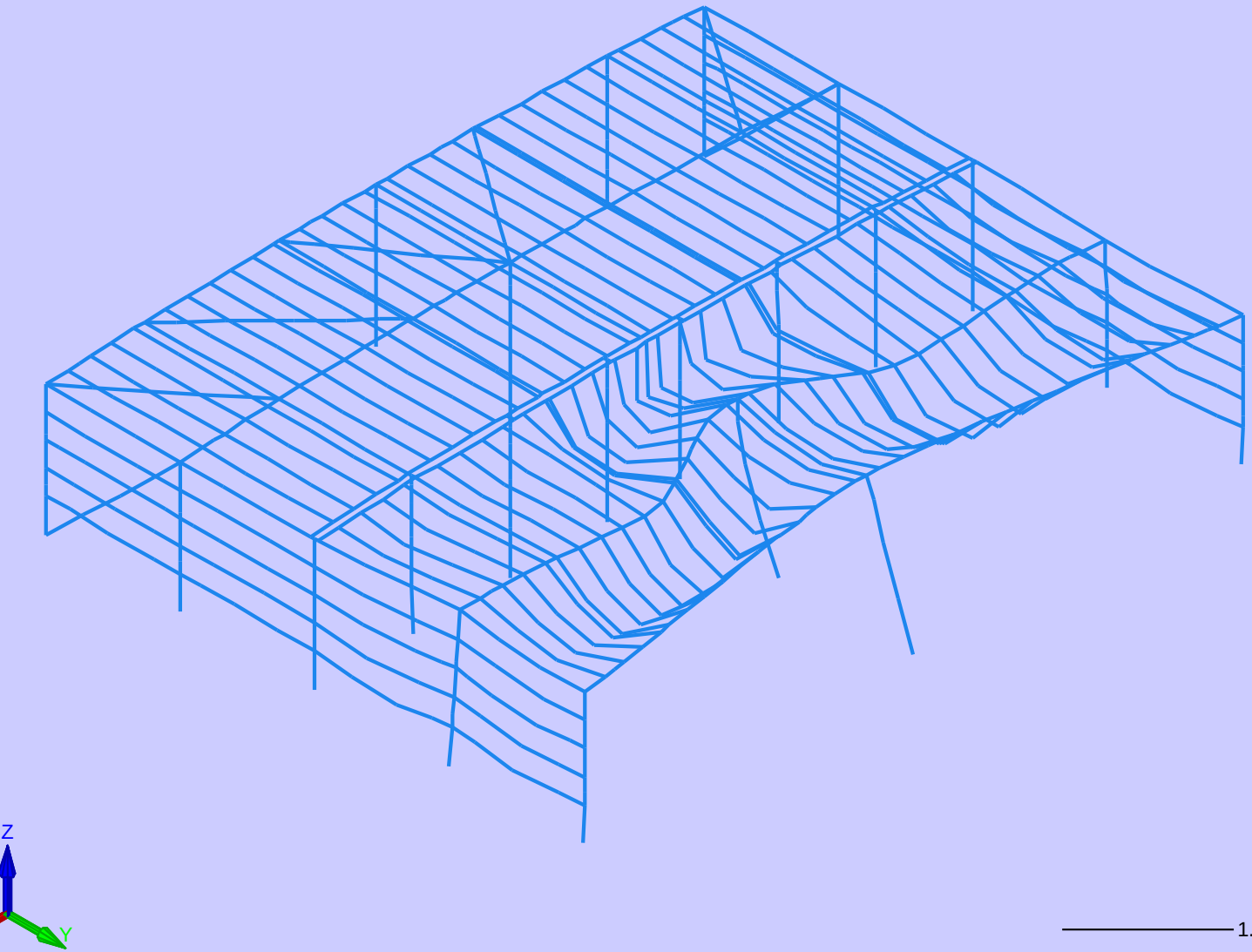


Diamond 2004 for SAFIR

FILE: bat
NODES: 1077
BEAMS: 520
TRUSSES: 0
SHELLS: 0
SOILS: 0

Mz BENDING MOMENT PLOT

TIME: 4 sec



Diamond 2004 for SAF

FILE: Modelo_Def_3
NODES: 2624
BEAMS: 940
TRUSSES: 0
SHELLS: 0
SOILS: 0

DISPLACEMENT PLOT (x

TIME: 739.0464 sec

1.0 E+01 m

Réalisations (suite)