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

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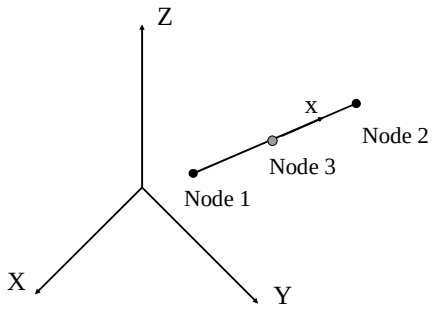
SAFIR

Basic theory of 3D beam F.E.

Three steps in the structural fire design:

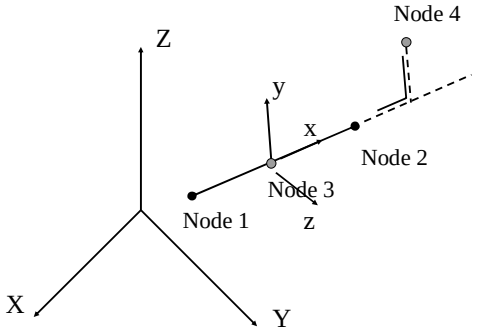
1. *Define the fire (not made by SAFIR).*
2. *Calculate the temperatures in the structure.*
3. *Calculate the mechanical behaviour.*

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
- + 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.

File "How to go to 3D.doc"

Step 3. Modify the IN file for the mechanical analysis.

1) Copy and rename the .IN file, for example C2M.IN into C3M.IN
2) Even if one single member, i.e. a beam or a column, is analysed, the number of nodes has to be increased by 1, here from 21 to 22 (see section 4.2 of the user's manual to see why this node is needed and how you can define the coordinates). In more complex structures, it is possible that more additional nodes are needed.
3) `NDIM` goes from 2 to 3.
4) `NDDLMAX` 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 node(s) that you have added, see point 3, has 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 node(s) that you have added, see point 3
10) Modify the `BLOCK` commands taking into account the new DoF's. they go in the order: X, Y, Z, tetaX, tetaY, tetaZ, warping. Note that 1 line is needed for each blocked node, and 1 blank line at the end of the series.
11) Add the fourth node (the one that you have added) to every beam finite element.
12) Modify the loads in order to reflect the new DoF's. Note that DISTRBEAM have 3 components, pX, pY and pZ. NODELOAD have 6 components, FX, FY, FZ, MX, MY, MZ.

It is necessary to introduce the stiffness in torsion.

Where do we get this value from?

This value can be calculated by SAFIR.

Use the same discretisation as for the thermal analysis.

The unknown D.o.F. is the value of the warping function.

See in the file "How to go to 2D.doc".

1. Copy the existing C2T.IN file and rename it in C2TOR.IN
2. In this new file, change the comment lines (optional)
3. In this new file, replace the commands

```
TEMPERAT
    TETA       0.9
TINITIAL      20.0
MAKE.TEM
```

by the command

```
TORSION
```

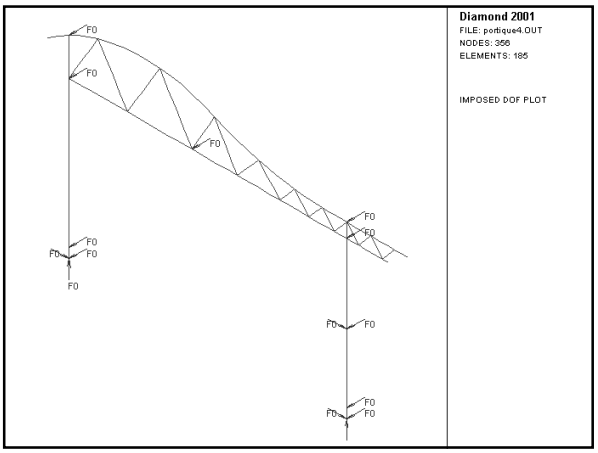
4. In this new file, change the name of the file which will be created, for example, replace "c2t.tem" by "c2tor.tor"
5. Delete all the `FRONTIER` and related commands (there is no fire curve applied here). The `SYMMETRY` command now follows immediately the definition of the elements.
6. Delete the `TIME` …. `ENDTIME` commands (there is no need of time steps because the calculation is done only once).
7. Use of symmetries
   a. If the whole section is modelled (no symmetry is used), IT IS ABSOLUTELY REQUIRED to fix the value of the solution to 0 in at least one node of the axis of symmetry. If not, the torsional stiffness will be correctly evaluated, but the warping function at all nodes will be offset by an arbitrary value and this will create amazing results in torsion during the mechanical analysis.
   b. `YSYM` cannot be used in a 3D problem. It means that, if the temperatures where previously calculated using the `YSYM` command because the .TEM file was to be used in a 2D mechanical analysis, it is now necessary to recalculate the temperatures and to replace this `YSYM` command by a `REALSYM` command.
   c. If one part of the section only is discretised and 1 or 2 `REALSYM` commands are used, it is necessary to fix the value of the solution to 0 at all the nodes which are on the axes of symmetry. If there is another axis of symmetry in the solution, but this axis is not used in a `REALSYM` command, the values of the solution must also be fixed to 0 on this axis. This is the example of a square section if ¼ of the section is discretised, then the solution must also be fixed to 0 on the diagonal of the square section.

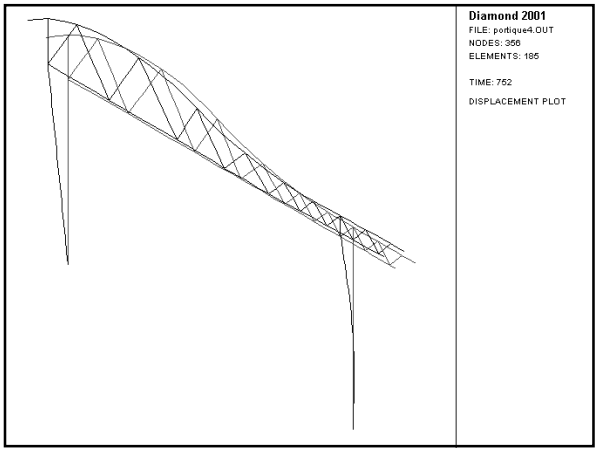
8. In the **MATERIAL** command, you must enter the material mechanical properties for each material (the same properties as the one you will use in the mechanical analysis. Don't forget the Poison's ratio).

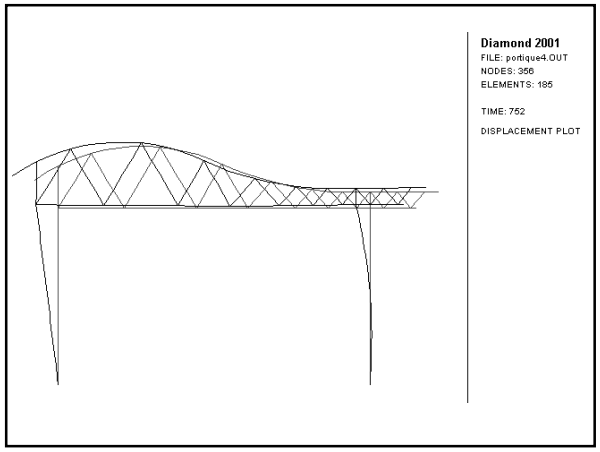
9. Run SAFIR with this new file. The CPU time is extremely short. The end of the .OUT file looks like this:

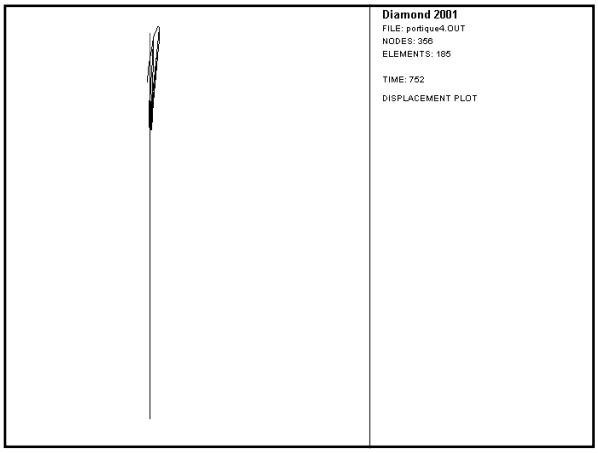
```
  G * Ip =   27259615.3846154
According to the principle of virtual works,
     GJ = 0.919990E+08
```

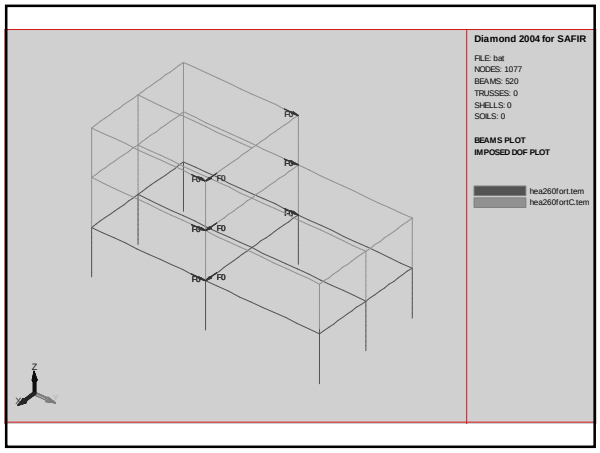
The value that is calculated is
- elastic (OK)
- at 20°C (you can reduce it by an arbitrary factor, especially in steel sections)
=> The beam F.E. should not be used when the load path is mainly by torsion.

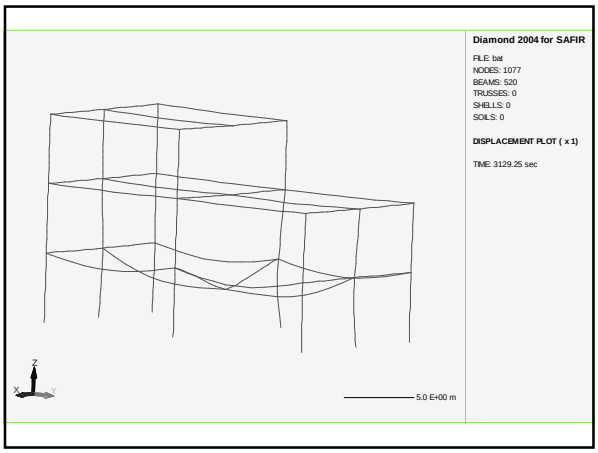


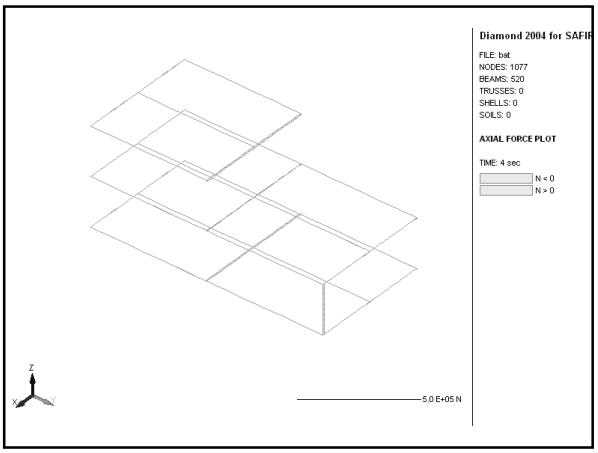


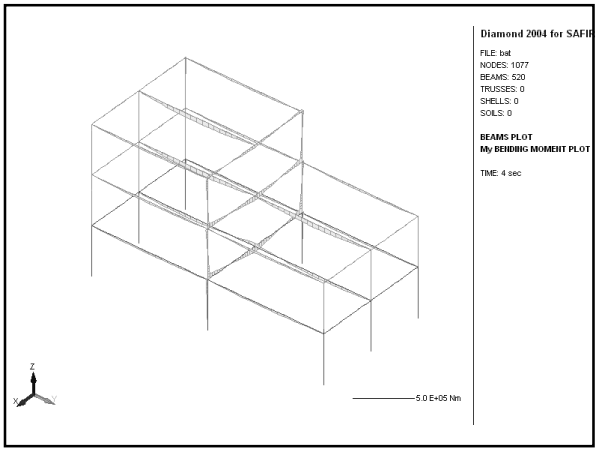


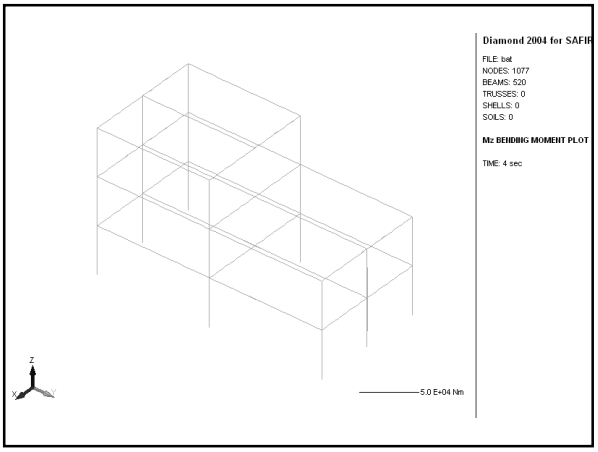


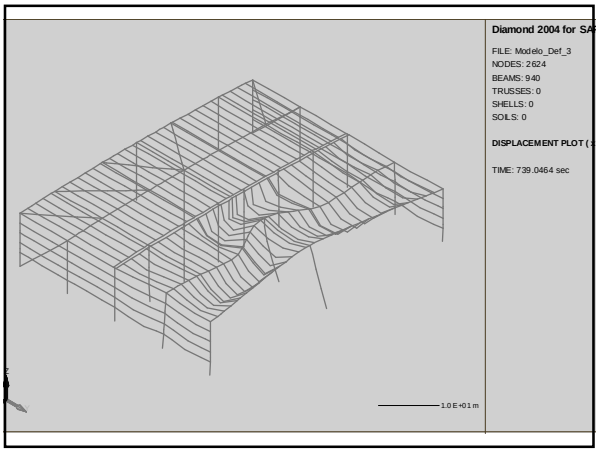



Diamond 2004 for SAFIR
FILE: bat
NODES: 1077
BEAMS: 520
TRUSSES: 0
SHELLS: 0
SOILS: 0
DISPLACEMENT PLOT (x 1)
TIME: 3129.25 sec
5.0 E+00 m


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
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
5.0 E+05 Nm


Diamond 2004 for SAFIR
FILE: bat
NODES: 1077
BEAMS: 520
TRUSSES: 0
SHELLS: 0
SOILS: 0
Mz BENDING MOMENT PLOT
TIME: 4 sec
5.0 E+04 Nm


Diamond 2004 for SA
FILE: Modelo_Def_3
NODES: 2624
BEAMS: 940
TRUSSES: 0
SHELLS: 0
SOILS: 0
DISPLACEMENT PLOT (
TIME: 739.0464 sec
1.0 E+01 m