SAFIR®
A software for modelling the behaviour of structures subjected to fire

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SAFIR®

LOCAFI model for localised fires

A model called LOCAFI has been implemented in SAFIR®

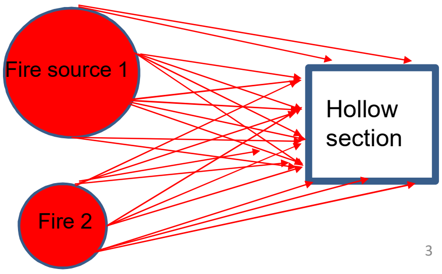
for heating any structural element

from one or several localised fires.

Each localised fire is represented by a solid flame.

The radiative flux from the solid flames to the elements is computed on the base of view factors.

The red arrows mean that every side of the fire sources will radiate to each boundary of the section (if they « see » each other).



3

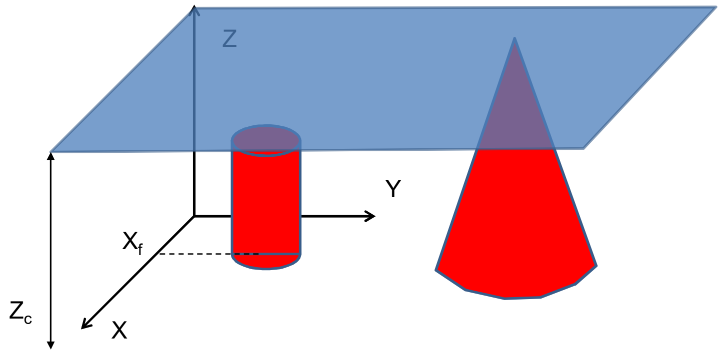
The main features of this implementation are:

a) All the input data for this model are in a format that is nearly exactly the same as the format for the HASEMI local model.
   All results are also organized in the TEM files in the same way as for the HASEMI model.

b) The structure can be subjected to one or several local fire sources. In case of multiple fires, the input fluxes from each fire are simply added (<= 100 kW/m² on each boundary of the section).

c) Each source has a shape that is either a cylinder or a cone. The shape is constant during the simulation.

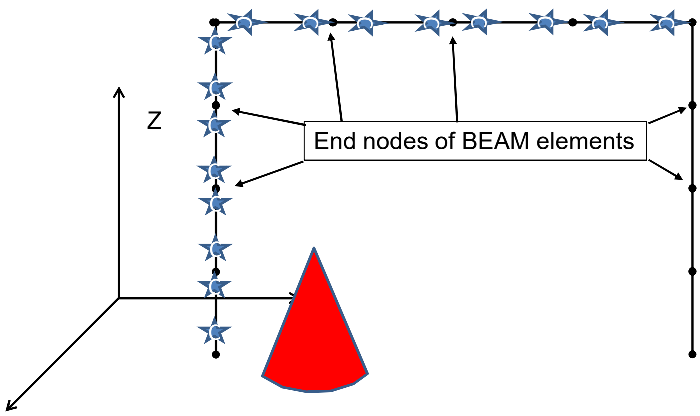
d) Each fire source is described by:
- the 3D position of the origin of the source in the structure (X_f, Y_f, Z_f),
- the shape of the source, cone or cylinder,
- the vertical position of the ceiling Z_c (used to check whether the flame touches the ceiling or not) and,
- as a function of time, the diameter of the fire and the rate of heat release of the fire.



5

e) The thermal model of SAFIR® calculates the temperature by a series of 2D thermal analyses performed at each longitudinal point of integration (PoI) of each BEAM finite element of the structure chosen by the user (=> no longitudinal heat flux in the element).

These BEAM elements can have any orientation in space: vertical in columns, horizontal in truss chords or inclined in truss internal members.

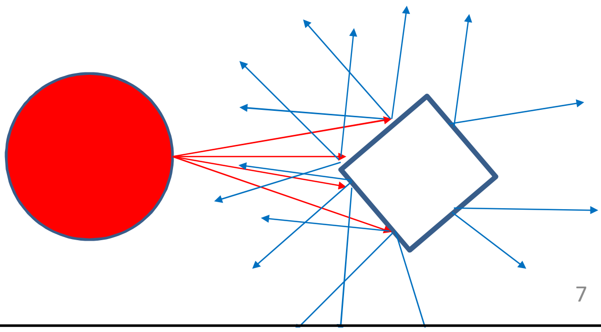


6

f) For each section, the heat flux at any time is calculated separately for each surface of the boundary. This means that the thermal attack from the local fires to the section is anisotropic: the boundaries that are facing the fire receive the highest flux while the boundaries on the opposite side receive no flux at all.

g) When a LOCAFI flux is calculated on a boundary, heat losses are automatically added from the boundary to the far field (supposed to be at ambient temperature if the PoI is not in the flame).

⇒ A frontier "F20" or a flux "LOCAFI" **must** be applied at the back of the section.
(the frontier condition will lead to shorter CPU time).



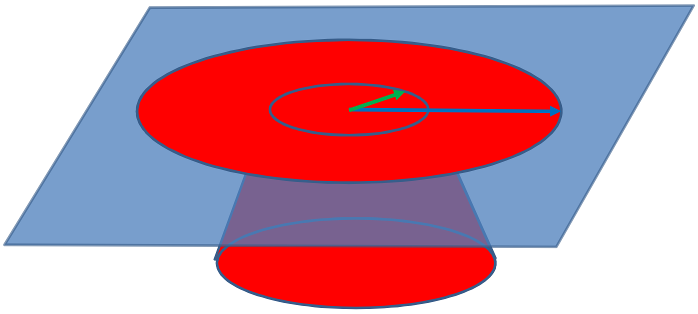
7

h) The length of the flame (i.e. length of the fire source in the direction of the axis of the cylinder or of the axis) is calculated according to Eq. C.1 of EN1991-1-2.

i) The temperature evolution along the centerline of the fire source up to the ceiling is calculated according to Eq. C.2 of EN1991-1-2.

8

j) If the length of the flame is greater than the source to ceiling distance, a disk will form underneath the ceiling.

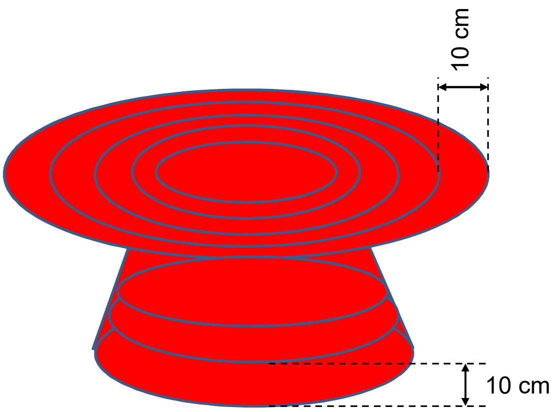


In this case, SAFIR will calculate the length of the flame underneath the ceiling according to the Hasemi model (Eq. C.5. of EN 1991-1-2).

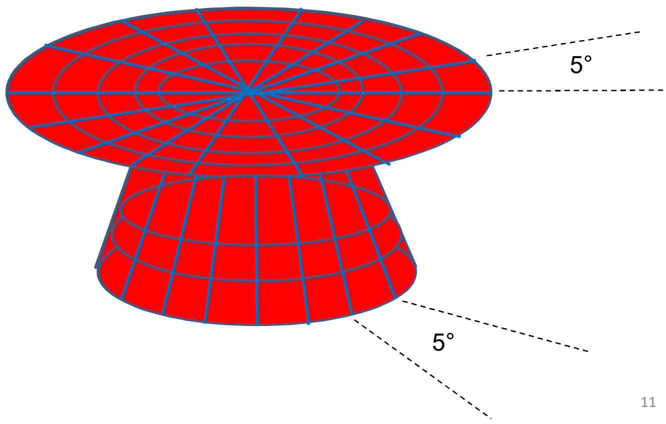
If this length is longer than the radius of the solid flame at that level, it will calculate the radius of the disk (equal to the horizontal flame length) and,

as a function of the radial distance, an adiabatic surface temperature corresponding to the flux of Hasemi.

k) The fire source is divided into horizontal slice of equal depth (10 cm) (and the disk is divided into concentric rings with a radial depth of 10 cm).
The temperature of each slice is uniform and taken as the temperature along the centerline at mid-level of the slice, see point i). The temperature of each ring is uniform and calculated from the Hasemi model at mid radial distance, see point j).

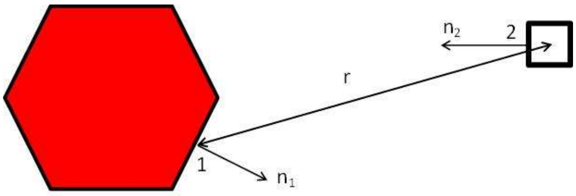


l) Each slice and each ring is divided into 72 sectors of 5 degrees opening each.



11

m) These two divisions mentioned under k) and l) define a series of facets that form the boundary of the solid flame.
The radiative flux from each facet is calculated to each boundary of the section where a LOCAFI flux has been defined.
The sum of the flux from all facets is called Φ

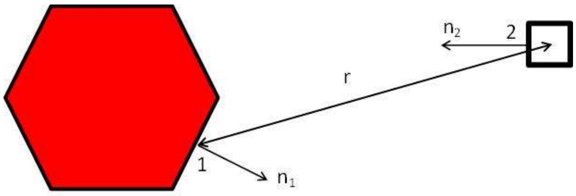


The total flux at the boundaries of the section is given by:

$q = \varepsilon_S \, \Phi - h \, (T_s - 293) - \varepsilon_S \, \sigma \, (T_S^4 - 293^4)$

12

m) As an simplification, the position of all receiving surfaces of a section is approximated to be at the axis of the system of coordinates of this section.



n) The structural part of SAFIR® will then, in a subsequent analysis, calculate the mechanical behaviour of the structure based on this transient and largely non uniform temperature distribution in the structure.

13

What if the Point of Integration is located in the flame?

=> The flame temperature considered for the heat exchange with the flame is the temperature in the centerline of the flame at the level of the PoI.

=> There is a convective flux with this temperature and a radiative flux with this temperature and a view factor of 1,0.

Notes:
1) The PoI is never in the disk that may exist underneath the ceiling (the disk has no thickness).
2) If two flame intersect and the PoI is in the intersection, the maxium flux from each flame is considered for each boundary of the section.
3) There may be a high discontinuity in term of thermal attack when the PoI « enters » in the flame, because, from this moment, there is no boundary opposed to the direction of the flame.

The boundary condition at the boundaries of the section is given by:

$$q = \varepsilon_S\, \Phi - \varepsilon_S\, \sigma\, T_S^4 - h\,(T_s - T_{flame})$$

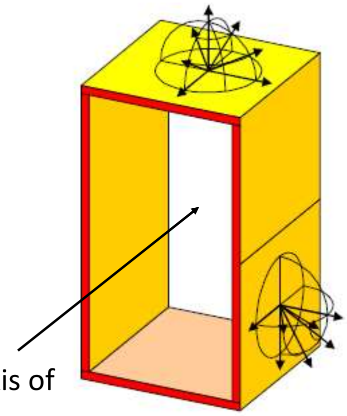
14

What if the section is concave?

=> The « view angle » from each boundary of the section to the flame is calculated. Only the rays 1-2 that belong to that view angle are considered.

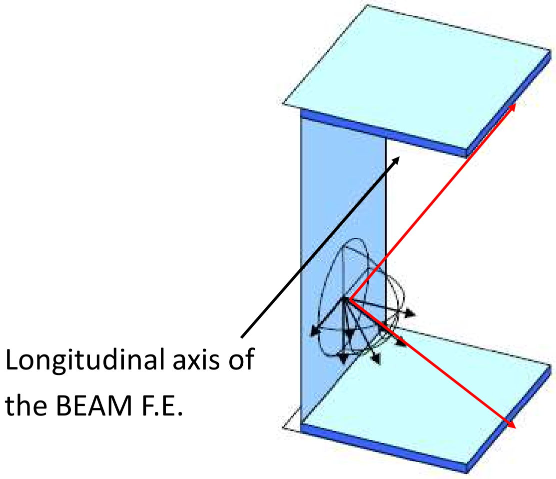
CONVEX ELEMENT

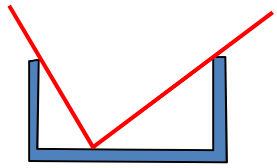
Flux from the complete hemisphere



CONCAVE ELEMENT

Flux only from the “clear sky”





Notes:

1) A « shaddow effect » is thus considered if the PoI is not in the flame.
No « shaddow effect » is considered if the PoI is in the flame.

2) No mutual radiation between different boundaries of the section

3) Obstruction by other members that would be located between the flame and the PoI is not considered.

18

Structure of the structural input file

1) Only 3D BEAM elements can be heated by a LOCAFI fire.
2) This file must exist before the LOCAFI thermal calculations are made.
3) It must be present in the same folder as the thermal input files.
4) The global axis Z must point upward.

Example

```
....
NODOFBEAM
B0001_1.tem                  ! This section type is heated by a LOCAFI fire
 TRANSLATE    1    1
 END_TRANS
IPE360.tem                   ! This section type is not heated by a LOCAFI fire
 TRANSLATE    1    1
 END_TRANS
B0031_1.tem                  ! This section type is heated by a LOCAFI fire
 TRANSLATE    1    1
 END_TRANS
....
```


Q: What is the structure of the 2D thermal input file?

A: Procedure very similar to the one used for HASEMI fire.

1) Replace MAKE.TEM by MAKE.TEMLF
2) Next line, give the name of the input file for the structural analysis (this file must be present in the same folder. It must be a 3D structure);
3) Next line, give the number of the BEAM type of section considered.

Example

```
....
   TEMPERAT
      TETA         0.9
  TINITIAL        20.0
MAKE.TEMLF
frame3D.in
 BEAM_TYPE    1
      NMAT    1
  ELEMENTS
     SOLID    60
....
```

4) In the FIXATION commands, introduce a FLUX command where is needed.

FLUX 105 NO NO LOCAFI NO

5) Create a file called LOCAFI.TXT that describes the local fire (see next slide). This file must be present in the same folder as the thermal input file

6) Introduce the information for torsion properties only in the first .TEM file of the list of elements of this section type, for example in b0001_1.tem

7) Repeat the procedure for all section types heated by the LOCAFI fire.

21

The file LOCAFI.TXT

```
Description of a local fire following the LOCAFI model.
There is only 1 local fire in this example.

NFIRE    1                Number of localised fires.

FIRE_POS   3.0    0.0   0.0    Position of the local fire in the SoC of the structure
Z_CEILING                11.0    Vertical coordinate of the ceiling
PLUME_TYPE   CONIC             Conical plume (could be CYLIND)

DIAMETER
            0.       0.0          Time (s) - Fire source diameter (m)
          846.       9.0
         3600.       9.0
END_DIAM

RHR
             0.          0.00       Time (s) - RHR (W)
        211.5          1.99e+06
        423.0          7.95e+06
        803.7          28.71e+06
        846.0          31.81e+06
       1263.639        31.81e+06
       1863.639        0
END_RHR
```