International Conference
APPLICATIONS OF STRUCTURAL FIRE ENGINEERING

Prague, Czech Republic
29, April 2011

Modelling of Multiple Localised Fires and Steel Structural Members Response Using the Software Elefir-EN

Paulo Vila Real | Carlos Couto | Nuno Lopes

University of Aveiro, LABEST - Department of Civil Engineering, Aveiro, Portugal

decivil universidade de aveiro departamento de engenharia civil

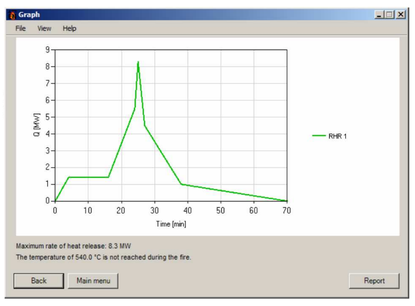
INTRODUCTION

The software Elefir-EN allows for considering natural fire scenarios based on the simple fire models given in part 1-2 of Eurocode 1.

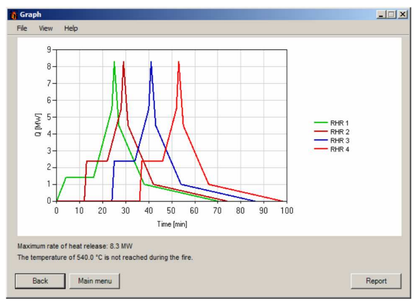
In this work, the software was used to model the thermal response of the steel beams of a closed car park subjected to a multiple localised fire according to Annex C of Part 1-2 of Eurocode 1, showing the capabilities of the new software Elefir-EN for calculating the critical temperature of the steel members and subsequent evaluation of the thickness of the fire protection material needed to fulfil the required fire resistance. The software allows for modelling multiple localised fires due to simultaneously burning of cars.

CHARACTERIZATION OF THE FIRE AND FIRE SCENARIOS

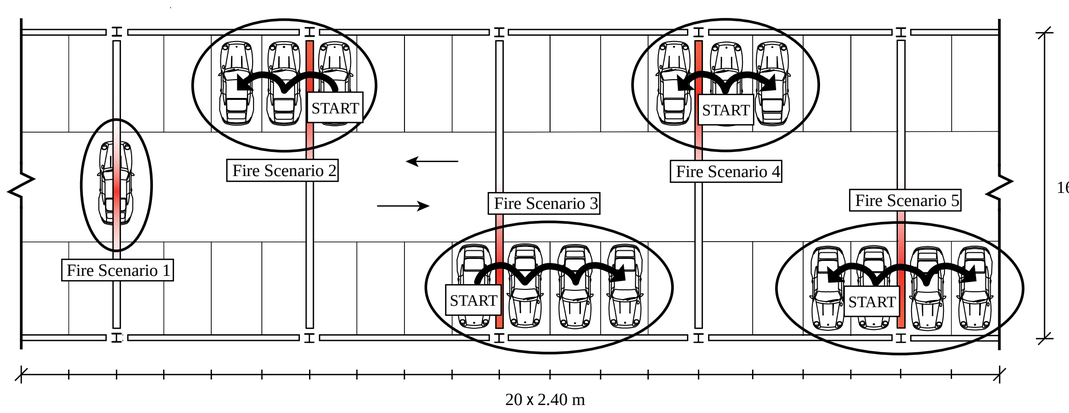
The Rate of Heat Release for category 3 cars, according the European Project "Demonstration of real fire tests in car parks and high buildings" (European Commission, 2001), was used in the software Elefir-EN:



Rate of Heat Release of a single class 3 car fire (Max: 8.3 MW)



Rate of Heat Release of a single class 3 car fire with a delay of 12 minutes



- ❑ Scenario 1 – 1 car burning below the beam at mid span
- ❑ Scenario 2 – 3 cars burning in a normal parking bay
- ❑ Scenario 3 – 4 cars burning in a normal parking bay
- ❑ Scenario 4 – 3 cars burning in a normal parking bay
- ❑ Scenario 5 – 4 cars burning in a normal parking bay

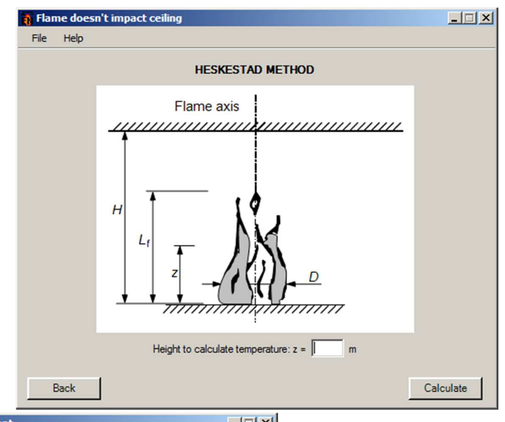
It was considered an ignition delay of 12 minutes between adjacent cars.

In the Scenario 3 the burning of the fourth car doesn't affect the maximum temperature of the steel beam.

LOCALISED FIRES

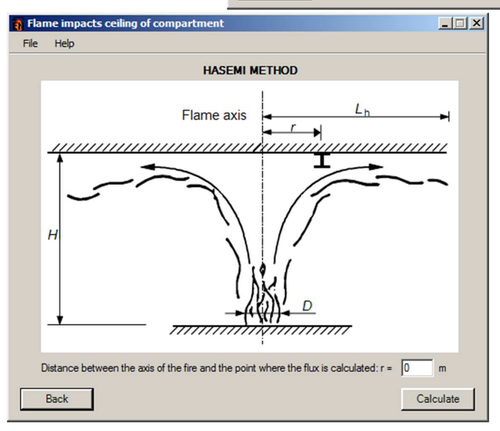
The vertical length of the flame is given by: $L_f = -1.02D + 0.0148Q^{2/5}$ [m], where *D* is diameter of the fire and *Q* the Rate of Heat Release.

Flame doesn't impact the ceiling Temperature calculated using the **Heskestad** method by: $\theta_{(z)} = 20 + 0.25Q_c^{2/3}(z - z_0)^{-5/3} \leq 900$ [ºC].



Flame impacts the ceiling Heat flux $\dot{h}$ calculated using **Hasemi** method:

$$\begin{cases} \dot{h} = 100\,000 & \text{if} \quad y \leq 0.30 \\ \dot{h} = 136\,300 - 121\,000\,y & \text{if} \quad 0.30 < y < 1.0 \\ \dot{h} = 15\,000\,y^{-3.7} & \text{if} \quad y \geq 1.0 \end{cases} \quad \text{[W/m2]}$$



The net heat flux can be calculated by $\dot{h}_{net} = \dot{h} - \alpha_c \cdot (\theta_m - 20) - \Phi \cdot \varepsilon_f \cdot \varepsilon_m \cdot 5.67 \times 10^{-8} \cdot [(\theta_m + 273)^4 - 293^4]$ [W/m2]

In case of several multiple localised fires the Total Heat flux is obtained by $\dot{h}_{tot} = \dot{h}_1 + \dot{h}_2 + \dot{h}_3 + ... \leq 100\,000$ [W/m2]

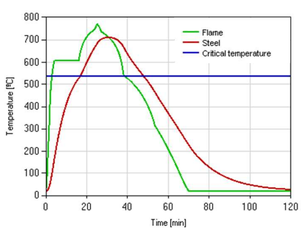
TEMPERATURE IN STEEL MEMBERS SUBJECTED TO LOCALISED FIRES

Unprotected steel members $\Delta\theta_{a,t} = k_{sh} \dfrac{A_m / V}{c_a \rho_a} \dot{h}_{net,d} \Delta t$

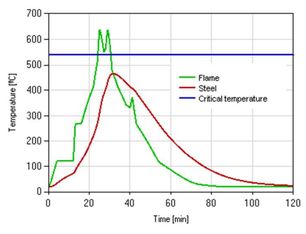
Protected steel members $\Delta\theta_{a,t} = \dfrac{\lambda_p A_p / V}{d_p c_a \rho_a} \dfrac{(\theta_{g,t} - \theta_{a,t})}{(1 + \phi/3)} \Delta t - (e^{\phi/10} - 1)\Delta\theta_{g,t}$

When the flame impacts the ceiling the effect of the fire is given by an impinging flux. A procedure has to be established to transform the impinging heat flux into an equivalent gas temperature. In Elefir-EN this is accomplished by considering the gas temperature as the temperature of a fictitious unprotected steel profile with very high section factor.

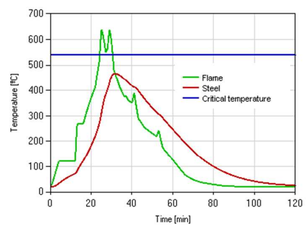
TEMPERATURES OF THE BEAM



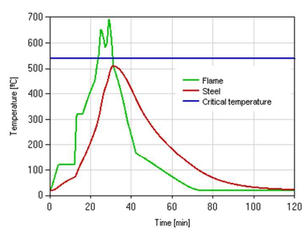
❑ Scenario 1



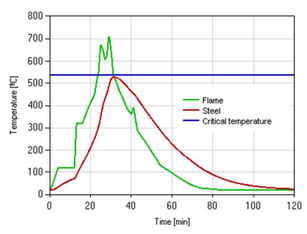
❑ Scenario 2



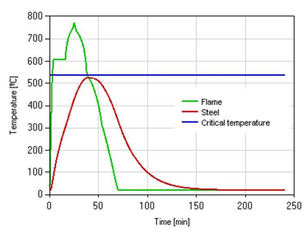
❑ Scenario 3



❑ Scenario 4



❑ Scenario 5



❑ Scenario 1 (protected beam)

5mm of sprayed vermiculite cement on the contour

Scenario	Flame	Steel Beam
1	770.7ºC	710.9ºC
2	647.6ºC	466.7ºC
3	637.6ºC	466.7ºC
4	691.4ºC	510.9ºC
5	709.4ºC	528.5ºC
1 (prot)	770.7ºC	527.0ºC

CONCLUSIONS

The software Elefir-EN allows for considering, in an easy way, multiple localised fires. The software is an essential tool for structural engineers in the design office, enabling quick and accurate calculations to be produced, reducing design time and the probability of errors in the application of the equations.