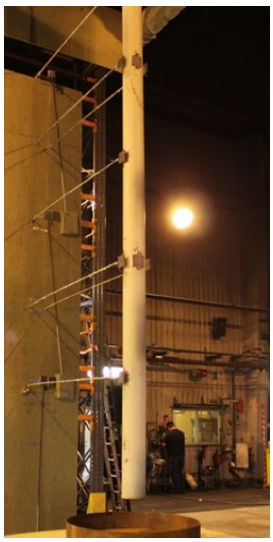
The thermal impact of local fires on structures

En A structure or more exactly its surface is thermally exposed by e.g. a fire by radiation and convection. These two phenomena are basically independent. Heat transfer by radiation is due to incident radiation intensity, which can also be expressed in terms of a radiative temperature. Heat transfer by convection, however, depends on the ambient gas temperature. Thus, one can say that the thermal influence depends on two parameters, gas temperature and incident radiation. When these are known the heat transfer to a surface can be calculated depending on the surface emissivity, the convection heat transfer coefficient and the surface temperature response of the exposed structure. Thus the boundary conditions defined and the temperature of an exposed structure may be calculated. In conclusion, one may say that thermal exposure is radiation temperature and the gas temperature while a thermal boundary conditions consist of the thermal exposure combined with the surface emissivity and convective heat transfer coefficient. These definitions are not internationally standardized and widely accepted often leading to misunderstandings, confusion and outright errors occur frequently in the fire technical literature. There is therefore, in principle, not only *one* fire temperature, but in principle always *two*. Of these the radiant temperature is the dominant at high temperature levels. But the radiant temperature or incident heat flux is very difficult to measure at a fire exposed surface. It can only be measured when the surrounding gas/air is at room temperature. Under other conditions, measurements with so called heat flux meters are very uncertain and difficult to interpret and use for temperature calculations.

A new way to measure fire exposure has for some years been introduced and developed at SP. With so-called plate thermometers an effective temperature, which is known as the adiabatic surface temperature AST, can be measured. The AST is the temperature of a surface of an ideally perfectly insulating material would get when it is exposed to current conditions. The temperature lies between the radiation temperature and gas temperature. This allows the thermal exposure to be represented by one temperature instead of two. And above all, this temperature can be used to calculate heat transfer to a surface of same emissivity and convective heat transfer coefficient and thereby the temperature of fire exposed structures. It has not been possible before the introduction of the plate thermometer and accompanying calculation method was developed! It was therefore of great interest to use this new measurement technique for measuring the thermal influence from a local fire and then compare steel temperatures measured with calculated. It was also of interest to compare the measured fire exposure in terms of adiabatic temperature and compare it with the recommendations of European standards (Eurocodes).



a) Column above fuel container

b) Leaning flames

c) Platea thermometer in front of the column

Figure 1 Experimental setup of the SPs main fire hall with a 6 m high steel column. Temperatures were measured approximately a cm from the column with plate thermometers and thermocouples, in the steel of the column.

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The tests of this project were performed in a large scale in which a six meter tall circular steel column was subjected to local fire in the form of pool fires. Careful measurements were made with traditional instruments, thermocouples and heat flux meters, as well as with plate thermometers. Also for this purpose specially developed plate thermometers were used. Measured temperatures were compared with temperatures calculated according to Eurocode (EN 1991-1-2) and calculated with the computer program FDS. Overall, it turned out that temperatures calculated according to Eurocode were above the measured, the Eurocode gives values on the safe side or in other words overdesign which may lead to unnecessary costs.

Temperatures in the fire exposed steel column were calculated using the finite element program Tasef. For these calculations the boundary conditions were expressed in the form of the adiabatic surface temperatures in four different directions around the column, extracted by plate thermometers measurements. The graphs in Figure 2 shows examples of steel temperatures, measured and calculated based on temperatures measured with plate thermometers. In the calculations, the effects of the internal heat transfer between the surfaces were considered. It was necessary because the flames leaned, see Figure 1(b), and the thermal exposure was therefore significantly asymmetric. As shown in the diagram the calculated temperatures matched well with the measured.

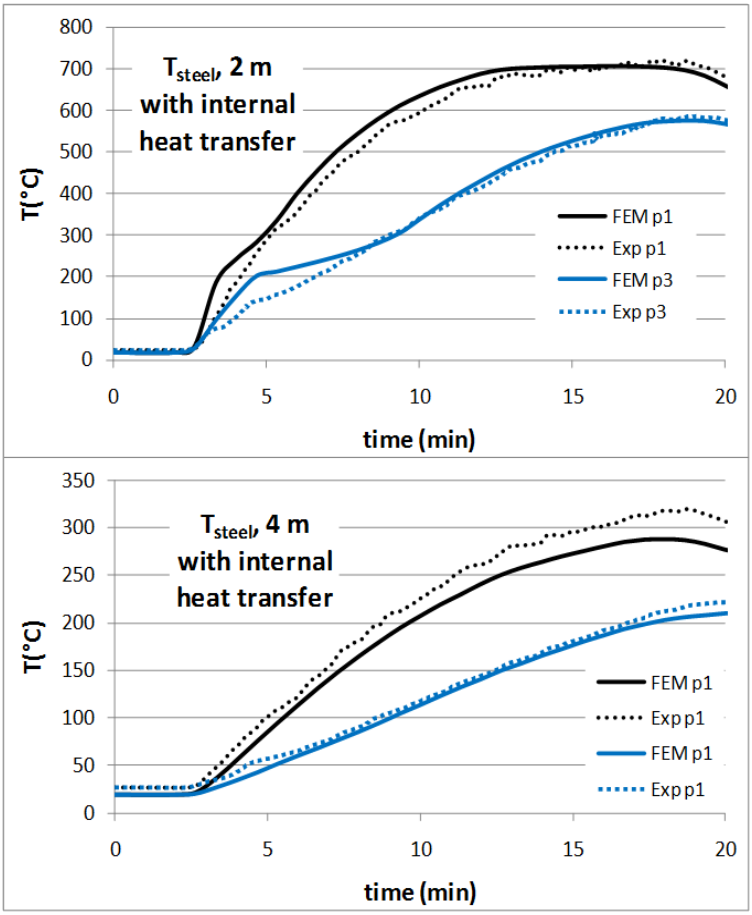

Figure 2 Example of steel temperatures on the heights of 2 m and 4 m, experimentally measured and calculated with a FEM program based on temperatures measured with plate thermometers. In the calculation, the impact of the heat transfer between the column internal surfaces was taken into account.

In Summary, one can draw the following conclusions from the project:

a) Temperature in fire exposed structures can be calculated on the basis of an adiabatic surface temperatures measured with plate thermometers.

b) Temperatures in structures exposed to local fires calculated according to Eurocode is above the measured resulting in overestimated expected steel temperatures.

Reporting from the project has been published as follows:

1) "Thermal exposure to a steel column from localized fires" Johan Sjöström, Alexandra Byström, David Lange, Ulf Wickström , SP Report 2012:04

2) "Large scale test to explore thermal exposure of column exposed to localized fire", 7th International Conference on Structures in Fire, Zurich, Switzerland, June 6-8, 2012 Alexandra Byström, Johan Sjöström, Ulf Wickström and Milan Veljkovic, (presented by AB) + Poster.

3) "A steel column exposed to localized fire" Nordic Steel Construction Conference 2012, Hotel Bristol, Oslo, 5-7 September 2012,(presented by AB).

4) "Large scale test on a steel column exposed to localized fire" accepted for publication in J. of Structural Fire Engineering. Alexandra Byström, Johan Sjöström , Ulf Wickström and Milan Veljkovic, 4) Alexandra Byström , Johan Sjöström, Ulf Wickström, David Lange and Milan Veljkovic.

You can download report and summary at www.brandforsk.se. For more information please contact, Ulf Wickström, ulf.wickstrom@ltu.se.

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