INTRODUCTION

- The software SAFIR, developed at the University of Liège for the analysis of structures under fire conditions, has been used to underline the field of application and limitations of existing analytical methods for predicting the distribution of temperature in steel and composite beams and joints under fire conditions.
- New analytical methods have been developed to improve the predictions of distributions of temperature in beams and joints. These proposals have been based on the numerical simulations performed with SAFIR.

EXISTING METHODS

- Lumped Capacitance Method (+ adaptations for insulated sections and steel-concrete composite sections)
  \[ \Delta Q_{\text{transferred}} = h_{\text{air,d}} k_{\text{ab}} A_w \Delta T = c_p A_w V \Delta \theta_{\text{d,ab}} = \Delta Q_{\text{heating}} \]
  Not able to account for non-uniform distributions of temperature nor for heat fluxes between steel profiles and concrete slabs in composite sections.
- Temperature profiles for steel beams covered by a concrete slab
  Only applicable to composite joints exposed to ISO fire curve. Does not account for the massivity of the connected elements.
- Finite Element Models
  Requires the meshing of the analyzed structures (time-consuming operation for practical applications) but leads to high level of accuracy.

HEAT EXCHANGE METHOD: Building of the Equilibrium Equation

- The heat transferred by convection and radiation between the top flange (or the upper zone joint) and the gases of the compartment \( \Delta Q_{\text{gas}} \) is calculated according to the recommendations of the EN 1994-1-2, where the top flange is heated on 3 sides:
  \[ \Delta Q_{\text{gas}} = h_{\text{air,d}} k_{\text{ab}} A_w \Delta T \]
- The heat transfer between the top flange (or the upper zone joint) and the rest of the steel section (or the other steel parts of the joint) \( \Delta Q_{\text{top-bottom}} \) is evaluated as follows:
  \[ \Delta Q_{\text{top-bottom}} = \dot{\lambda} \left( T_f - T_{\text{ambient}} \right) x A_{\text{top-bottom}} \Delta T \]
- The quantity of heat transferred between top flange (or the upper zone joint) and concrete slab \( \Delta Q_{\text{concrete}} \) has been evaluated on the basis of numerical investigations. The flux \( \phi \) is given for parametrical fire curves defined in Annex A of EN 1991-1-2 during heating and cooling phases:
  \[ \Delta Q_{\text{concrete}} = \dot{h}_k \phi \Delta T \]
  \[ \Delta Q_{\text{concrete}} = \phi A_{\text{transfer}} \Delta T \]

HEAT EXCHANGE METHOD: Application

- IPE 330 – Beam Top Flange
- IPE 550 – Beam Top Flange
- IPE 330 – Joint Upper Zone
- IPE 550 – Joint Upper Zone

CONCLUSIONS

- The Heat Exchange Method gives good predictions of distribution of temperature in composite beams and joints, at the level of beam top flange. Heat transfers with other steel parts and concrete slabs are taken into account.
- The implementation and the use of this method is much easier than Finite Element Methods.