$\Delta Q_{transferred} = \dot{h}_{net,d}\ k_{sh}\ A_m\ \Delta t = c_a\ \rho_a\ V\ \Delta\theta_{a,t} = \Delta Q_{heating}$

European Network COST TU 0604 – Integrated Fire Engineering and Response
Applications of Structural Fire Engineering

Prague, Czech Republic
29th April 2011

DISTRIBUTION OF TEMPERATURE IN STEEL AND COMPOSITE BEAMS AND JOINTS UNDER NATURAL FIRE

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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.

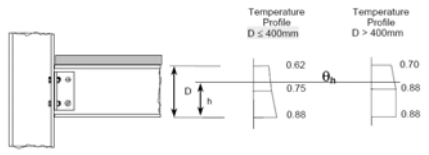
EXISTING METHODS

➢ Lumped Capacitance Method (+ adaptations for insulated sections and steel-concrete composite sections)

$$\Delta Q_{transferred} = \dot{h}_{net,d}\ k_{sh}\ A_m\ \Delta t = c_a\ \rho_a\ V\ \Delta\theta_{a,t} = \Delta Q_{heating}$$

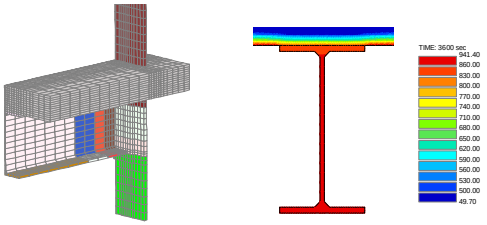
Not able to account for non-uniform distributions of temperature nor for heat fluxes between steel profiles and concrete slabs in composite sections.

➢ 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 : Objectives and Principles

➢ The Lumped Capacitance Methods predicts with reasonable accuracy the distribution of temperature in i) steel beams and joints and ii) steel-concrete composite beams and joints at the level of bottom flange. The Heat Exchange Method is a new method aimed at predicting the evolution of temperature in steel-concrete composite beams and joints under natural fire.

➢ The Heat Exchange Method is based on the Lumped Capacitance Method, stating an equilibrium between i) the quantity of heat received (or emitted) by a beam flange or a joint zone and ii) the heat consumed (or produced) by the flange or the zone to modify its temperature. Three contributions to the first term (heat exchanges) of this equation are considered and estimated independently.

HEAT EXCHANGE METHOD : Building of the Equilibrium Equation

➢ The heat transferred by convection and radiation between the top flange (or the upper joint zone) and the gases of the compartment ΔQ_{gas} is calculated according to the recommendations of the EN 1994-1-2, where the top flange is heated on 3 sides :

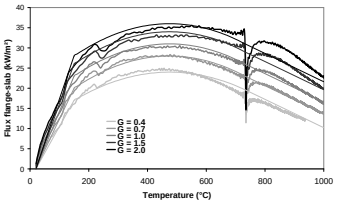
$$\Delta Q_{gas} = \dot{h}_{net,d}\ k_{sh}\ A_m\ \Delta t$$

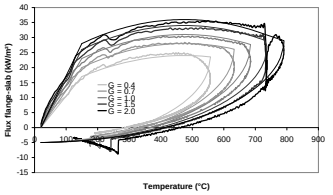
➢ The heat transfer between the top flange (or the upper zone joint) and the rest of the steel section (or the other steel parts of the joint) $\Delta Q_{top\text{-}bottom}$ is evaluated as follows :

$$\Delta Q_{top-bottom} = \lambda \frac{(T_2 - T_1)}{x} t_w\ \Delta t \qquad \Delta Q_{top-bottom} = \lambda \frac{(T_2 - T_1)}{x} A_{top-bottom}\ \Delta t$$

➢ The quantity of heat transferred between top flange (or the upper zone joint) and concrete slab $\Delta Q_{concrete}$ has been evaluated on the basis of numerical investigations. The flux ϕ is given for parametrical fire curves defined in Annex A of EN 1991-1-2 during heating and cooling phases.

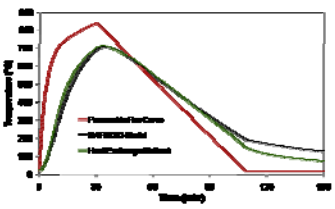
$$\Delta Q_{concrete} = b_b\ \phi\ \Delta t \qquad \Delta Q_{concrete} = \phi\ A_{transfer}\ \Delta t$$



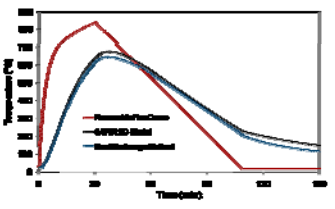


HEAT EXCHANGE METHOD : Application

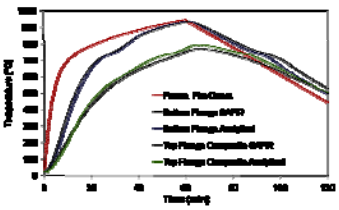
IPE 330 – Beam Top Flange



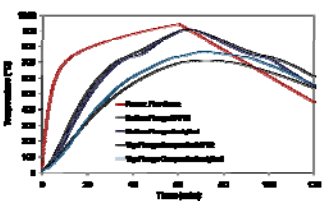
IPE 550 – Beam Top Flange



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.

More information in *Analysis of simple connections in steel structures subjected to natural fires*, Hanus, F., Ph. D. Thesis, Univ. of Liege, http://hdl.handle.net/2268/66090