Fire safe buildings with thin-walled steel + insulation systems

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Background

It is important that buildings should be able to withstand a fire during evacuation and extinguishment. To determine a building's fire resistance ability, full scale experiments would be ideal, but these are very expensive. Therefore an existing simulation approach will be extended, which enables theoretical models and design rules to be developed to predict system failure as a function of component failure.

Objectives

(a) A two-way coupled CFD-FEM model to simulate the fire and thermomechanical behaviour of Thin-Walled Steel + Insulation Systems. Taking into account component behaviour with multi-scale techniques.

(b) Verification of the model with full-size experiments.

(c) New theoretical fire protection models for assessment and application of current and new systems.

Methodology

- **Definition of component models on each scale**
  - E.g. for a lipped channel, on the component length scale (5-500 mm) the lips are neglected, and a set of flat shells remain. Then on the system scale (1-10 m), it is both for mechanical and thermal aspects sufficient to model the liner tray as a single flat shell, thus neglecting the (lipped) flanges.

- **Definition of CFD model (Figure 2)**
  - The adiabatic surface temperature is used as input for thermal and mechanical finite element models to calculate the overall thermo-mechanical response of the structure [1]. Then, a script applies failure criteria and reports back failed structural elements, which are removed for the next run of the CFD fire simulation.

- **New FEM simulation approach**
  - On the connection scale, liner tray or sheeting is modelled, limited to a zone around the connection, and the connection itself. Using temperature dependent constitutive material laws, the force response of the connection for specific deformations (being output of the existing mechanical simulation) is predicted, and used as input for the existing simulation in the next iteration. Note that the existing mechanical finite element simulation should be dynamic as needed for thin-walled steel components [2].

Future work

(I) Three to four dedicated new experiments will be carried out for more rigorous verification, comprising tests of a liner tray-sheeting and insulation system, a sandwich panel system, a self-supporting sandwich panel system, and a thin-walled sheeting roof system with stone wool insulation. Different from the past tests, special attention is paid in these new tests to overall system behaviour, fastener behaviour, and opening of the systems, and complete failure or collapse is enforced.

(II) The simulation approach is extended by combining the existing CFD fire and thermomechanical finite element simulations with a new mechanical finite element simulation on the connection scale. Namely, in the existing mechanical finite element simulation, all the components are modelled using the “component scale”.

(III) In order to improve the accuracy and reliability of these new fire protection models, they will be developed and tested in (1) a parameter study using different representative part sizes, and (2) a single run of the mechanical finite element simulation on the component scale incorporating the connection scale model at every connection location. The latter is normally to be avoided for its computational costs.

Figure 1: Left: frame sandwich panel (Kingspan), Middle: self-supporting sandwich panel (Interdam), Right: liner tray sheeting and insulation system (www.steelconstruction.info)

Figure 2: A typical two-way coupled CFD-FEM analysis in which one panel fails [3]

References

