The investigation of steel structures exposed to fire conditions has developed as an important area of research, especially after 9/11. During a fire, the structural stability needs to be maintained so that people can escape the building safely, the property is protected, and firefighters can enter the building with a minimal risk of structural collapse. The aim of this research is to develop a model for the complex, coupled thermomechanical behaviour of steel structures during a fire, and to use the model for i) the understanding of the collapse response of steel structures under practical fire conditions, and ii) to provide the design rules presented in the building codes with a strong fundamental basis.

Starting from a framework of thermodynamics, the variational form of the coupled thermomechanical equations was derived, thereby accounting for i) the non-linear dependency of the mechanical properties on the temperature, and ii) large deformations generated during non-linear buckling. The governing equations were discretized into a Finite Element Method (FEM) formulation, which was implemented into a Matlab code. The Matlab code was used to analyse steel structures subjected to various thermomechanical loading schemes. The computational results were presented in terms of critical buckling loads, critical collapse temperatures, and translated into structural collapse times. A comparison of the numerical results with the design curves presented in building codes was made, showing a very good correspondence.

Figure: (a) Braced frame building subjected to a compartment fire on the ground level, (b) highlighted steel column subjected to the compartment fire hinged on the ground floor and clamped at the first floor giving a buckling length of \(l_b=0.7l\) used for the analysis.