Lateral-Torsional Buckling of Steel I-Beams Under Fire Conditions

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Aims and Objectives

The primary objective of this research is to develop a greater understanding of the phenomenon of lateral-torsional buckling of steel I-beams at elevated temperature.
A model for the fire resistance of lateral-torsional buckling of steel I- beams, based on numerical analyses, will be developed. For this proposal, the work will develop a non-linear computer program based on finite strip methods that will analyse this phenomenon.
The numerical results obtained by this computer program will be compared to that from the models presented in various codes of practice, as well as experimental and numerical results already available.
Accordingly, new design rules will be suggested to ensure efficient use of the steel structures to accommodate fire conditions.

Background

A structural element that is bent in its stiffer principal plane may suddenly buckle out of that plane in a flexural-torsional mode by deflecting laterally and twisting. This is shown in Figure 1. Open section elements that have low out-of-plane flexural rigidities and low torsional and warping rigidities are susceptible to this mode of failure, especially when they are not closely braced.
At room temperature, the basic influences on elastic flexural-torsional buckling of cross-section geometry, member length, supports, moment distribution, load height, and restraints are all well understood. Analytical and finite-element solutions for the out-of-plane strength have been presented and summarized in various texts. However, a comprehensive study of this phenomenon under elevated temperature was not formally available.
The effect of fire on a structure has the direct consequence of increasing the temperature of the material. This effect causes variation of the mechanical and thermal properties of the material. As a consequence the resistance to fire is lowered and the load bearing characteristics of the structure altered due to thermally induced changes in load orientation and position. These changes can lead to early collapse of the structure.

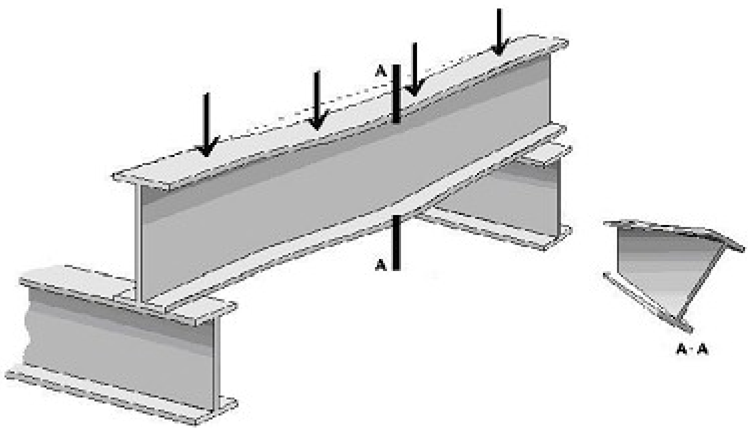

Figure 1. Flexural-torsional buckling of an I-section

Such failure is actually reached when applied loads can no longer be supported. Failure is often assumed for steel structures when an appropriate critical or limiting temperature of the steel is reached under standard fire exposure. In this context, the critical temperature presupposes a more or less uniform temperature over the cross section. In fact the limiting temperatures are the highest temperatures of a cross section containing a significant temperature gradient. Figure 2 shows the real temperature distribution in an I-cross section.

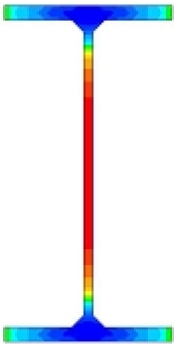

Figure 2. Temperature field in an I-cross section, fire on all sides.

Methodology
This study will analyse simply supported steel I-beams (the end can not deflect laterally or twist), with two planes of symmetry shown in Figure 3.

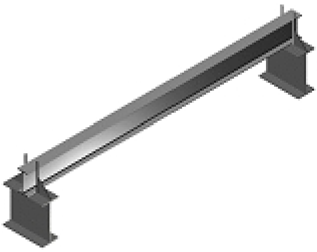

Figure 3. Simply supported beam.

Figure 4. I-Beam divided by strip method.

To analyse the behaviour of these steel I-beams under fire conditions, a finite strip analysis computer program has been developed. This method assumes that the cross section is divided in a required number of plates (Figure 4), and that the material properties as well as the temperature effect are considered for each individual plate along the length.

Using finite element software based on a non-linear analysis, a finite element modelling of the complete collapse behaviour of I-beams at high temperatures will also be developed.
The calculation models employed on those computer programmes briefly cited above, allow a precise mechanical and thermal simulation. These may be used to solve two different problems. Firstly the behaviour at room temperature with a step-by-step increase of the static load, and secondly the behaviour at elevated temperatures with static and thermal calculations as a function of the fire duration time. This process makes it possible to consider any geometric non-linear effects, which must be considered when buckling is involved.

Main References

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