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Cold-formed steel members affected by interaction phenomena involving distortional buckling: behaviour, strength, and design

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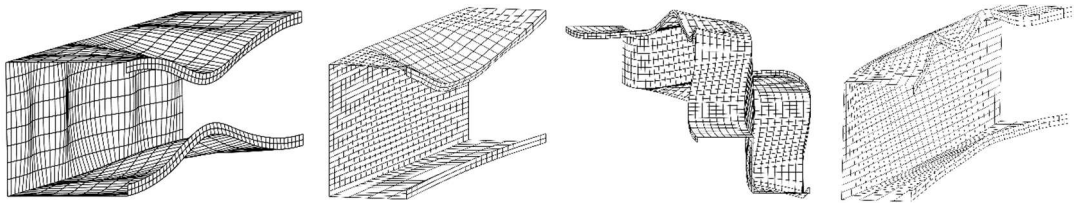
Summary

The numerical investigation carried out in this work aims at acquiring in-depth knowledge on the structural behaviour, ultimate strength and design of cold-formed carbon steel (CFS) members affected by mode coupling phenomena involving distortional buckling. In particular, it is intended to analyse and quantify the influence of the local-distortional (L-D) and distortional-global (D-G) interaction on the post-buckling behaviour (elastic and elastic-plastic) and ultimate strength of members (columns and beams) with (i) distinct slenderness values, (ii) several interaction levels, i.e., different relations between the critical local, distortional and/or global buckling loads/moments and (iii) exhibiting (iii1) several support conditions and (iii2) commonly used CFS open cross-sections, i.e., lipped channels, hat-sections, zed-sections and rack-sections (with or without intermediate stiffeners). Due to the complexity inherent to the coupling phenomena under investigation (they are intrinsically geometrically non-linear), it was decided to begin by investigating their mechanics, in the elastic regime, by means of Generalised Beam Theory (GBT) analyses and taking advantage of their unique modal features. The GBT approach makes it possible to identify and quantify the various structural contributions to a member response, since they are well reflected by the evolution, as loading progresses, of the participations of the various deformation modes in the member deformed configuration. These modal features provide the means to acquire in-depth knowledge on the member behaviour, thus ensuring a deeper understanding of the key aspects influencing the problems under scrutiny (columns and beams affected by L-D and D-G interaction).

Then, extensive parametric studies were conducted to (i) understand the elastic-plastic behaviour of members affected by L-D and D-G interaction, (ii) assess the relevance of these interaction effects and (iii) assemble ultimate strength data concerning such members. The ultimate strengths were determined through shell finite element geometrically and materially non-linear analyses carried out in the code ABAQUS and accounting for critical-mode initial geometrical imperfections with different amplitudes. Finally, the ultimate strength data gathered (including experimental values taken from the literature) are used to develop, calibrate and validate new design methodologies/rules, based on the Direct Strength Method (DSM), which constitutes the ultimate goal of the research effort reported in the thesis – note that the currently codified DSM strength curves only cover local-global interaction.

Keywords

Cold-formed steel members (columns and beams), thin-walled open cross-sections, modal coupling buckling phenomena, local-distortional (L-D) interaction, distortional-global (D-G) interaction, buckling and post-buckling analysis, Generalised Beam Theory (GBT), shell finite element analysis (SFEA), ultimate strength, Direct Strength Method (DSM) design.



Illustrative examples of cold-formed steel members affected by mode interaction phenomena.