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Post-buckling behaviour and direct strength design of lipped channel columns experiencing local/distortional interaction

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A B S T R A C T

This paper reports an investigation aimed at developing a Direct Strength Method (DSM) approach to estimate the ultimate strength of lipped channel columns affected by local/distortional buckling mode interaction. Following a brief presentation of a few relevant aspects concerning the shell finite element analysis of the geometrically and materially non-linear behaviour of thin-walled members, one illustrates the methodology adopted to obtain a lipped channel column ultimate load "data bank" intended to be used in the development and assessment of a DSM design approach. Next, the current DSM expressions to predict the load-carrying capacity of columns failing in local and distortional modes are briefly reviewed, devoting special attention to an approach that takes into account the above mode interaction. Then, the results of a parametric study, carried out by means of the code ABAQUS, are presented and discussed — this study involves the evaluation of the "exact" ultimate loads of *276* lipped channel columns with various geometries and two boundary conditions (pinned and fixed end supports), all exhibiting local/distortional interaction. Finally, these ultimate strength data are compared with the estimates provided by the available DSM expressions and, on the basis of this comparison, one identifies several features that a DSM approach successfully accounting for local/distortional interaction must incorporate.

1. Introduction

Most cold-formed steel members display very slender thin-walled open cross-sections, making them highly susceptible to several instability phenomena, namely *local*, *distortional* and *global* (flexural or flexural–torsional) buckling (see Fig. 1(a)–(d)) — depending on the member length and cross-section shape and dimensions, any of these buckling modes may be critical. Moreover, since several commonly used members exhibit geometries associated with rather similar local and distortional buckling stresses, their overall structural behaviours are likely to be affected by the occurrence of mode interaction phenomena involving these two buckling modes.

It is well known that thin-walled members exhibit stable local and global post-buckling behaviours with high and low post-critical strength reserves, respectively. On the other hand, recent studies showed that the distortional post-buckling behaviour fits in between the previous two and exhibits a non-negligible asymmetry with respect to the flange-lip motion (outward or inward) — e.g., [1,2].

Until the beginning of this century, the classical "Effective Width Method" (EWM) provided the only approach to predict the ultimate strength of thin-walled members, namely those built from cold-formed steel profiles. This widely employed method is able to take into account both the local post-buckling strength reserve and the interaction between local and global (flexural or flexural–torsional) buckling. However, the advent of more complex cross-section shapes, exhibiting several walls and including additional lips and/or intermediate stiffeners, made the application of the EWM excessively cumbersome and time-consuming, thus paving the way for the development of the "Direct Strength Method" (DSM), viewed as capable of overcoming the above problem.

The DSM was originally proposed by Schafer and Peköz [3], about twelve years ago, and has been continuously improved since, mainly due to the research activity carried out and/or fostered by Schafer [4,5]. Moreover, it is worth mentioning that the DSM has already been included in the current versions of the Australian/New Zealander [6] and North American [7] specifications for the design of cold-formed steel structures. The method has been shown to provide an efficient and general approach to estimate the ultimate strength of cold-formed steel columns and beams (i) exhibiting global (flexural, torsional or flexural–torsional), distortional or local failure modes or (ii) failing in collapse mechanisms involving interaction between local and global buckling modes. Indeed, the most recent DSM version stipulates the need to perform three independent safety checks, regardless of the member critical buckling mode nature: (i) one against distortional failure, (ii) another against global failure and (iii) a third one against a local or a combined local/global collapse. In the latter case, the DSM provides an efficient alternative to the more traditional (and conservative) EWM. However, as repeatedly pointed out by Schafer [4,5,8,9], further research is needed before the DSM approach can be successfully applied

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