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Buckling resistance of axially loaded cold-formed steel columns

Hélder D. Craveiro, João Paulo, C. Rodrigues *, Luís Laím

ISISE – Institute for Sustainability and Innovation in Structural Engineering., University of Coimbra, Portugal

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ABSTRACT

This paper reports an experimental campaign on the buckling behaviour of compressed single and built-up cold-formed steel columns. Four types of cross-sections were tested, namely, one single, one open built-up and two closed built-up, considering two end-support conditions, pin-ended and fix-ended. The obtained results were compared with the design predictions of EN1993-1-3:2004 and AISI S100-07. For pin-ended lipped channel columns the design predictions are in good agreement with the experimental results, however for the fix-ended columns the predictions may be conservative. For built-up columns was found that increasing the number of profiles may lead to unsafe design predictions.

1. Introduction

There have been some significant developments in cold-formed steel (CFS) structures over the past few decades, mainly due to improving technology of manufacture (higher quality steels, more complex section shapes, improved forming technology) and corrosion protection. This leads to greater competitiveness of this structural solution which has been translated into an increasing market share throughout the world. In the past few decades researchers have been focused on the behaviour of cold-formed steel structures. Regarding the behaviour of CFS columns, research has been mainly focused on open sections, such as plain and lipped channels, channels with simple and complex edge stiffeners, with and without holes and angles [2–7]. More recently built-up members have also been investigated by some researchers.

Nowadays built-up members are widely used in the building construction industry. Several cross-sections can be built using the available standard single sections (for instance C, U, etc.), namely open built-up and closed built-up cross-sections. Built-up cross-sections present several advantages when compared with single sections. A built-up section can span more distance, present a higher load carrying capacity and higher torsional stiffness [8]. Moreover, usually built-up members are symmetric, eliminating eccentricities between shear and gravity centres, leading to higher member stability. Also the use of built-up cross-sections can be a major economic advantage since all manufacture process remains the same [9]. Usually this type of cross-sections is built using self-drilling screws or by seam welding [10–12]. Some research concerning the ultimate load-carrying capacity of built-up closed CFS columns has already been undertaken [8–14].

However, so far, the design of built-up members is only briefly addressed in current design codes. Traditionally two design methods are used, the Effective Width Method (EWM) used globally and the Direct Strength Method (DSM) [15] used in North America, Australia/New Zealand [16,17]. The EN 1993-1-3:2004 [1] only predicts that the buckling resistance of a closed built-up cross-section should be determined using the buckling curve *b* in association with the basic yield strength f_{yb}, and buckling curve *c* in association with the average yield strength f_{ya} provided that $A_{eff}=A_g$. For built-up members the 2007 AISI Specification [16], in section D1.2, states that this type of members should be designed considering a modified slenderness ratio $(KL/r)_m$ if the buckling mode involves relative deformations that produce shear forces in the connections between individual shapes (Eq. (1)).

$$\left(\frac{KL}{r}\right)_m = \sqrt{\left(\frac{KL}{r}\right)_0^2 + \left(\frac{a}{r_i}\right)^2} \quad (1)$$

where, $(KL/r)_0$ is the overall slenderness ratio of the entire section about the built-up member axis, *a* is the intermediate fastener or spot weld spacing and r_i is the minimum radius of gyration of full unreduced cross-sectional area of an individual shape in a built-up member.

The increase usage of this type of structural solution demands a thorough investigation on this subject. In order to assess and

* Corresponding author.
E-mail address: jpaulocr@dec.uc.pt (C. Rodrigues).

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Notation

A_{eff}	effective cross-sectional area
A_g	gross cross-sectional area
b_{eff}	effective width
CFS	cold-formed steel
CV	coefficient of variation
DSM	Direct Strength Method
d_h	lateral deformation
d_v	axial displacement
f_{ya}	average yield strength
f_{yb}	basic yield strength
H	height of the column
$N_{b,Rd}$	design buckling resistance of a compression member
P	compressive load
P_{max}	maximum compressive load
P_N	nominal axial strength of a member according to AISI S100
t_n	nominal thickness of the cross-section
β_i	rotation of the end plate of the support device for the pin-ended support
ε	strain
$\bar{\lambda}$	non-dimensional slenderness
$\bar{\lambda}_p$	plate slenderness
μ	mean value
σ	standard deviation

better understand the structural behaviour of single and built-up cold-formed steel columns, twenty-four full scale buckling tests were undertaken. Four different cross-section shapes, namely single (C), open built-up (I), and two closed built-up (R and 2 R), and two end-support conditions, namely pin and fix-ended, were tested in the scope of this investigation. The main objectives were to assess the failure loads and failure modes of the tested columns as well as to compare the structural response of the different kinds of columns. In all buckling tests axial load, axial displacements, lateral displacements, rotations of the end-support devices and strains at several points of each cross-section, at mid-height of the column were monitored and recorded. With this paper it is intended to present a detailed description of the entire test set-up as well as a detailed description of all obtained results. Also it is worth mentioning that the reported results were also compared with the design predictions of EN1993-1-3:2004 and AISI S100-07.

2. Experimental tests

2.1. Test set-up and test procedure

The test set-up specifically designed for conducting buckling tests on CFS columns is thoroughly described in this section. With this experimental system it was attempted to simulate both pin and fixed-ended conditions in order to assess lower and upper bounds of the buckling load of the tested CFS columns. The experimental test set-up comprised a 2D reaction steel frame (1), a concrete footing (2), the designed end-support devices (3), a load cell used to measure the applied load (4), a hydraulic jack (5) used to apply the load to the CFS column, a servo hydraulic central unit W+B NSPA700/DIG2000 (6) and a data acquisition system TML TDS-530 (7) (Fig. 1). The concrete footing was specifically designed and fabricated for this experimental campaign. To the concrete footing (1) two steel plates were fixed, one on the bottom and the other on top of the concrete layer (2 and 3, Fig. 3(a)). The hydraulic jack used to apply loading ((4)Figs. 2 and 3) was connected to the top steel plate (2) of the concrete footing (1) (Figs. 2 and 3). To the

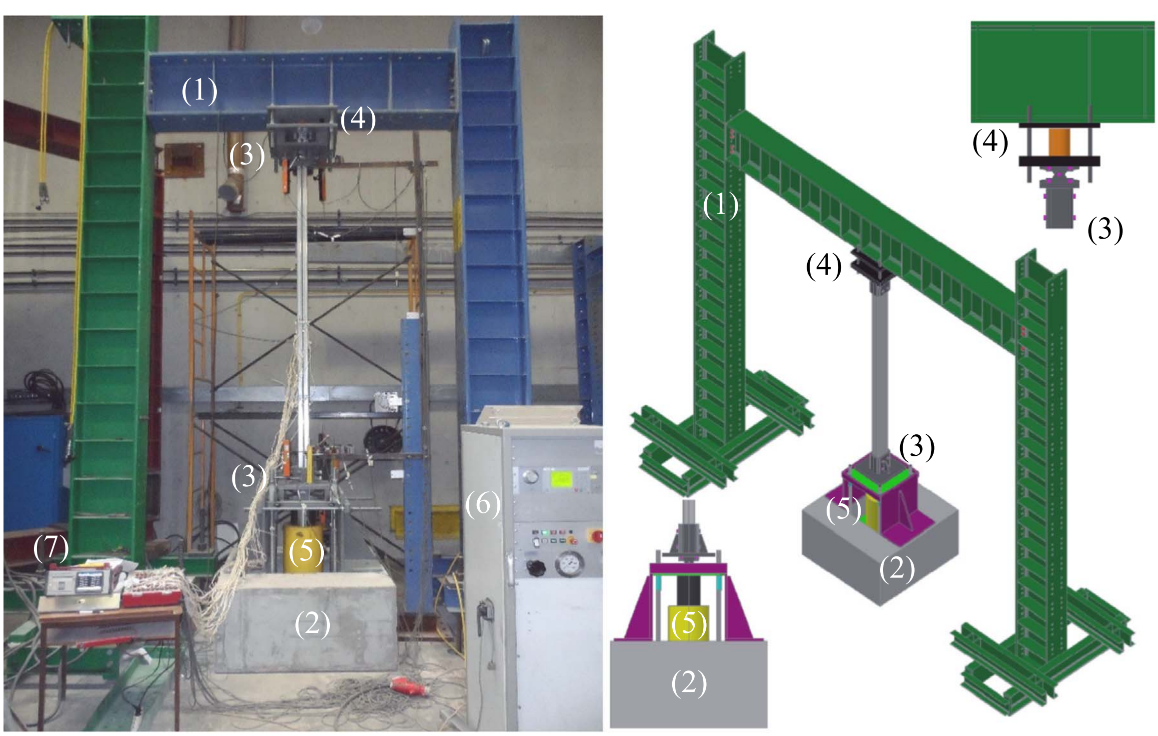

Fig. 1. Experimental test set-up built for buckling tests. (a) general view. (b) schematic view.