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# Nonlinear behaviour of back-to-back gapped built-up cold-formed steel channel sections under compression

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ABSTRACT

In cold-formed steel structures, such as trusses and portal frames, the use of back-to-back gapped built-up cold-formed steel channel-sections for column members are becoming increasingly popular. In such an arrangement, the lowest flexural buckling mode may not necessarily be overall buckling of the whole column. In the literature, only three test results have been previously reported for such cold-formed steel columns, and limited to values of non-dimensional slenderness ranging from 1.08 to 1.16. This issue is considered herein. The results of 40 experimental tests are reported, conducted on back-to-back gapped built-up cold-formed steel channel-sections covering the range of non-dimensional slenderness from stub to slender columns. A nonlinear finite element model is then described that shows good agreement with the experimental results. The finite element model is then used for the purposes of a study comprising 84 models. Using the experimental and finite element results, it is shown that design in accordance with the American Iron and Steel Institute (AISI) and Australian and New Zealand Standards (AS/NZS) can be conservative by as much as 53%. However, use of a modification to the non-dimensional slenderness, that considers the gap, results in the design standards being within 5% conservative with respect to the experimental and finite element results.



## 1. Introduction

In this paper, the results of forty new experimental tests on back-to-back gapped built-up cold-formed steel channel sections, with the sections acting as columns, are presented. Fig. 1 shows the details of gapped section investigated herein. As can be seen from Fig. 1, the gap is formed through a link-channel screwed between the webs of the back-to-back channel-sections. Such gaps are commonly introduced in struts in steel trusses and columns in portal frames, increasing the lateral stability of such columns.

In the literature, only three such experimental results are available, as reported by Rondal and Niazi [1] in 1990; the values of non-dimensional slenderness in these tests ranged from 1.08 to 1.16. The forty new experimental tests reported herein have a value of non-dimensional slenderness ranging from 0.23 to 1.42, thus covering stub to slender columns.

In current design standards, such as American Iron and Steel Institute [2] and Australian and New Zealand Standards AS/NZS 4600:2005 [3], the beneficial effect of the gap is ignored i.e. the design axial compressive strength is simply twice that of a single channel-section. This is the case regardless of whether the Effective Width Method (EWM) (reproduced in Section 2) or the Direct Strength Method (DSM) is used. It should be noted that the DSM does not include post-local-buckling capacity, however, Kumar and Kalyanaraman [4], modified the DSM equations, referred here as M-DSM, to include post-local-buckling capacity. The axial strength calculated in accordance with EWM, DSM and M-DSM are all presented in this paper.

Ting et al. [5] recently presented an experimental and numerical investigation on the behaviour of back-to-back built-up CFS channel sections under axial compression (see Fig. 2). The experimental tests reported herein, extends the work of Ting et al. [5]. As a result of the gap, for some combinations of column length and gap size, the lowest

*Abbreviations:* A′, Overall web length of section; $A_1$, Cross sectional area of single channel-section; $A_e$, Effective area of the section; B′, Overall flange width of section; C′, Overall lip width of section; CFS, Cold-formed steel; COV, Coefficient of variation; E, Young's modulus of elasticity; $F_e$, Least of the elastic flexural, torsional, and flexural torsional buckling stress; $F_n$, Nominal buckling stress as per AISI & AS/NZS; $F_y$, Yield stress which is equal to the 0.2% proof stress ($\sigma_{0.2}$); FEA, Finite element analysis; $I_1$, Moment of inertia of single channel-section; k, Effective length factor; l, Effective length of the built-up gapped section; L, Total length of the built-up gapped section; P, Applied axial load; $P_{AISI\&\ AS/NZS}$, Axial strength from AISI & AS/NZS; $P_{DSM}$, Axial strength from Direct Strength Method; $P_{EXP}$, Axial strength from experiments; $P_{M\text{-}DSM}$, Axial strength from Modified Direct Strength Method; S, Longitudinal spacing of link-channels; w′, Gap between back-to-back channel-sections; $\lambda_c$, Non-dimensional slenderness ratio as per AISI & AS/NZS; $\lambda_{c,GAP}$, $\lambda_c$ as for sections with gap; $\sigma_{0.2}$, Static 0.2% proof stress.

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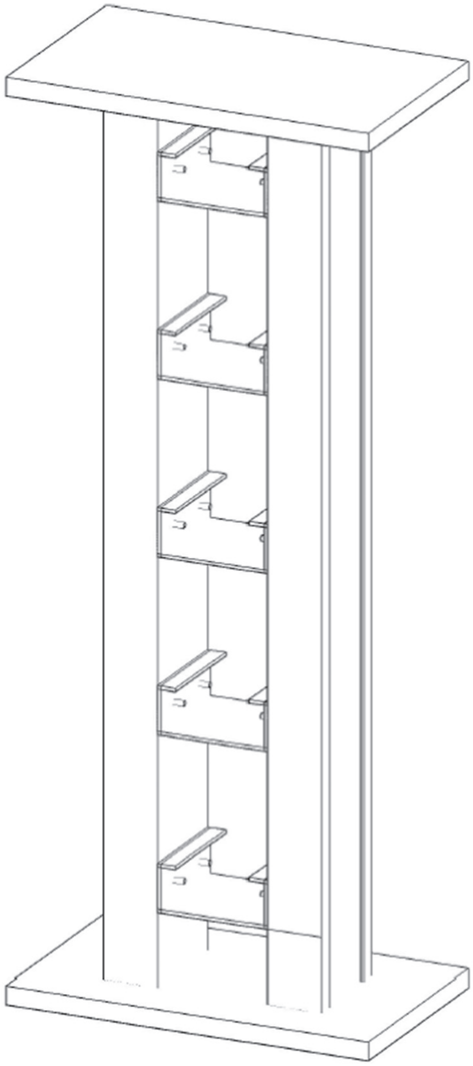


(a) General arrangement

(b) Cross section

**Fig. 1.** Back-to-back gapped built-up cold-formed steel channel-sections.

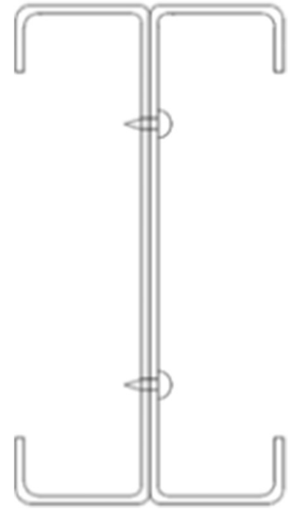
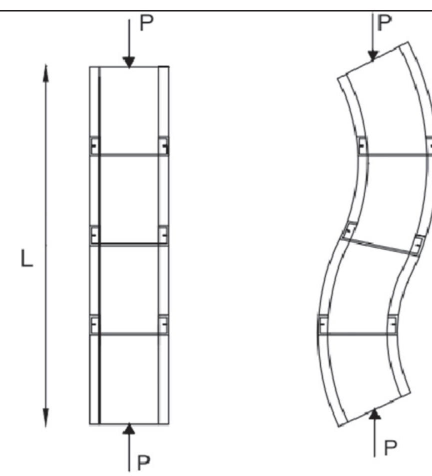
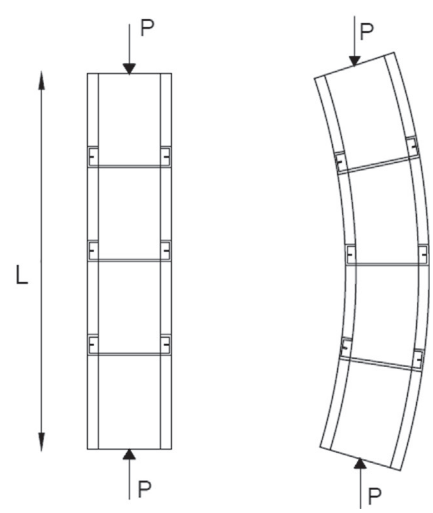


**Fig. 2.** Back-to-back built-up cold-formed steel channel columns without a gap as investigated by Ting et al. (2017).




(a) Mode A




(b) Mode B

**Fig. 3.** Overall flexural buckling modes of back-to-back gapped built-up cold-formed steel channel-sections.