The Effectiveness for Installations and Strengths of the Application of Cold-formed Steel SupaCee Sections

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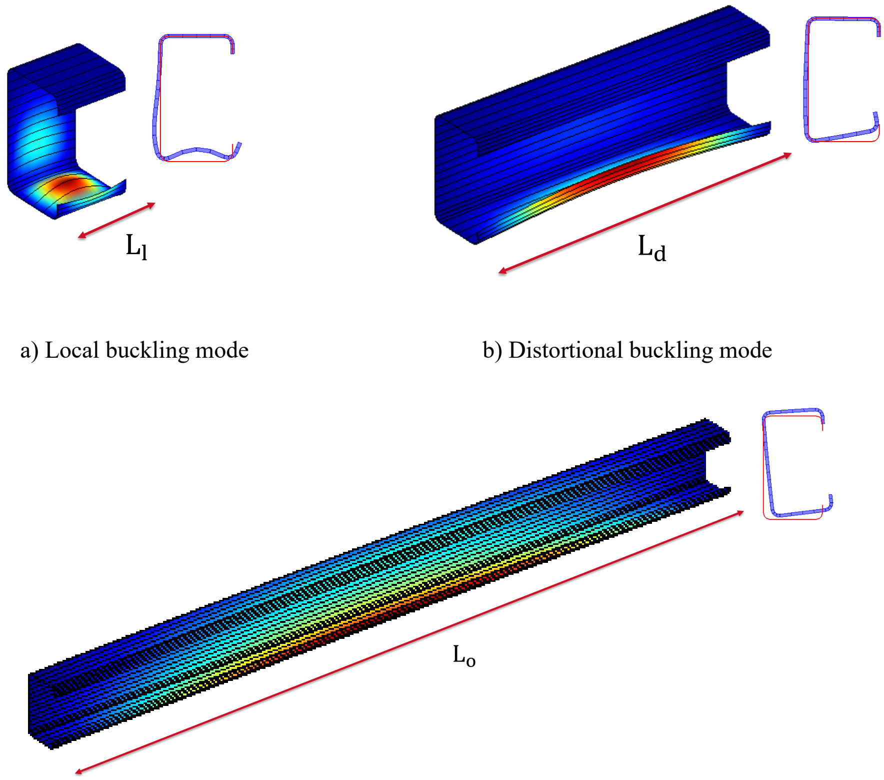
Abstract. Cold-formed steel structures have been progressively used in structural buildings with the application of typical channel sections. The cold-formed channel sections in the form of thin-walled sections are prone to be instable due to the small thickness and large web, this leads to the occurrence of the buckling phenomenon at the early stage wasting the material expenditure. Therefore, stiffeners have been added to the web of this section to increase the sectional stability to form a new section termed SupaCee. The paper will investigate the capacities of cold-formed steel channel and SupaCee members under compression or bending by using the Direct Strength Method regulated in the Australian Standard AS/NZS 4600-2018. The obtained results are the basis to evaluate the strength improvements of SupaCee members in comparison with those of traditional channel members. The installation effectiveness of the innovative SupaCee sections is also analysed on the basis of technical reports from the manufacturers.

Keywords: Effectiveness, Installation, Cold-formed steel sections, SupaCee.

1 Introduction

Cold-formed steel structures have been progressively used for structural buildings worldwide due to their advantages in manufacturing, transportation and assembly. In America, a variety of buildings including offices, hotels, hospitals and schools have successfully applied this structural type. This structure is suitable for low buildings combining other materials such as timber, brick or glass in Australia. The application of this structure is also commonly used in European countries with a series of structural solutions for resident houses. The groups of cold-formed steel structures have been established in many countries, and they incorporate together to provide facilities to promote the development of this structural type in the civil engineering field [1]. In Vietnam, the cold-formed steel structure has been intended to use for industrial buildings with a variety of scales. The appearance of multinational steel corporations in Vietnam allows applying international standards in design and erection, which results in high-quality structural buildings. This steel structure has been used for offices, schools, supermarkets, sports centres and industrial buildings. More details were presented in [2].

Cold-formed steel sections in the form of thin-walled sections prone to buckling including sectional and global modes, where sectional buckling modes consist of local and distortional modes (see Figs 1(a) and (b)), and global buckling modes can be flexural, torsional or flexural-torsional modes. Fig 1(c) illustrates the flexural-torsional buckling mode.



a) Local buckling mode

b) Distortional buckling mode

c) Global buckling mode

Fig. 1. Buckling modes of cold-formed steel channel sections.

In terms of design methods, the effective width method (EWM) has become common in the design of cold-formed steel members, and this method was proposed on the basis of the stability of flat plates [3]. Although the EWM accounted for the impact of local buckling modes on the capacities of cold-formed steel members, it was found to be cumbersome in the design of complex shape sections [4]. The Direct Strength Method (DSM) subsequently was proposed and developed to solve the drawbacks of the EWM. The DSM allows the design procedure to become simple and faster, even complicated shape steel sections[4]. This new method has been regulated in the Australian/New Zealand AS/NZS 4600-2018[5] or American Specification [6]. This method was also presented in the research project of Pham [7].

Cold-formed steel channel sections have become popular in the world for more than thirty years. The local buckling modes are found to occur quite early in these channel sections due to their small thickness, leading to material wasting [2]. These channel sections, therefore, were strengthened by adding stiffeners on the sectional webs to increase their stability, this resulted in the form of new sections termed SupaCee sections (see Fig. 2) [2]. These new sections illustrated their effectiveness in capacities and installations in comparison with the traditional channel sections. This innovation was made due to the presence of stiffeners in the webs of channel sections.

The impacts of stiffeners on the capacities of channel sections have been investigated by many researchers. Studies on channel columns with stiffeners ([8]–[12]) were conducted via experiments to investigate their strengths and behaviours. These obtained results were subsequently used to propose the modification in the design. The influence of web stiffeners on channel member capacities was also investigated by Ye et.al [13] or Chun-gang et.al [14]. These previous studies focused on experimental and numerical programs, which were the base for the modifications in the design. However, the effectiveness of stiffeners on the web of channel sections was not quantified in detail, especially for available channel sections in the markets. This effectiveness is cared for by the users and designers. This paper, therefore, is aimed to analyse the effectiveness of SupaCee sections in terms of capacities under compression or bending as well as provide their advantages for installations in comparison with the traditional channel sections.

2 The effectiveness in installations of SupaCee sections

The characters of channel and SupaCee sections were summarized on the basis of works of BlueScope Lysaght [15]. The shapes of these sections are illustrated in Fig. 2. Channel sections can be widely applied in structures such as beams, columns, purlins or girts. In terms of shape features, channel sections include a single web, top and bottom flanges with equal widths, and lip stiffeners at free ends. These lip stiffeners not only help to increase the stability of such channel sections but also ensure safety during transportation and installation. These single channel sections can be combined together to have built-up sections such as I-sections (back-to-back shape) or box sections (lip-to-lip shape).

Based on the traditional channel sections, SupaCee sections had similar shape features including a single web, two flanges and lip stiffeners. These latter sections were made by adding two couple stiffeners to the web and the lip stiffeners were bent toward the centre of the profiles. The benefits of the traditional channel sections were retained, SupaCee sections were found to have other benefits as follows [15]:

- The lip stiffeners were bent, which helped to be safer from handling sharp edges while fabrication, transportation and assembly;

- More safety and less labour requirements for installations due to the increase in rigidity and stability of SupaCee sections compared to the channel sections;

- The rounded lip stiffeners result in more safety and ease of sliding of purlins on rafter surfaces while installation, and avoid damaging the painted surface rafters while sliding;
- The capacities of SupaCee members were found to be significantly higher than those of channel members. This innovation can be illustrated and clearly presented in Section 3 in terms of compression and bending.

3 The capacity innovations of SupaCee members

The evaluation of strength improvements of SupaCee members in comparison with the capacities of channel members is based on the research results of Pham and Vu ([7], [16]). The investigated sections are taken from the available sections in the market provided by BlueScope Lysaght [15], as presented in Table 1 for both channel and SupaCee sections. The comparisons were conducted on the basis of the equal material expenditures for two types of investigated sections to evaluate the effectiveness of stiffeners on the webs of SupaCee sections. The steel material for the investigation was grade G450 according to the Standard AS 1397 [17] with the yield strength f_y = 450 MPa and Young modulus E = 200000 MPa.

The investigated member lengths varied from 2.0 meters to 8.0 meters under the actions of compression or bending. The configurations of boundary conditions include pin connections at two ends, and the bracing systems were attached to the mid-length of members to reduce the effective lengths about the weak-axis. The Direct Strength Method (DSM) can be used to determine the capacities of channel and SupaCee members under compression or bending. According to the DSM, the member capacity of a member can be taken as the least of three strength values including local buckling, distortional buckling and global buckling strengths. The detail of DSM and capacity calculations of both channel and SupaCee members were fully presented in the works of Pham and Vu ([7], [16]). The strengths of the three above buckling failure modes are demonstrated in Figs 3 and 4 (a), (b) and (c), and the member strengths are illustrated in Figs 3 and 4 (d), where the horizontal axes are the capacities of channel members, and the vertical axes are the capacity deviations between channel and SupaCee members (in percentage).

Figs 3(a) and 4(a) show that the global buckling strengths of SupaCee members are significantly lower than those of channel members with the deviation reaching 15% for both compression or bending. This can be explained due to the smaller of section properties (I_x, I_y, I_w, J) of SupaCee sections compared to those of channel sections. These reductions become noticeable for members with large lengths.

The distortional buckling strengths are insignificant differences between channel and SupaCee members with deviations less than 2% as shown in Figs 3(c) and 4(c).

Figs 3(b) and 4(b) reveal that the local buckling strengths of SupaCee sections are higher than those of channel sections in general. However, several local buckling strength values of SupaCee sections are lower compared to those of channel sections. The reason for these lower strengths of SupaCee sections is related to the interaction buckling modes between global buckling and local buckling. The significant reduction of SupaCee members as discussed leads to the reduction of local bucking strengths of SupaCee members. More details for this reduction were presented and analysed in Pham [7].

Table 1. Dimensions of channel and SupaCee sections [7]

Sections	t	D	B	L_1	L_2	L	GS	S	α_1	α_2
SC/C15012	1.2	152	64	7.5	7.5	14.5	64	42	5	35
SC/C15015	1.5	152	64	7.5	7.5	14.5	64	42	5	35
SC/C15019	1.9	152	64	7.5	7.5	14.5	64	42	5	35
SC/C15024	2.4	152	64	7.5	7.5	14.5	64	42	5	35
SC/C20012	1.2	203	76	10	10	19.5	115	42	5	35
SC/C20015	1.5	203	76	10	10	19.5	115	42	5	35
SC/C20019	1.9	203	76	10	10	19.5	115	42	5	35
SC/C20024	2.4	203	76	10	10	19.5	115	42	5	35
SC/C25015	1.5	254	76	11	11	21.5	166	42	5	35
SC/C25019	1.9	254	76	11	11	21.5	166	42	5	35
SC/C25024	2.4	254	76	11	11	21.5	166	42	5	35
SC/C30019	1.9	300	96	14	14	27.5	212	42	5	35
SC/C30024	2.4	300	96	14	14	27.5	212	42	5	35
SC/C30030	3.0	300	96	14	14	27.5	212	42	5	35
SC/C35019	1.9	350	125	15	15	30.0	262	42	5	35
SC/C35024	2.4	350	125	15	15	30.0	262	42	5	35
SC/C35030	3.0	350	125	15	15	30.0	262	42	5	35
SC/C40019	1.9	400	125	15	15	30.0	312	42	5	35
SC/C40024	2.4	400	125	15	15	30.0	312	42	5	35
SC/C40030	3.0	400	125	15	15	30.0	312	42	5	35

Note: inner radius $r_1=r_2$ = 5mm; t, D, B, L_1, L_2, L, GS, S (mm); α_1, α_2 (^{0})

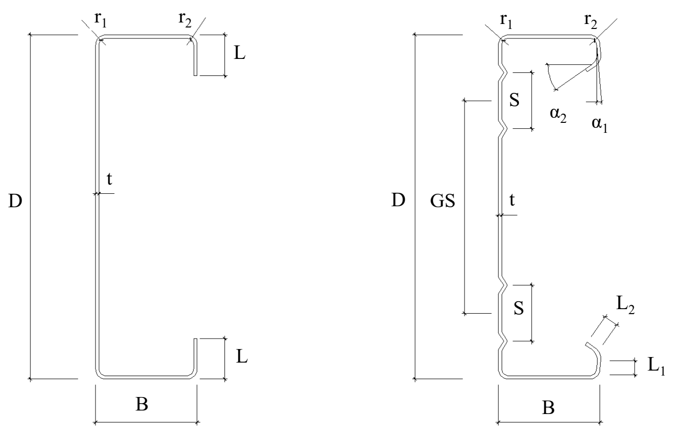
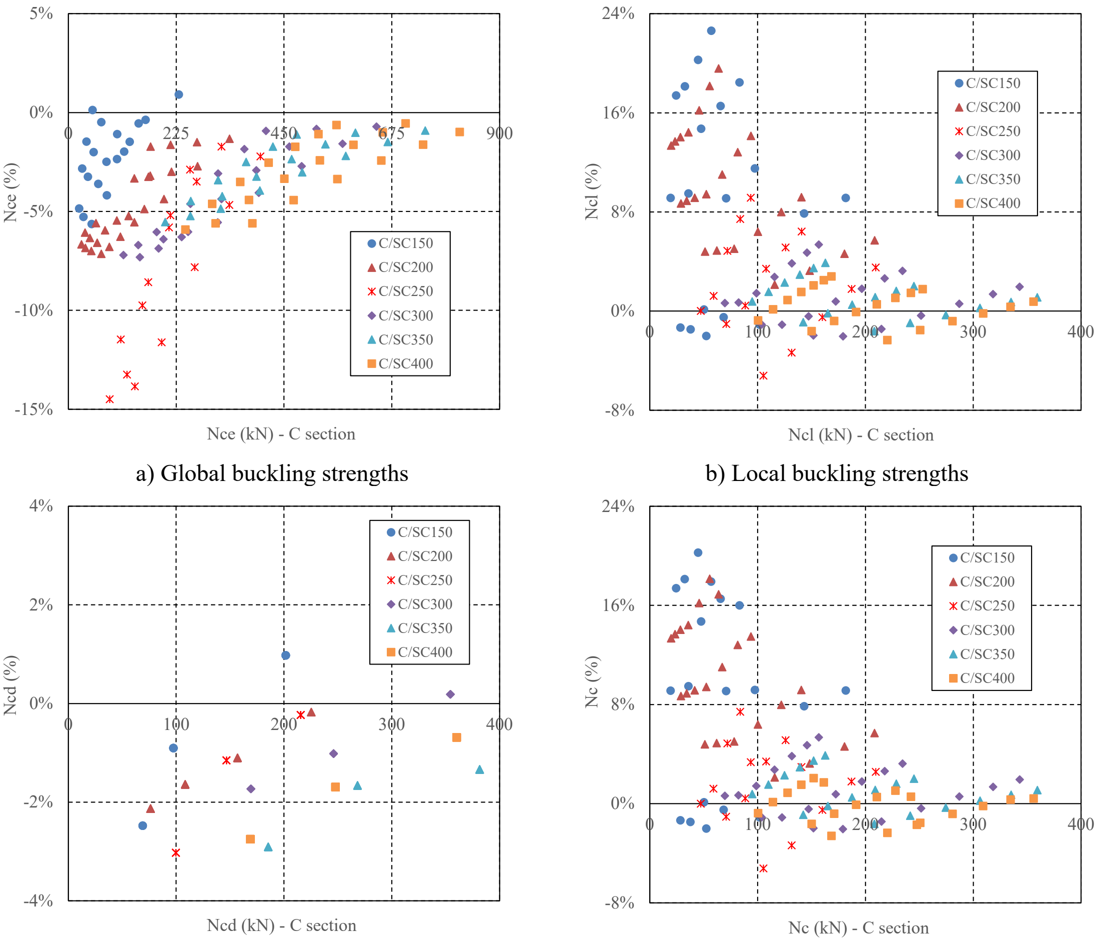


Fig. 2. Nomenclature of channel and SupaCee sections.



a) Global buckling strengths

b) Local buckling strengths

c) Distortional buckling strengths

d) Compressive capacities

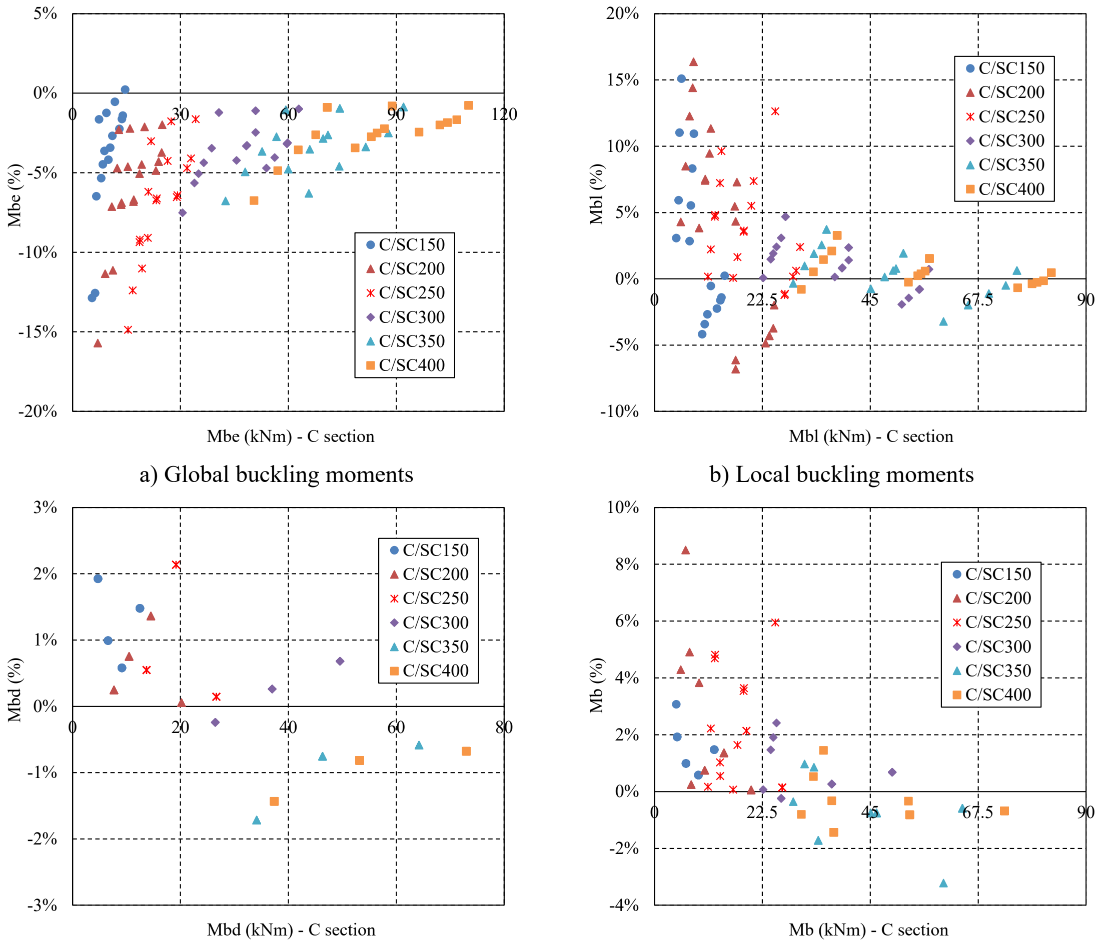
Fig. 3. Comparisons of compressive capacities between channel and SupaCee members [7]

In general, the capacities of investigated SupaCee members are higher than those of channel members with deviations of about 20% and 9% for compression and bending, respectively. Several SupaCee members, however, still have lower strengths in comparison with those of channel members due to the following reasons:

- The members were failed due to global buckling modes. These failure modes are witnessed for members with large thicknesses and lengths;

- The noticeable reduction of global buckling strengths of SupaCee members leads to the significant falls in capacities of SupaCee members due to the interaction buckling modes between global and local buckling modes.

- The failure was governed by distortional buckling modes for SupaCee members with short lengths and small thicknesses.



a) Global buckling moments b) Local buckling moments

c) Distortional buckling moments d) Flexural moments

Fig. 4. Comparisons of flexural capacities between channel and SupaCee members [7]

4 Conclusions

The paper presented the effectiveness of SupaCee sections in capacities and installations compared to the traditional channel sections. Based on the report from the BlueScope Lysaght about the SupaCee sections, the effectiveness of such sections can be included as follows:

- Add safety for transportation and assembly due to the removal of sharp edges;
- Reduce labour requirements while installations due to the high stability of SupaCee sections with the appearance of web stiffeners.

In terms of strength improvements, the investigations were carried out to evaluate the capacity innovations of SupaCee members compared to channel members under compression or bending using the Direct Strength Method in design. Based on the investigated results, several remarks are provided as follows:

- The strength improvements were significantly demonstrated for sections with small sectional dimensions and thicknesses, but become negligible for large sections and thicknesses.
- The global buckling strengths of SupaCee members were found to be lower than those of channel members, especially for slender members.

These remarks are the bases for the selection of suitable sections to adapt the requirements for installations and capacities.

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