Parametric Investigation of Cold-formed Steel Section for Wall Panel

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Abstract

Cold-form Steel Section has been known for its high strength due to high strength to weight ratio. Cold form steel (CFS) sections are used for load bearing primary members in substantial structures like high storey building and bridges, and non-bearing structural elements like composite roofing, slab decks and wall panels. Limited experimental study on CFS sections for wall panel has been conducted, which is not sufficient to understand its behaviour. As experimental investigation conducted on CFS sections for wall panel is expensive and time consuming, the development of FE models, well validated against experimental data, would be form a useful alternative to overcome any experimental limitations. In this paper, parametric study using finite element (FE) analysis has been conducted to investigate the behaviour of the CFS sections for wall panel under flexural loading. The FE model is validated by comparing the FE model results with test results. The extensive parametric study is conducted to investigate the effects of different combinations of steel sections and gypsum plasterboard, that can possibly influence the elastic behaviour of the cold form steel sections. The parametric results show that the presence of gypsum plasterboard has significant influence on the elastic behaviour of the CFS sections used in wall panel.

Keywords: Cold-Form Steel, Parametric Study, Local Flexural Buckling, Finite Element Analysis

1. INTRODUCTION

Cold-form Steel (CFS) sections and gypsum plasterboards are widely used to fabricate the wall panels. CFS sections with gypsum plasterboards provide a higher strength to weight ratio. The concept of wall panels is advantageous for the designer as it can act as load bearing infill walls around the perimeter of a structure. Gypsum is used on either side of the CFS as it effectively isolates sound and is fire resistant. These wall panels are not load bearing and are only used as partition walls. CFS sections are provided in the wall panels to support their own self-weight and reduce the overall weight of the structure. Hence, CFS sections in a wall panel not only helps a structure in reducing the total weight but may also acts as load bearing infill walls. In addition to the lateral loads, gravity loads are also resisted by the wall panels. Baran and Alica (2012) conducted several tests on different types of wall panels with diagonal struts and different sections and compared the results from various empirical formulae. Gunalan et al. (2013) has conducted a research to determine the elastic behaviour and the analysis of CFS Wall system under high fire rating. The conclusion from the report was that the CFS Wall using composite panel system has higher structural and thermal performance than other load bearing walls with varying arrangements of gypsum plasterboard. However, the research did not look at fundamental behaviour of CFS section failure mode. Therefore, the research herein is going to study these failure modes.

CFS sections are also used for non-bearing structural elements like composite roofing, slab decks and wall panels. Lee and Miller (2000) conducted a research on a composite wall panel with two C-sections with gypsum plasterboards on either side. The assumption taken in their research was that the axial load acts on the centroid of the cross-section. The flexural as well as the combined effect of torsional and flexural buckling loads are calculated using the differential equation of equilibrium and an energy method. To study the behaviour of the local and distortional failure of the standard CFS sections, Yu and Schafer (2007) conducted a series of experimental tests on C-sections and Z-sections. They examined the influence of moment gradient on distortional buckling of CFS beams. Maduliat et al. (2015) conducted a research to study the failure behaviour of 42 CFS sections under pure bending. The conclusion of their research was that when the width to depth ratio, which is extremely important in the design of CFS, of a section is less, torsional buckling failure takes place. However, when the ratio is high, the failure is more inclined towards the distortional buckling failure. In addition, it has been observed that the specifications in many international standards are un-conservative.

In recently, Fairly (2016) conducted the experimental study to investigate the behaviour of CFS wall panel under bending. Fairly (2016) mainly investigated the fundamental behaviour of CFS wall frame panels under elastic limits to further understand and improve these members. The research involved experimental study using three four-point bending test (FPBT) specimens. Two specimens are wall frames (CFS section with gypsum plasterboard) and one back-to-back steel without gypsum plasterboard. All specimens are tested using universal testing machine applying 75% of the design load of the studs. Test results demonstrate that back-to-back CFS studs can be used to overcome the buckling problem for light load bearing wall panels due to their higher rigidity. Gypsum plasterboard included in CFS wall panel also have significant influence on the failure modes, which is understood by testing limited two specimens of wall panels.

It can be concluded from the previous studies that research on CFS sections for wall panel under bending is still very limited, and further research is required. The goal of this research is to further investigate the behaviour of CFS section with gypsum plasterboard as conducted in Fairly (2016). An extensive parametric study will be conducted to investigate the effect of various factors that can possibly influence the elastic behaviour of the cold form steel sections. The three validated models are further modified with different combinations of steel sections and gypsum plasterboard and seven more models are formed and the effect of gypsum plasterboard on the CFS section is observed.

2. FINITE EELEMENT MODELLING AND VALIDATION

2.1 General

To develop the FE model of CFS wall panel, ABAQUS software package was considered throughout the analysis. All components of a CFS wall panel with or with gypsum plasterboard are simulated by using 8-noded brick elements (C3D8R), with three translational degrees of freedom at each node. The surface to surface interaction is defined for the contacts between the plasterboard and CFS sections. Tie constraint is used to simulate the screw connectors. In ABAQUS, the normal interaction between the surfaces is defined as the "hard contact". The tangential behaviour of the surface to surface contact is defined using the Coulomb friction. Figure 1 shows the developed FE model of a CFS wall panel with both sides gypsum plasterboard.

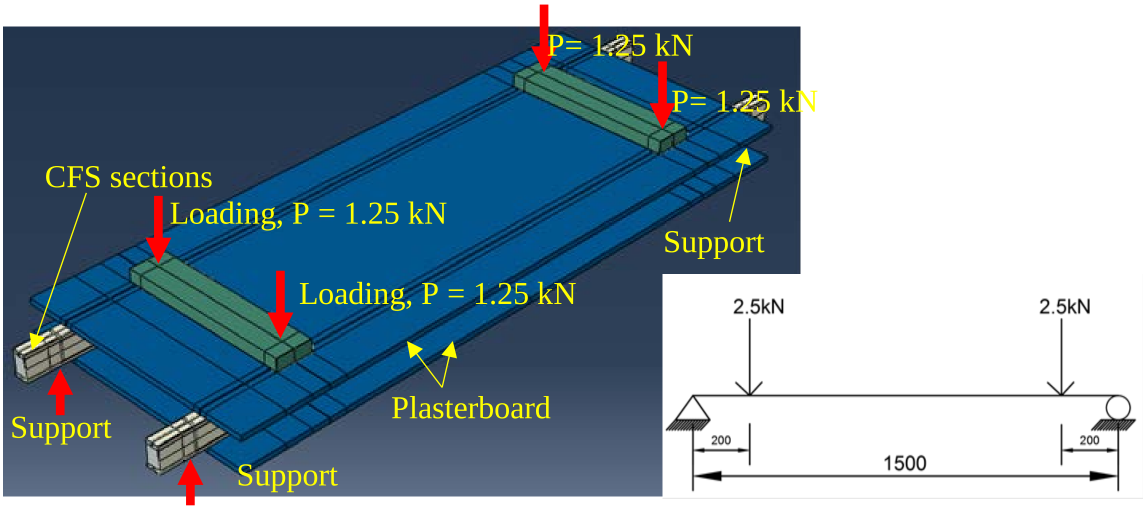


Figure 1. Load and boundary condition of a CFS wall panel with both sides plasterboard specimen1

2.2 Material Models

The elastic and inelastic properties of the steel section and the gypsum plasterboard are assigned . The wooden block material is assigned as of a high stiffness as it provides the support between the flanges and acts along with the boundary condition. The steel plate is assigned the same material property as the steel section as the only function of the steel plate is to disperse the load equally on the surface of the section. The elastic property of gypsum plasterboard and CFS Sections are shown in Table 1.

Table 1. Elastic properties of CFS section and Gypsum plasterboard

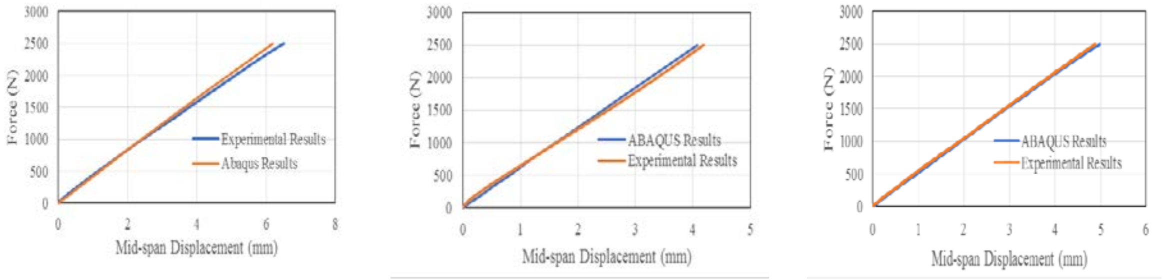
Characteristics Properties	CFS Section	Gypsum plasterboard
Modulus of elasticity	200 GPa	900 MPa
Poisson's ratio	0.3	0.2

2.3 Boundary Conditions

Loading and boundary conditions are considered according the test conducted by Fairly (2016) for CFS wall panel under bending as shown in Figure 1. Loading has been provided on the steel plate which enables to convert the point load to the uniformly distributed load. The load applied is 5kN. The boundary conditions are taken as pinned support on both the edges making the frame symmetrical.

2.3 Validation of FE model

FE models are established to conduct the parametric analysis. Before conduct the parametric analysis, FE simulation results are compared with test data reported by Fairly (2016) to verify the FE model. Once validated, the parametric study might not be validated and it hence eliminates the time requirements and excessive resources used in the experimental studies. The accuracy of the models depends on how well the ABAQUS model stimulates the behaviour of the CFS section under the four-point bending test. The comparisons between FE and test results are shown in Figures 2 (a)-(c). The error percentage between the FE and test result of specimen 1 is less than 1% which is less than both other specimens. This may be because of the absence of gypsum plasterboard. Hence the increase in the error percentage inn specimen 2 and 3. Specimen 2 is uni-symmetrical with gypsum plasterboard only on the bottom. The gypsum plasterboard on the top may act as a compression flange of the composite section. Similarly, the gypsum plasterboard on the bottom may end as the tension flange, though the amount of stress on the compression would be more than the amount of stress on the tension due to gypsum plasterboard as gypsum plasterboard like concrete is good in compression than in tension. In specimen 3, the neutral axis distance would vary less than in specimen 2 because of gypsum plasterboard present on either side of the CFS sections. Having considered these facts, it can be concluded that Figures 2 (a)-(c) show a good agreement between the FE models and the experimental studies.



(a) specimen 1 *(b) specimen 2* *(c) specimen 3*

Figure 2. Comparison between FE and test results

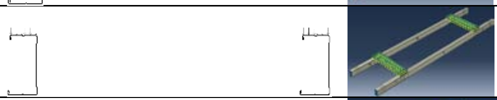
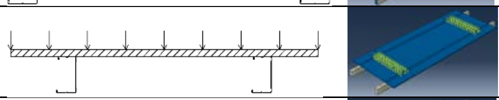
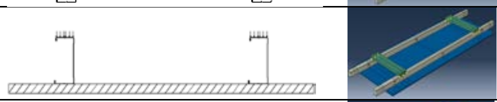
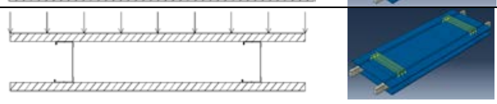
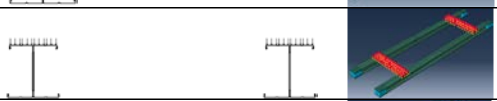
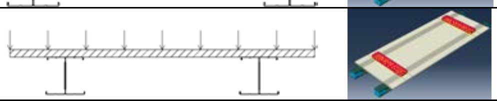
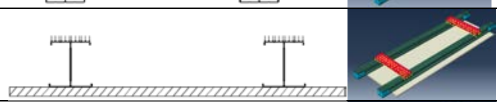
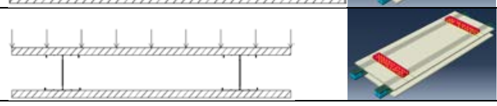
3. INVESTIGATION OF DIFFERENT PARAMETERS

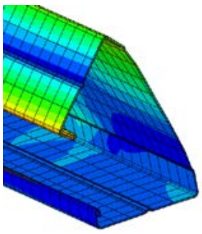
Based on the verified FE model, parametric study is conducted r to understand the behaviour of the composite combination of CFS sections know as studs and the gypsum plasterboard. The parametric study is conducted in order to expand the available structure performance data and to understand further the elastic behaviour of the frame and the steel studs. In the parametric study, the combinations of the gypsum plasterboard and the CFS section are changed to understand the effect of one on another. The load is applied on either of the part of the frame and the results are compared and discussed. The aim of the parametric study is to understand the different modes of buckling behaviour in the CFS sections with respect to gypsum plasterboard. This is done by observing the slenderness, structural behaviour and different failure modes. A total of 10 FE models was included. The ten FE models have been divided into two categories as can be observed from the nomenclature. Specimens A1 toA5 as shown in Table 2 are made using single stud with or without gypsum plasterboard. This has been done because the back to back channel studs results in a combined I-section. Channels are uni-symmetric but I-sections are bi-symmetric and thus have higher moment of inertia, and different behaviour patterns. Table 2 also shows another five specimens (specimens B1-B5) considered double studs (back to back channel) with or without gypsum plasterboard.

The deflection of these specimens subjected to the bending load of 2.5kN is summarised in Table 2. Deflection of each specimen is calculated at the mid-span of the frame. Deflection of CFS wall panel decrease when different combinations of gypsum plasterboard are used in back-to-back channel frame (specimens B2 to B5) and its values are lower compared to the single channel frames (specimens A2 to A5) with different combinations of gypsum plasterboard are used. The lowest deflection is observed when both sides plasterboards are considered.

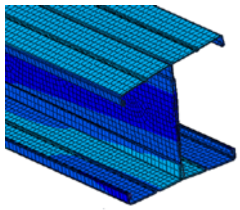
Buckling behaviour of the CFS sections with single side or back to back side channel is illustrated in Figure 3. As can be seen from the Figure 3(a) which shows the mode of failure at the centre of the stud section, local buckling of the compression zone of the flange and the web are observed for specimen A1. This local buckling is due to the absence y-axis symmetry of the channel. This behaviour is absent in the failure of specimen B1 as can be seen in Figure 3(b). The local buckling is minimised in the compression flange and the failure is eliminated is very negligible in the web. This is due to the connection of the webs into each other. The very minimum buckling of the web which is observed in the Figure 3(b) is due to the small gap between the centre of the two webs. The mirror studs provide a symmetry in the section, decreasing the stresses in the flange and hence increasing the stiffness, thus reducing the deflection. The deflection in specimen A1 is more than twice the deflection of the specimen B1. This is because the back-to-back section provides twice the moment of inertia.

Table 2. Parameters considered for CFS wall panels and their results

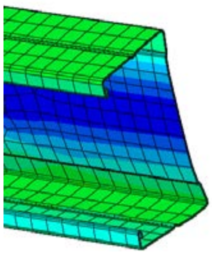
Sample No.	Stud Type	Gypsum plasterboard	Configuration of CFS sections with or without plasterboard	Deflections
A1	Single	Absent		11.293
A2	Frame	Absent		8.282
A3	Frame	Top		6.360
A4	Frame	Bottom		6.081
A5	Frame	Top & Bottom		4.325
B1	Single	Absent		4.780
B2	Frame	Absent		4.329
B3	Frame	Top		3.554
B4	Frame	Bottom		2.864
B5	Frame	Top & Bottom		1.699



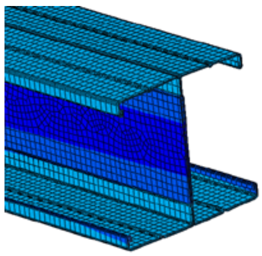
(a) Specimen A1



(b) Specimen B1



(c) Specimen A2



(d) Specimen B2

Figure 3. Buckling modes of specimens A1, A2, B1 and B2

However, comparing the specimen A1 and specimen A2, the failure behaviour of both specimens is almost same as shown in Figure 3(a) and (c). This is because the two studs are the same and the spacing between the studs does not affect the elastic behaviour of the frame. The combined frame provides twice the moment of inertia and reduced displacement. The same can be seen from the failure behaviour of back-to-back channel specimens B1 and B2, as shown in Figure 3 (b) and (d).

4. CONCLUSIONS

This research has described a detailed investigation into the behaviour of the composite action of CFS section and gypsum plasterboard in a wall panel subject to local buckling failure. The following conclusions can be drawn from the parametric investigations of CFS wall panels.

1) The local buckling of the compression zone of the flange and the web is observed on the single side channel of CFS sections when gypsum plasterboard is not considered.
2) For back-to-back side channel with plasterboards, the local buckling is minimised in the compression flange and the failure is eliminated is very negligible in the web.
3) When gypsum plasterboards are considered to the CFS wall panel, stiffness of a CFS wall panel is increased and thus reducing the deflection.

Thus, the buckling problem observed on CFS wall panel can be overcome by considering either gypsum plasterboard or back-to-back side channel.

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