Experimental Study of Cold-formed Steel Section for Wall Panel

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Abstract

The use of Cold-formed Steel (CFS) has rapidly increased in recent times in building construction as CFS wall frame panels due to their simple forming procedure and easy to assemble Most common CFS sections used in wall panel are C-channel and Z-sections. The behaviour of CFS is different from other steel known as hot-rolled steel. The structural behaviour of CFS wall frame panels subjected to flexural loading are normally characterised by many buckling modes which have not yet been completely understood. Buckling modes under flexural loading are generally either eliminated or delayed to increase the ultimate bending capacity of the members. So, it is very important to understand the behaviour of CFS under bending loading. This research studies the behaviour of cold-formed steel under flexural loading and an extensive four-point bending test (FPBT) are considered. This research mainly investigates 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 FPBT specimens. Two specimens are wall frames and one back-to-back steel stud. 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 two wall panels. Tested results are validated by comparing with finite element analysis results.

Keywords: Cold-formed steel (CFS), Wall panel, Gypsum plasterboard, and Four-point bending test.

1. INTRODUCTION

Nowadays, the use of composite Cold-formed Steel (CFS) gypsum wall systems in low to mid-rise buildings and houses is a widespread practice. The flexural strength of composite wall panels is greatly influenced by the strength of the studs. Amongst the numerous advantages over traditional timber wall framing, are their lightweight and simplicity in installation. Even though the concept of CFS in walls began in 1850's the application did not develop until 1940's (Hardwani and Patil, 2012, Yu, 1973). More recently, CFS are becoming increasingly more popular for mid-rise building when compared with timber wall frames, because of strength to weight ratio, consistency and greater span ability.

Typical composite cold-formed steel (CFS) wall panels consist of a stud, top and bottom tracks attached to gypsum plasterboard. Composite CFS wall panels are considered effective due to their advantages. According to (Gunalan, 2011), gypsum plasterboard can withstand lateral load. Therefore, gypsum plasterboard can be used to minimise the lateral buckling behaviours against steel wall panels. The understanding of buckling behaviour of CFS in wall panels is of high importance in regards to exposure to flexural loading. Additionally, CFS buckles before the yielding strength (Schafer, 2008).

Local, lateral and distortional buckling is critical for CFS members, due to having a high width to thickness ratio. Therefore, CFS buckle elastically under low compressive strength causing failures (Hancock, 2001). Research regarding the buckling behaviours of CFS is limited and not yet understood.

This paper investigates the composite behaviour of CFS wall panels under flexural loading. The behaviour of CFS wall panels with or without gypsum plasterboard is also investigated to understand the stud behaviour. The aim and objective of the research is to observe and analyse the buckling failure mode and to understand the composite behaviour of CFS wall panels under flexural loading.

2. EXPERIMENTAL STUDY

2.1. Test specimens

The CFS used for the experiment was taken from the same batch to ensure consistency in results. The studs used for the experimental study is $64 \times 25 \times 0.5\text{BMT CFS}$ with a length of 1600 mm. In addition, the studs have 3 holes located in the middle of the web having a diameter of 25.4 mm and spacing of 150 mm to the edge and spacing of 600 mm between each hole. The holes in the studs also have a lip that helps it to withstand more stresses.

Clamps are used in the boundary condition to eliminate failure when load being applied. Clamps could also pose unnecessary buckling behaviours such as distortion buckling. Therefore, wooden blocks are needed inside the stud section where clamps are used to eliminate any buckling when load being applied.

Each wall frame consisted of 2 studs, 2 tracks, 4 wooden blocks, 4 clamps and 1 plasterboard or 2 depending on the wall frame. Each stud was connected with track using screw connection on the top flange and bottom flange, example of the connection is shown in Figure 1. Wooden block was also placed at each corner inside the stud section and just under the clamps, as shown in Figure 1. The four clamps were used to prevent unnecessary failures or buckling when placed on the universal testing machine. Plasterboard was connected to the stud's flange using screw connection with spacing of 150mm from the edge and 300mm between each screw connection, detail drawing is shown in.

Figure 1. CFS wall frame with gypsum plasterboard at the compression side

Figure 2. Back to back CFS stud

Back-to-back CFS stud consisted of two studs, four wooden blocks and two clamps. The two studs were connected back-to-back using two parallel screws at the web section with a spacing of 150 mm from the edge and 300 mm between each screw, as shown in Figure 2 . Therefore, ten screws were used for this specimen. The clamps for back-to-back CFS stud are different to wall frame specimens due to the specimen shape. The wooden block was placed inside the stud where the clamp is located. Clamps were used to hold two studs back-to-back, as shown in Figure 2 to prevent unnecessary failures or buckling at the elastic behaviour of the studs. Figure 2 shows the details of wall panel considered gypsum plasterboard in both side.

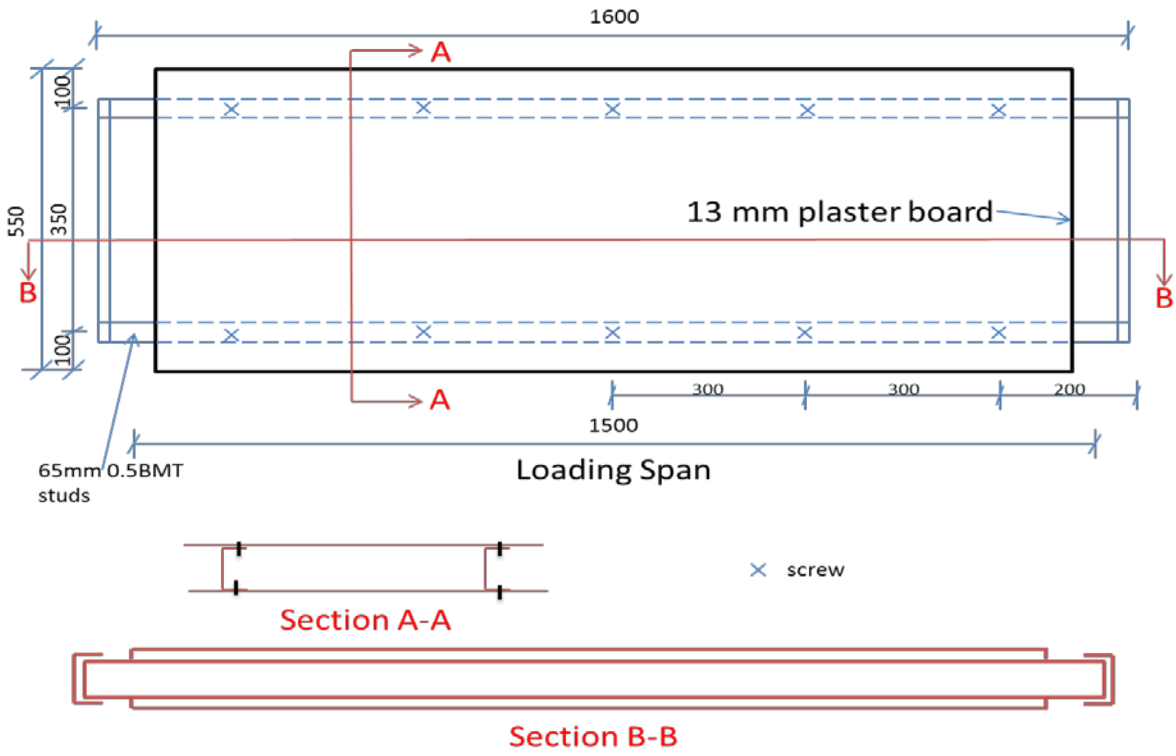

Figure 3. Details of wall panel with gypsum plasterboard in both side

2.2.Test setup and instrumentations

The FPBT method was conducted according to AS/NZS4600. The FPBT method involved applying two point loads on the top of the wall frame on each of the two stud's flanges. The FPBT was formed by having wall frame consisting of two studs connected to top and bottom tracks channel section using screw (connection. The frame placed horizontally on the universal testing machine, where the bottom flanges were placed on two pin supports and the top flanges had two roller loads applied at the top. The threes specimen of FPBT were conducted, including back to back CFS section, wall frame with gypsum plaster board at the bottom and CFS wall panel with double sided gypsum plasterboard.

2.2.1. Loading procedure

The load was applied at a gradual rate of 2.5*kN* which is approximately 75% of the design loading of the stud. Figure is side view of the specimens showing spacing of both the loads and boundary conditions. In order to effectively reduce errors in the results obtained, 10% of the loading was gradually applied in small increments to ensure no slip would occur and specimen would settle. This loading precaution was repeated twice before the section was subjected to the entire 2.5*kN* loading. However, some test specimens were incorrectly tested due to the lack of a 10% precaution load placed on the test specimen. Preliminary results showed that the presence of this precaution load yielded more accurate results. However, if the precautions load not considered the graph will not have straight linear line.

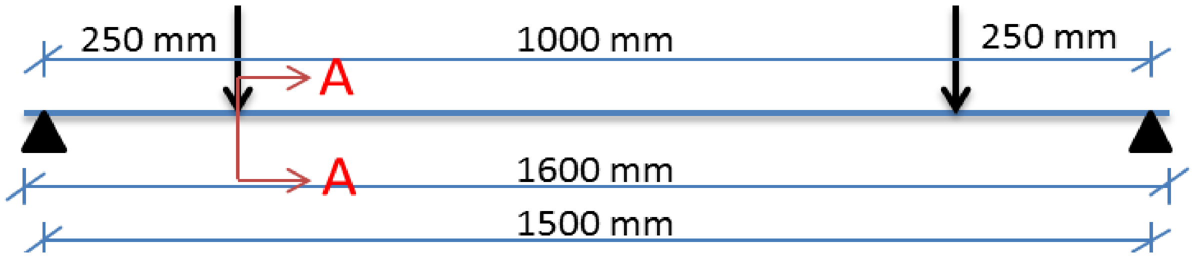

Figure 4. Stud length and loads spacing

2.3.Results and Discussion

Experimental results have elaborated the three specimen results for load versus mid-span, including discussion for each specimen readings.

2.3.1. Comparison of Test Results

The three specimens were tested under FPBT having maximum load 2.5kN. Figure 4 illustrate the linear reading of all three readings. The specimen's behaviour can be distinguished using the mid-span displacement. According to Figure 4, S5 reading obtained the least displacement due to both side plasterboard increasing its rigidity by having a displacement of 4.22 mm; S1 reading obtained 4.82 mm that is 1.65 mm less than S4 that had the maximum displacement of 6.47 mm. All 3 specimens are discussed below where some observation have been recorded for future research.

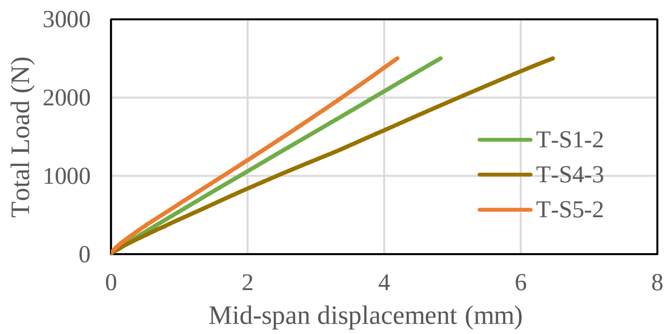

Figure 4. Comparison of the experimental specimens

3. VEREIFICATION OF EXPERIMENTAL AND NUMERICAL RESULTS

The results of the three finite element models are outlined in this section, including comparison with experimental results. The results data have been illustrated via force versus mid-span displacement graphs. Behaviour of each specimen has been discussed.

3.1. Comparison between Experimental and Numerical Results of Specimen S4

According to the reading in Figure 5, Figure 6, and Figure 7, the numerical results have achieved the elastic behaviour, no failure in any component was observed, since, the graphs achieved linear behaviour. According to Figure 5, Figure 6 and Figure 7 numerical results for S4, S5 and S1 achieved 6.35, 4.07 and 4.98 mm respectively. In comparison experimental results achieved 6.45, 4.20 and 4.89 mm respectively. Therefore, numerical analysis results are less than 10% away from the experimental results. In conclusion numerical analysis is validated. However, the reason for numerical results achieving small percentage in discrepancy, as shown in Table 1, is due to the contact between plasterboard and stud for S4 and S5 and both studs for specimen S1. In the experiment, 3 screw connection were used between gypsum plasterboard and each stud flange, while for numerical results full contact between plasterboard and studs were given, due to the limitations of ABAQUS.

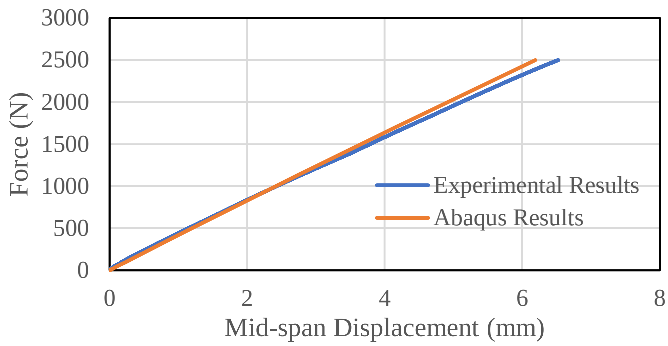

Figure 5. Comparison between test and numerical result of specimen S4

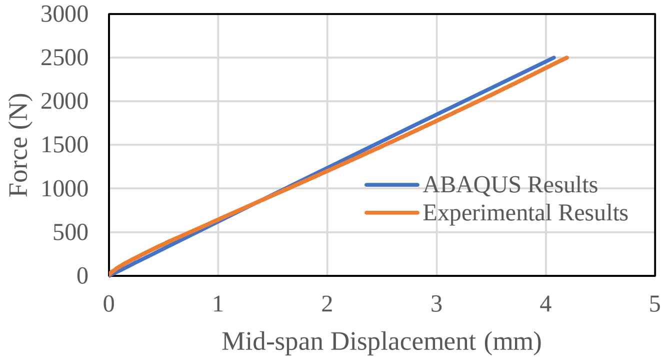

Figure 6. Comparison between test and numerical result of specimen S5

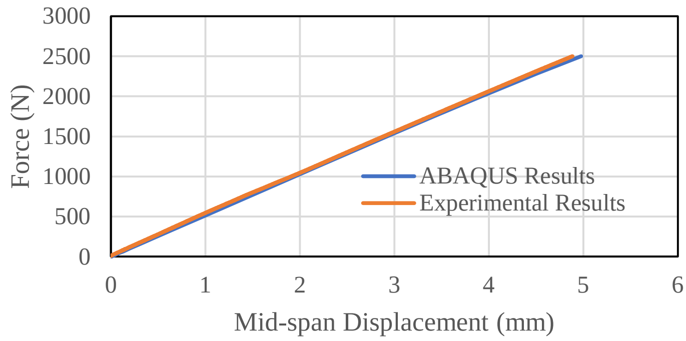

Figure 7. Comparison between test and numerical result of specimen S1

3.2.Verification of experimental study and numerical analysis summary

Comparative summary of the results obtained from experimental and ABAQUS is given in Table 1. Displacement reading was taken from the mid-span of both experimental and numerical results from Figure 5, Figure 6 and Figure 7.

Table 1 Difference between experimental and numerical results at the mid-span

Specimen ID	Experimental (mm)	ABAQUS (mm)	Difference (%)
S4	6.45	6.35	1.55
S5	4.20	4.07	3.09
S1	4.89	4.98	1.81

4. NUMERICAL ANALYSIS STRESS DISTRIBUTION

Contour plot was obtained from ABAQUS software to show the stress distribution of the steel studs, where the maximum stress for the contour plot was set as 512 MPa to show clear stress distribution, due to steel stud having a yield stress of 512 MPa. According to Figure , stress distribution of the stud is represented in a range of colour from the maximum stress (512 MPa) is in red to no stress (0 MPa) is in dark blue. In Figure stresses can be seen distributed to the stud where high stresses can be observed at the top flange and web-flange junction, where the top flange having higher stresses than the bottom base flange. Although maximum stress is achieved near loading and maximum stress located near boundary condition at the bottom flange lip. However, very low stresses can be observed at the middle of the web, except near holes at the sides medium to high stresses can be seen. When the load is applied on the loading plate, stresses are distributing from loading plate to the stud. Snowberger (2008), stated that the maximum stress occurs on a small area of the bending section (theoretically at the edge), this have been confirmed through the finite analysis. In this case, it was the bottom flange lip of the hole represented in light red with maximum stress of 400.0Mpa. Therefore, the steel studs did not reach its yield limit.

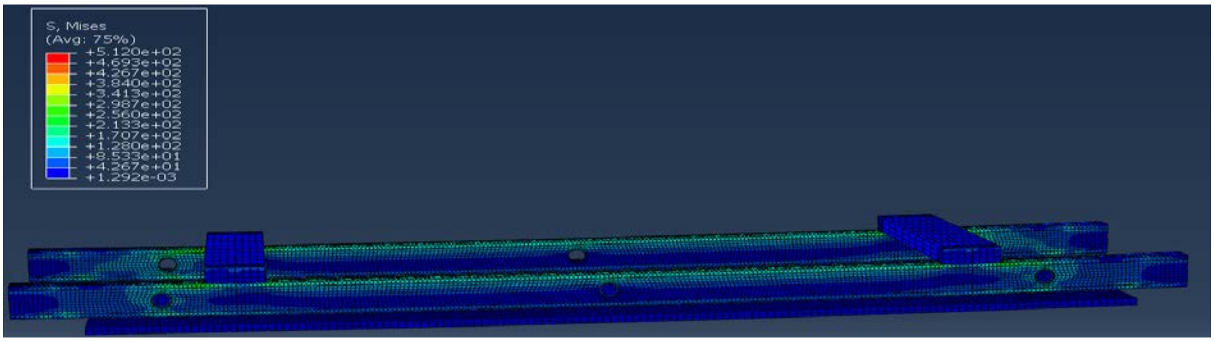

Figure 9. Finite analysis stress distribution contour plot at 2.5 kN loading (specimen S4)

4. CONCLUSIONS

The primary objective of this research was to investigate the composite behaviour of cold-formed steel section for wall panel under flexural loading. Four-point bending test was conducted as part of both the experimental study and numerical analysis to determine the behaviour of cold-formed steel under elastic limit. Numerical analysis has been conducted to validate the experimental results. It is seen from experimental and numerical results that when gypsum plasterboards are considered to the CFS wall panel, deflection of a CFS wall panel is decreased. Further research is required to understand the effects of different combinations of steel channel and gypsum plasterboard on the CFS wall panel.

ACKNOWLEDGMENTS

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