Investigation of Behaviour of Axially Loaded Back-to-Back Sigma Gapped Cold Formed Built up Section

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Abstract – *Cold-formed steel structural components have become popular in the construction industry as a cost-effective option for single-story commercial and industrial structures. When a single section is insufficient, cold formed steel built-up sections are often utilized as compression components to handle higher loads. However, the built-up portions display certain unusual buckling behaviours for which there are no complete provisions in the present regulations. Clause C4.5 of the American Iron and Steel Institute (AISI) North American Specifications on cold formed steel design, adopted from research and recommendations for hot-rolled steel built-up members connected with bolts or welds, is the only provision. The behaviour of hot rolled steel differs from that of cold formed steel, therefore this is confusing. Furthermore, few investigations of cold formed steel built up sections such as back to back sigma columns without a gap, battened and laced columns have been conducted. A complete analytical approach to the design of cold-formed steel built-up sections is also lacking. Through design calculations, finite element analyses, and experimental tests, the goal of this research is to investigate the behaviour of axially loaded cold formed steel back-to-back sigma built-up columns.*

***Key Words*: ANSYS, Cold-formed steel built-up section, FE models.**

1.INTRODUCTION

Cold-formed steel members are structural steel items manufactured by bending a flat sheet of steel into a shape that can sustain greater weight than the flat sheet itself at room temperature. [1].

Cold roll forming is the most common manufacturing method. Using 6 to 15 pairs of rollers, this method gradually forms the appropriate cross section from rolled-up steel stripes. It is cost-effective, especially when large quantities of a specific form are required. When low production volume and a variety of shapes are required, press braking is used instead. The press braking process is cost-effective due to the reduced number of machines and tools required. Due to minimal machinery required and ease of fabrication, the cross-sections of cold-formed steel are easily changed to meet building needs. This leads in a diversity of joint configuration. This results in a variety of joint configurations which make standardisation difficult. Unlike cold-formed steel, the production of traditional hot-rolled steel requires higher cost thus cross sections are standardised. [5].

The characteristics of cold-formed steel are different from hot-rolled steel due to the fabrication process. The yield stress of cold-formed steel is much higher than that of the conventional hot-rolled steel because the cold-forming process induces residual stresses which increase the yield stress. It is important for design standards to cater for these characteristics because they differentiate cold-formed steel from hot-rolled steel [3].

1.1 Historical Overview:

Producing of the CFS sections has been initiated for more than a century since the first steel flat sheets were made by the steel mills. Great Britain and the United CFS members in building construction in the 1850s. In the 1920s, there was not a wide acceptance of CFS to be as a construction material, because there were inadequate design guidelines and a lack of building codes information. Virginia Baptist Hospital, which constructed around 1925 in Lynchburg, Virginia is constructed as early applications used CFS in building material [4]. In the past few decades, more development of CFS has been archived by aesthetic architecture projects or light weight steel building [7]. The usage of CFS members as structural frame is increased not only in multi-story commercial structures. This is because of the advantages of cold formed steel, which get over the disadvantages of conventional products. Therefore, the interest of CFS in both research and construction aspects increased rapidly in industrialized countries

2. SECTION DETAIL

The test specimen column length is 1500mm, and it is made up of two back-to-back sigma sections that are linked by an intermediary link channel section.

The specimen was constructed up of columns manufactured from various sigma sections of cold formed steel with varying gap and spacing and channel section widths. Size of intermediate link channel sections according to gap and spacing as indicated in the table below, & 200×30×20×0.9 (H×B×C×t) channel sections utilised in all columns for back to back channel length 1500mm.

Table No- 1. Sigma sections sizes for creation of back to back channel gapped cold formed built up column section.

Sr. No	Profile name	Channel Size in (mm)	H	B	C	T
1	GBU-70,S-325	200×30×20×0.9	200	60	20	0.9
2	GBU-70,S-350	200×30×20×0.9	200	60	20	0.9
3	GBU-70,S-433	70×30×20×0.9	200	60	20	0.9
4	GBU-110,S-325	200×30×20×0.9	200	60	20	0.9
5	GBU-110,S-350	200×30×20×0.9	200	60	20	0.9
6	GBU-110,S-433	200×30×20×0.9	200	60	20	0.9
7	GBU-170,S-325	200×30×20×0.9	200	60	20	0.9
8	GBU-170,S-350	200×30×20×0.9	200	60	20	0.9
9	GBU-170,S-433	200×30×20×0.9	200	60	20	0.9

The AISI-S100-07 standard is used to select all section sizes. There are nine sections in all, each with a different gap and spacing. The gap and spacing for various back-to-back channels gapped made up nine parts are detailed in the table below.

Table No- 2. Gap & intermediate link channel spacing sizes

Sr. No	Profile name	Gap (mm)	Spacing (mm)	Length (mm)
1.	GBU-70,S-325	70	325	1500
2.	GBU-70,S-350	70	350	1500
3.	GBU-70,S-433	70	433	1500
4.	GBU-110,S-325	110	325	1500
5.	GBU-110,S-350	110	350	1500
6.	GBU-110,S-433	110	433	1500
7.	GBU-170,S-325	170	325	1500
8.	GBU-170,S-350	170	350	1500
9.	GBU-170,S-433	170	433	1500

Symbols:
E - Young's modulus
δ - Density of steel
μ - Poisson's Ratio
Fy - yield strength of steel
H - Depth/height of the beam
B - width of the beam
C - Depth/ height of the lip
t - thickness of the beam cross-section
L - length of the beam

3. NUMERICAL ANALYSIS

3.1 General

A three-dimensional (3D) finite element model was developed to determine buckling loads of the back-to-back sigma gapped cold formed built up column section by using the ANSYS workbench [4].

3.2 Analysis procedure

For the test specimen, the entire geometry was modelled. Welding is done at the back-to-back channel portions between the link channel and the web.

3.3Geometry & material modeling & meshing

Geometry for back-to-back sigma gapped cold formed built up section should be done in ANSYS workbench module, as shown in Fig., and material properties for back-to-back sigma gapped cold formed built up section should be listed in the table below.

Table No-3. Properties of cold formed steel

Material	Cold formed steel
Modules of elasticity	2 x 105 N/mm2
Poisson's ratio	0.3
Density	7850 kg/m3
Yield strength	250Mpa

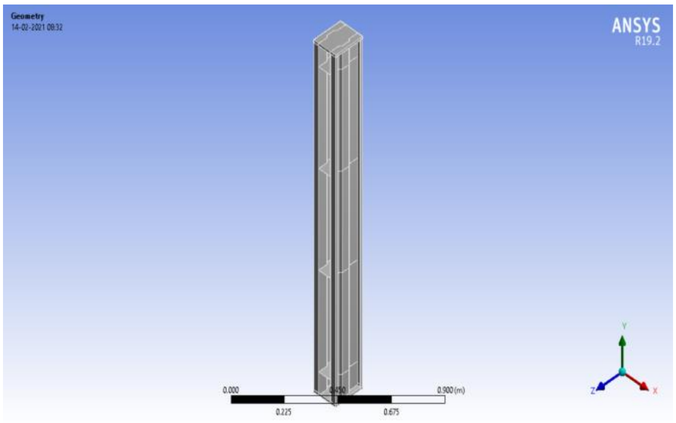

Fig.1 CFS sigma section modeling in ANSYS

A four-node shell element with six degrees of freedom at each node was used to represent the specimen. An optimum mesh size of 10mm is selected for the study based on mesh convergence research. Figure 1 shows a typical finite element.

3.4 loading & boundary condition

In the finite element model, pin-pinned boundaries were used. At the top and bottom of the built-up columns, two hard plates were employed. Using a reference point, the pin-pin boundary condition was simulated by adding rotational and translational restrictions to both end plates. The center of gravity 'CG' of the cross- section of the back-to-back gapped built-up column was used as the reference point. The load was applied through the upper end plate using the reference point.

3.5 Analysis

For back-to-back sigma gapped cold formed built up section, a non-linear static analysis is performed. Vertical displacements were also measured at mid-span for the aim of producing a load–deflection graph in the large displacement study. The following parameters were utilized in the nonlinear static analyses were:

- Maximum number of load increments = 100.
- Initial increment size = 0.1.
- Minimum increment size = 0.000001.
- Automatic increment reduction enabled, and large displacements enabled [1]

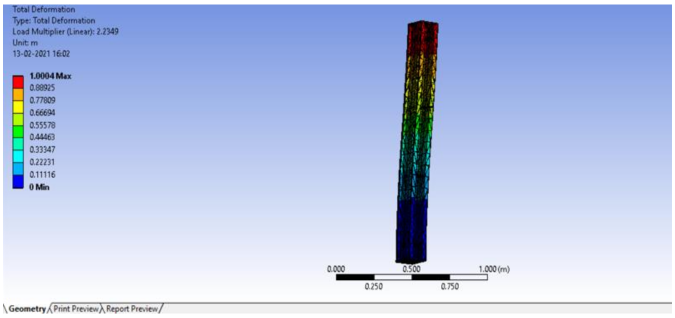

Fig.2 CFS column maximum displacement in ANSYS

4. ANALYSIS RESULT

4.1 Load carrying capacity-

On back-to-back sigma gapped cold formed built up sections, one point loading was performed. Column section to determine ultimate load bearing capability. The comparison of the load carrying capacity of the CFS column generated from finite element analysis (FEA) utilized for the model calibration is shown in Fig.7.In the numerical simulations, it can be seen that the maximum load carrying capacity of column for various gaps like 70 mm, 110mm 170mm are as follows for 70 mm gap in beam maximum load is taken by beam GBU-70, S-325 similarly for 110mm gap in column maximum load is taken by beam GBU-110, S-325 & for 170mm gap in beam maximum load is taken by taken by beam GBU-170, S-325 & as compare to spacing of 325mm, 350mm,433mm are 325mm spacing is more effective in 70mm,110mm & 170mm gap.

In below table ultimate load for nine Back-to-back sigmal gapped cold formed built up column section as shown in below.

Table No-4. Ultimate load & maximum displacement in mm

Sr. no	Profile name	Ultimate load in kN[Ansys]	Ultimate load in kN[Experimental]
1.	GBU-70,S-325	70	60
2.	GBU-70,S-350	68	-
3.	GBU-70,S-433	62	-
4.	GBU-110,S-325	66	54
5.	GBU-110,S-350	60	-
6.	GBU-110,S-433	52	-
7.	GBU-170,S-325	45	38
8.	GBU-170,S-350	40	-
9.	GBU-170,S-433	32	-

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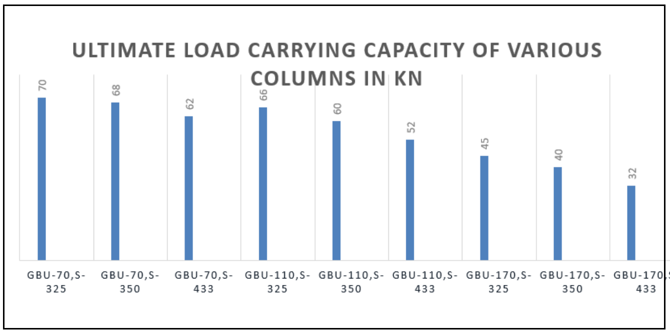


Fig. 3 Ultimate load carrying capacity of various columns in kN

5. Experimental Investigation

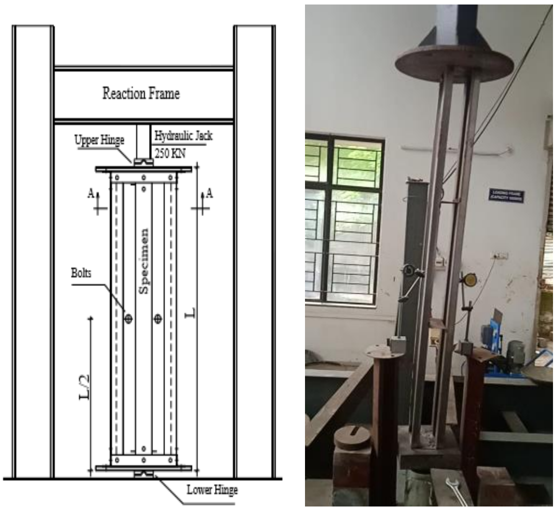
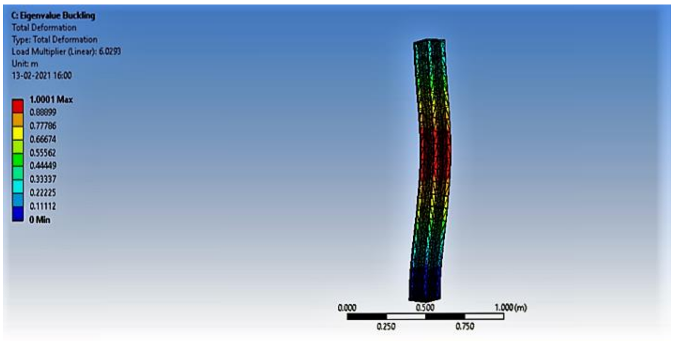


Fig.4 Schematic diagram for the test setup

Figure 5 shows a picture of the test setup. At the top of the column, an external load cell was installed. On the web of the columns, two longitudinal strain gauges and three additional strain gauges were utilized to measure the strain. Strain gauge arrangements are shown in Fig. 6. A Structural Loading Frame was used to apply axial load to the columns. The displacement control was used to apply the axial force to the columns, which can include the post buckling behavior of the columns. Displacement rate was kept as 0.03 mm/s for all test specimens. Strain values were recorded from longitudinal strain gauges near the top end plate and middle of the columns to verify that the load was applied through the centroid of the sections. In order to ensure, there is no gap between the two pin-ends and end plates of the specimen, all columns were loaded initially up to 25% of their expected failure load and then released.



6. CONCLUSIONS

One-point bending numerical simulations performed with the finite element program ANSYS were made.in finite element analyses we found that ultimate load carrying capacity for back-to-back sigma gapped cold formed built up column section. According to finite element analysis, a 70 mm gap produces a better result with intermediate 325mm link channel spacing than a 110mm or 170mm gap, and a 70 mm gap improves load carrying capacity than a 110mm or 170mm gap. GBU-110, S-325 shows ultimate load carrying 60 KN, GBU-170,S-325 shows ultimate load carrying 45 KN, and GBU-70,S-325 shows ultimate load carrying 70 KN, thus we may conclude that as the gap is widening, the load carrying capacity decreases.

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