IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

STUB COLUMN BEHAVIOUR OF COLD-FORMED SPECIAL SHAPED HOLLOW STEEL SECTIONS UNDER ECCENTRIC LOADING

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Abstract: This study has been undertaken to investigate the eccentric compressive behaviour of single and double loop CFS stub columns. Seven different cross sections are analyzed with ANSYS R 19.0 workbench. Material properties of the specimen were found out by tensile coupon test. A total of 14 non-linear analysis were performed with different stub columns. Primary objective of finite element modeling were to find out the ultimate load carrying capacity of each cross section under eccentric loading and to compare single and double loop cold-formed steel columns. Models were solved and total deformations, ultimate load carrying capacity, deformation at ultimate load were reported. Load-deformation curves were plotted for each model and results are tabulated. Strength index is calculated for each model and the values are compared with each other.

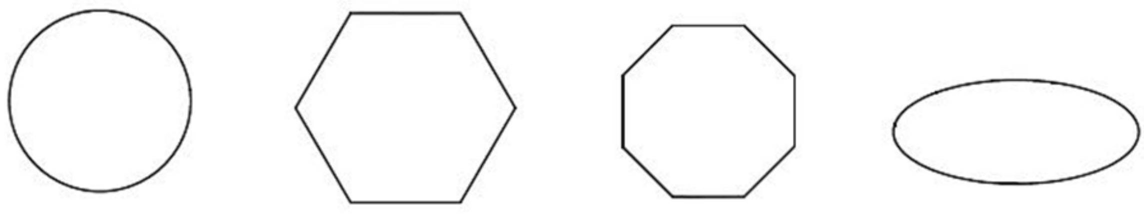
***Index Terms* - Cold-formed steel (CFS), Single loop (SL), Double loop (DL), Strength index (S.I), Eccentric Load (EL)**

1.INTRODUCTION

Cold formed steel (CFS) tubular sections have great significance in structural engineering due to their high strength to weight ratio, easy fabrication, low material costs and faster construction. As an economical and sustainable material, CFS has become very popular in the construction industry. By using CFS we can reduce the energy and resource consumption, transportation costs and carbon footprints. Existing studies have been performed using conventional sections like rectangular, circular, C section, L section, Z section and with built up sections. But very few studies have done using continuous irregular hollow cross sections or continuous closed welded sections. This paper aims to study eccentric compressive behaviour of single and double skin closed loop cold-formed columns.

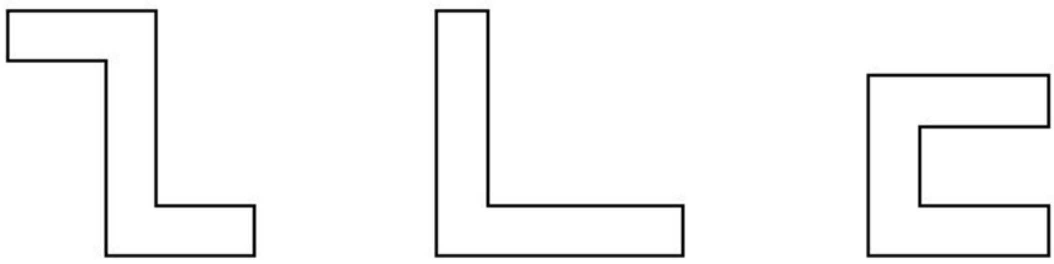
2.SPECIMEN DETAILS

Seven different cross sections are analyzed with ANSYS R 19.0 workbench. The various cross sections consist of single loop (SL) CFS columns and double loop (DL) CFS columns. Single loop hollow sections used in the analysis are circular, hexagonal, octagonal and elliptical shaped. Double loop hollow sections are Z section, L section and C section. All stub columns are continuous cold-formed sections connected by single weld at the end. Different cross sections was denoted by circular hollow section as SL-C, hexagonal hollow section as SL-H, octagonal hollow section as SL-O, elliptical hollow section as SL-E, double loop Z section as DL-Z, double loop L section as DL-L and double loop C section as DL-C. Cross sections of single loop and double loop cold-formed steel stub columns are shown in Figure 1 and Figure 2.



(a) SL-C (b) SL-H (c) SL-O (d) SL-E

Fig. 1 Cross Section of Single Loop CFS Columns



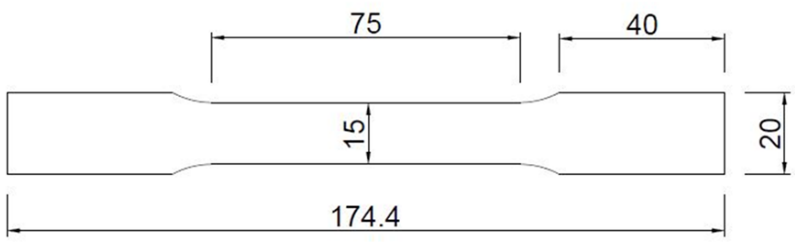
(a) DL-Z (b) DL-L (c) DL-C

Fig. 2 Cross Section of Double Loop CFS Columns

Diameter of circular hollow section was selected as 300 mm. The material selected was cold-formed galvanized iron sheet of thickness 1.6 mm, available in market. The height of the circular hollow stub column was 896 mm with a cross sectional area of 1500mm^2. This cross sectional area was kept same for all stub columns. The edge length of hexagonal hollow section was 181.25 mm. The edge length of octagonal hollow section was 117.8 mm. The length of semi-major and semi-minor axis of elliptical hollow section was 202.5 mm and 86.5 mm respectively. The overall width and overall depth of double loop Z section and double loop L section was 236 mm. The width of hollow region was 50 mm. The overall width and depth of double loop C section was 174 mm and the width of hollow region was 50 mm. The height of all stub columns were 896 mm and thickness of metal sheet was 1.6 mm. Cross sectional area of all stub columns were 1500 mm^2.

2.1 Material Properties

The preliminary tests were conducted on G.I sheets of thickness 1.6 mm. The material properties of test specimens were found out by tensile coupon test. Three tensile coupons were extracted from G.I structural steel sheet of thickness 1.6 mm. Test coupons were prepared and tested according to IS 1608 (part 1) : 2018. The dimensions of tensile coupon test specimen are shown in Figure 3. The mean of three coupon test values including yield stress (f_y), ultimate stress (f_u), Young's modulus (E) and Poisson ratio are given in Table 1. The stress- strain curve of test specimen is shown in Figure 5.



All Dimensions are in mm

Fig. 3 Dimensions of Tensile Coupon Test Specimen

Fig. 4 Tensile Coupon Test Specimens

Table 1 Test Results of Tensile Coupon Test

No of Coupons	Thickness of Material (mm)	Yield Stress, f_y (N/mm^2)	Ultimate Stress, f_u (N/mm^2)	Young's Modulus (N/mm^2)	Poisson's Ratio
3	1.6	276	345	2.05×10^5	0.3

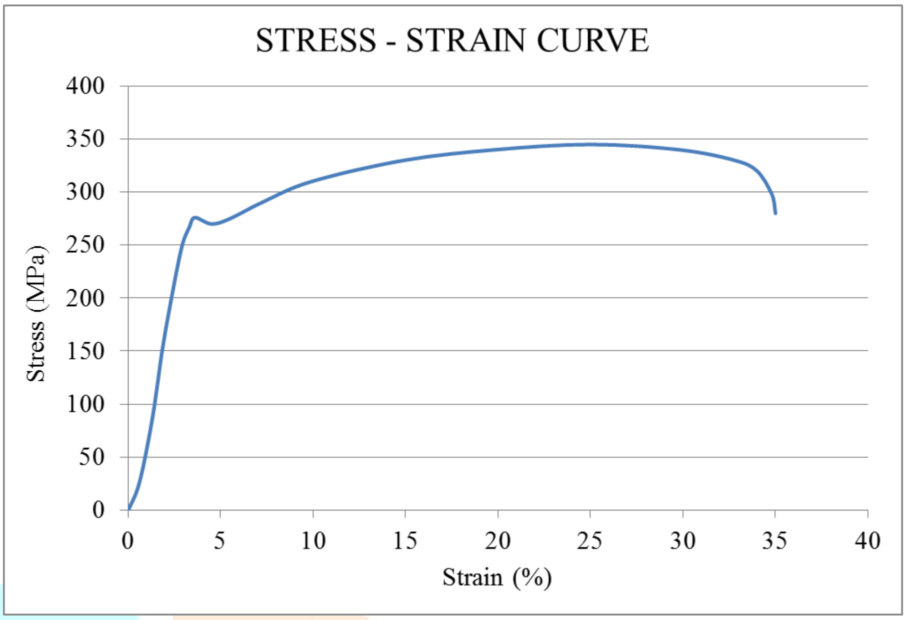
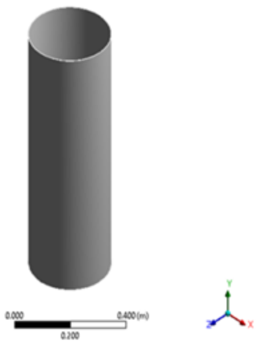


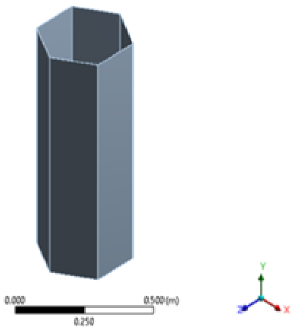
Fig. 5 Stress - Strain Curve of the Specimen

3.MODELLING AND ANALYSIS

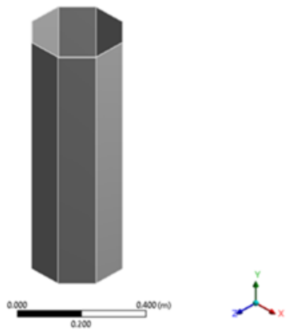
The stub columns were modeled in ANSYS R 19.0 workbench. Material properties were assigned to each model which was obtained from tensile coupon test. All stub columns was modeled with 20 node SOLID 185. The height and area of cross section of all the sections were 896 mm and 1500 mm^2 respectively. The material used for all the CFS columns was G.I structural steel plain sheet with thickness 1.6 mm. The finite element models of different single and double loop stub columns are given in Figure 6.



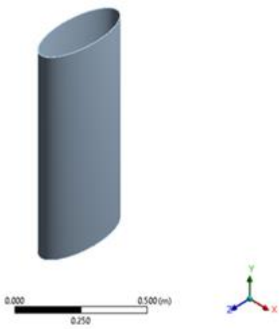
(a) SL-C



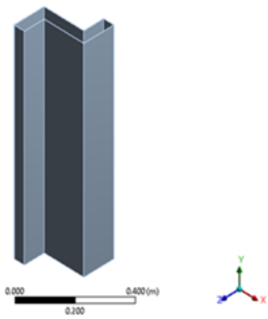
(b) SL-H



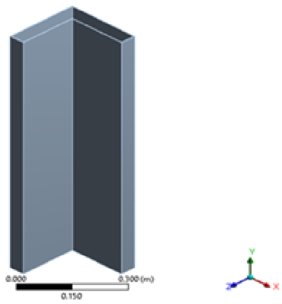
(c) SL-O



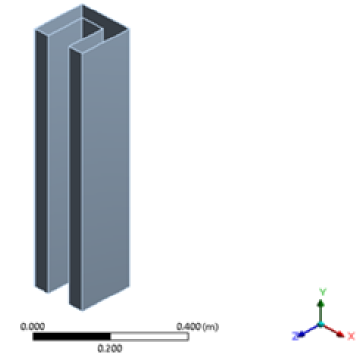
(d) SL-E



(e) DL-Z



(f) DL-L



(g) DL-C

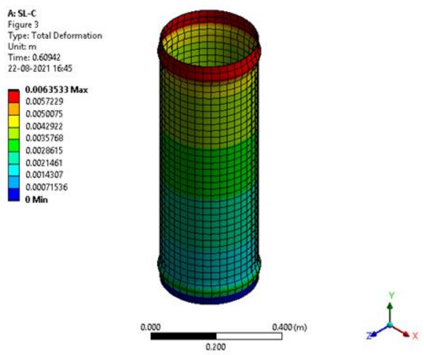
Fig. 6 Finite Element Models of Single and Double Loop CFS Stub Columns

Non-linear finite element (FE) analysis was conducted for all single loop and double loop CFS hollow sections using ANSYS R 19.0. A total of 14 non-linear analysis were performed with seven different cross sections of stub columns. Four models of single loop and three models of double loop CFS hollow columns were subjected eccentric loading. Two types eccentric loading was applied to each finite element model. Biaxial eccentricity of 25 % and 100 % was applied to find out the eccentric compressive behaviour. Finite element analysis was done by keeping the area of cross section of different stub columns as same. The primary objective of FE analysis was to find out the ultimate load carrying capacity of each cross section under eccentric loading. Meshing was done in ANSYS R 19.0 with a mesh size of 50 mm. Boundary conditions were both ends fully restrained against all degrees of freedom except for the eccentric translation at the loaded end. Eccentric load was applied by displacement controlled method. Models were solved and total deformations, ultimate load carrying capacity, deformation at ultimate load were reported. Load-deformation curves were plotted for each model and results are tabulated. Strength index is calculated for each model and the values are compared with each other.

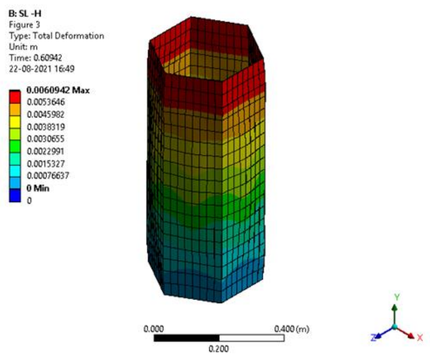
4.RESULTS AND DISCUSSIONS

4.1 Single and Double Loop CFS Columns Subjected to Eccentric Loading of 25%

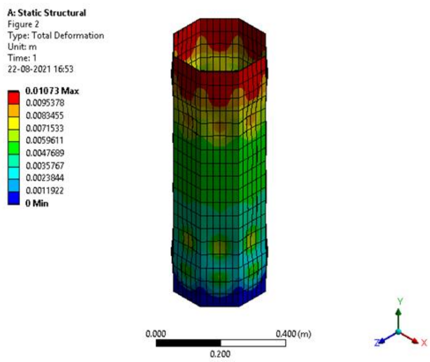
The eccentric compressive behaviour of single and double loop CFS hollow columns was studied. A biaxial eccentricity of 25% is provided to analyze single and double loop sections. Total deformations of different stub columns are shown in Figure 7. The load-deformation curves of single and double loop CFS columns are shown in Figure 8. The analysis results of single and double loop CFS hollow columns subjected to 25% eccentric load are shown in Table 2.



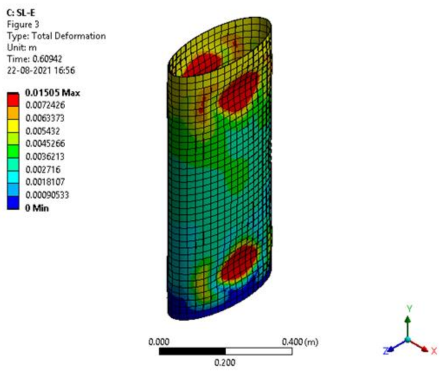
(a) SL-C



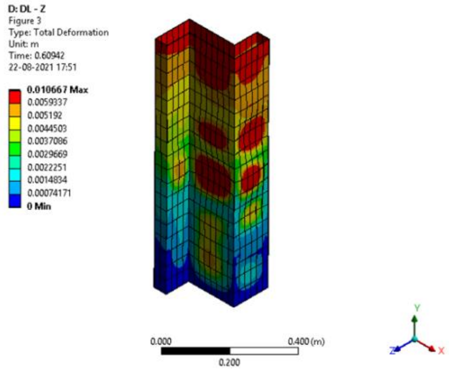
(b) SL-H



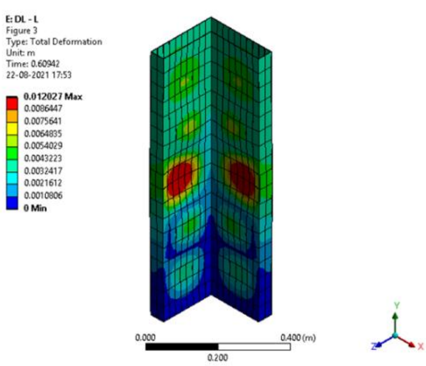
(c) SL-O



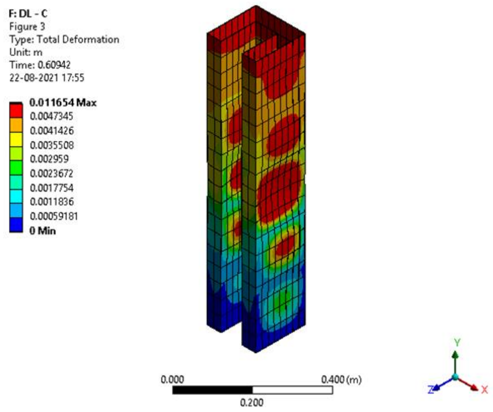
(d) SL-E



(e) DL-Z



(f) DL-L



(g) DL-C

Fig. 7 Total Deformation of Single and Double Loop CFS Stub Columns with e = 25%

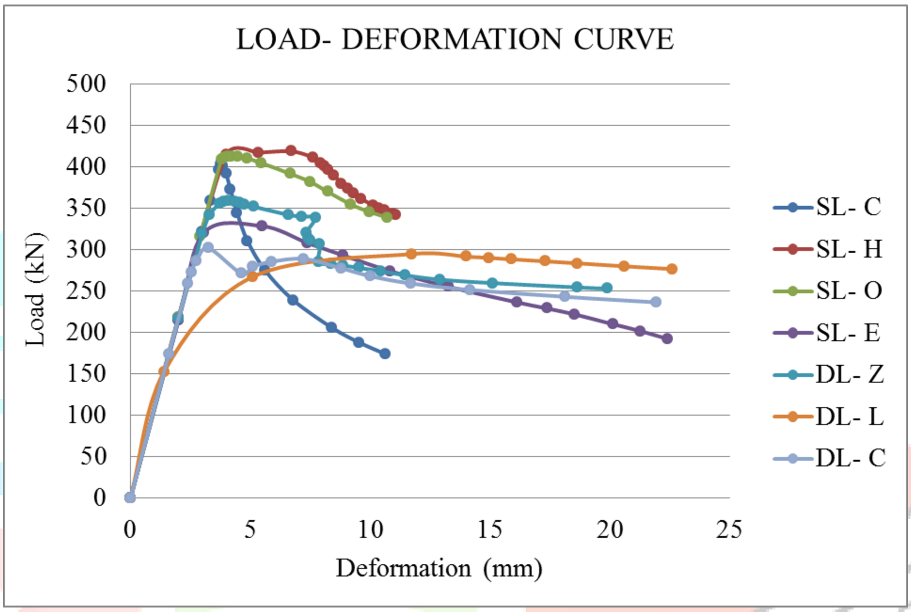


Fig. 8 Load – Deformation Curves of Single and Double Loop CFS Columns under Eccentric Loading with e = 25%

Table 2 Analysis Results of Single and Double Loop CFS Columns under Eccentric Loading with e = 25%

Model	P_u (kN)	δ_u (mm)	Area, A (mm^2)	Strength Index (S.I)
SL-C	404	3.78	1500	0.98
SL-H	419	6.70	1500	1.01
SL-O	412	4.21	1500	1.00
SL-E	328	5.48	1500	0.79
DL-Z	359	4.08	1500	0.87
DL-L	295	11.75	1500	0.71
DL-C	302	3.25	1500	0.73

Strength index is calculated by the formula given below.

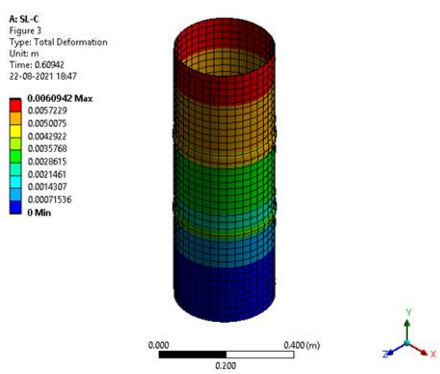
$$\text{Strength Index} = \frac{\text{Ultimate Load}}{(\text{Area} \times \text{Yield Strength of Material})}$$

This analytical study shows that hexagonal hollow section (SL-H) has highest load carrying capacity among single loop (SL) sections under eccentric loading with e = 25%. The ultimate load carrying capacity of hexagonal hollow section was found to be 419 kN with a deformation of 6.7 mm. Hexagonal hollow section has a strength index value of 1.01. Elliptical hollow section (SL-E) has least value of ultimate load among single loop hollow sections under biaxial eccentric loading of 25%.

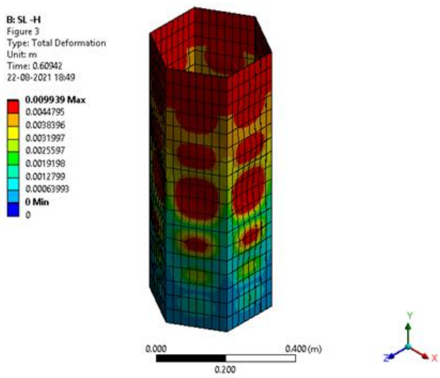
Among double loop (DL) hollow CFS columns, Z section (DL-Z) has higher load carrying capacity under eccentric loading with e = 25%. The ultimate load of double loop Z section was recorded as 359 kN with a deformation of 4.08 mm. The strength index value of DL-Z was calculated to be 0.87. Double loop L section (DL-L) has least load carrying capacity among double loop sections under biaxial eccentric loading of 25%.

4.2 Single and Double Loop CFS Columns Subjected to Eccentric Loading of 100%

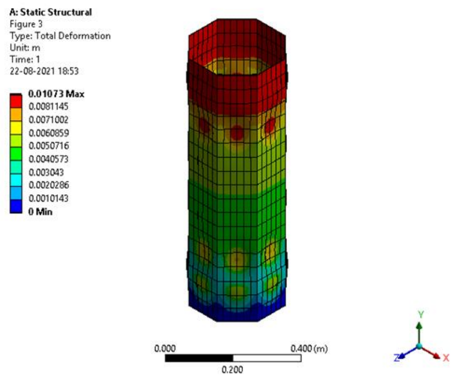
The eccentric compressive behaviour of single and double loop CFS hollow columns was studied. A biaxial eccentricity of 100% (maximum eccentricity) is provided to analyze single and double loop sections. Total deformations of different stub columns are shown in Figure 9. The load-deformation curves of single and double loop CFS columns are shown in Figure 10.



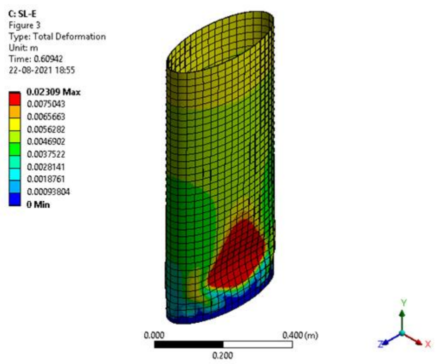
(a) SL-C



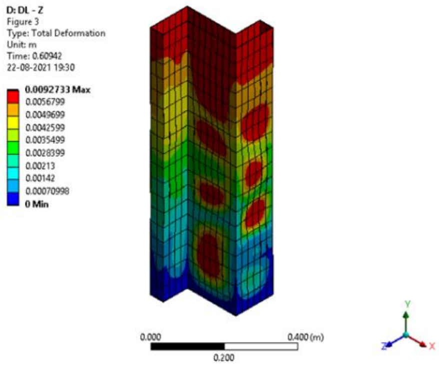
(b) SL-H



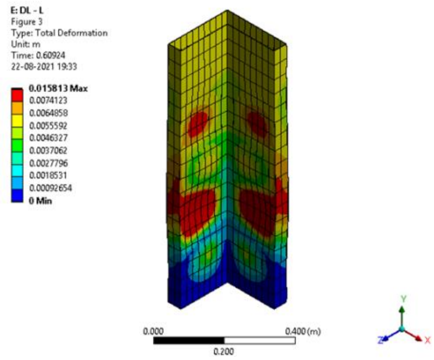
(c) SL-O



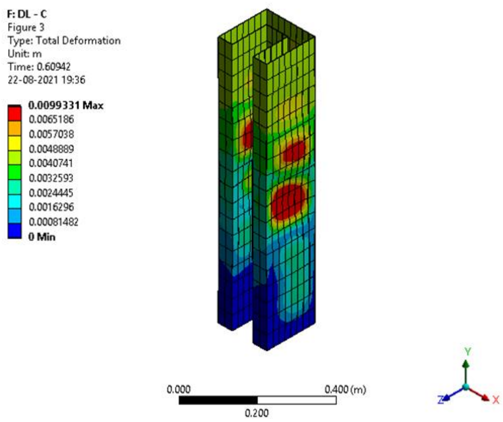
(d) SL-E



(e) DL-Z



(f) DL-L



(g) DL-C

Fig. 9 Total Deformation of Single and Double Loop CFS Stub Columns with e = 100%

This analytical study shows that octagonal hollow section (SL-O) has highest load carrying capacity among single loop (SL) sections under eccentric loading with e = 100%. The ultimate load carrying capacity of octagonal hollow section was found to be 410 kN with a deformation of 4.22 mm. Octagonal hollow section has a strength index value of 0.99. Hexagonal hollow section (SL-H) has least value of ultimate load among single loop hollow sections under biaxial eccentric loading of 100%.

Among double loop (DL) hollow CFS columns, Z section (DL-Z) has higher load carrying capacity under eccentric loading with e = 100%. The ultimate load of double loop Z section was recorded as 359 kN with a deformation of 4.08 mm. The strength index value of DL-Z was calculated to be 0.87. Double loop L section (DL-L) has least load carrying capacity among double loop sections under biaxial eccentric loading of 100%. The analysis results of single and double loop CFS hollow columns subjected to 100% eccentric load are shown in Table 3.

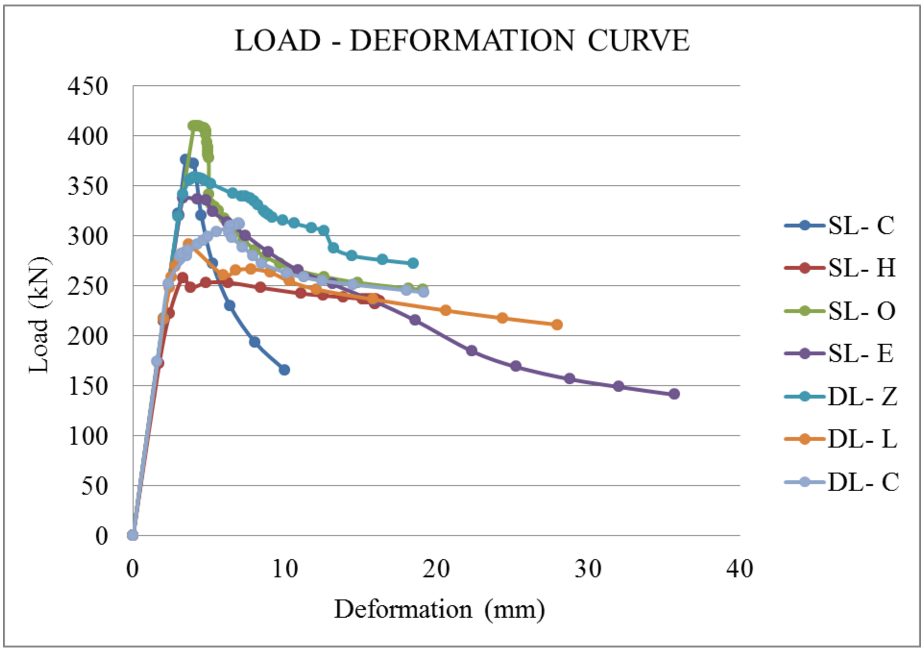
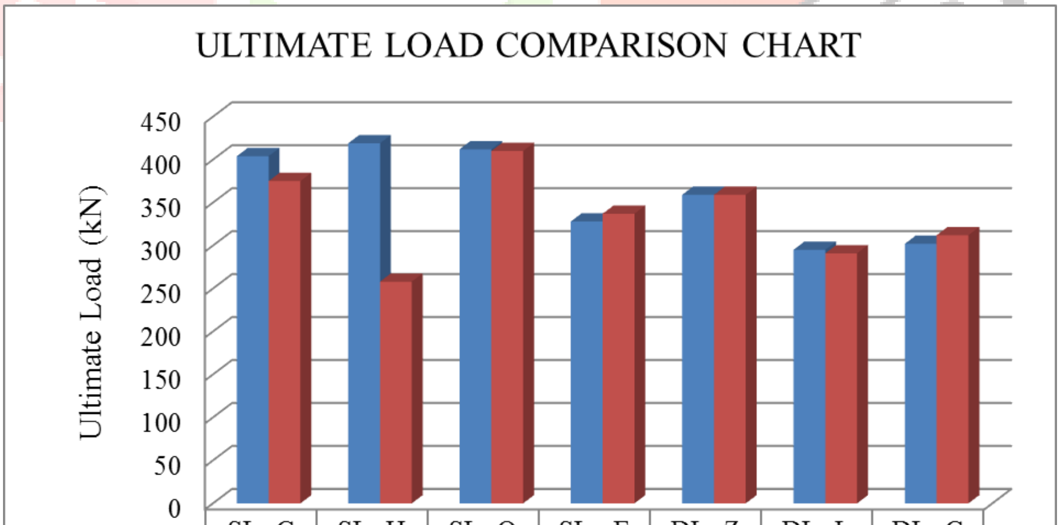


Fig. 10 Load – Deformation Curves of Single and Double Loop CFS Columns under Eccentric Loading with e = 100%

Table 3 Analysis Results of Single and Double Loop CFS Columns under Eccentric Loading with e = 100%

Model	P_u (kN)	δ_u (mm)	Area, A (mm^2)	Strength Index (S.I)
SL-C	375	3.50	1500	0.91
SL-H	258	3.27	1500	0.62
SL-O	410	4.22	1500	0.99
SL-E	337	3.28	1500	0.81
DL-Z	359	4.08	1500	0.87
DL-L	291	3.69	1500	0.70
DL-C	312	6.95	1500	0.75

4.3 Comparison of Ultimate Load Capacity of Single Loop and Double Loop CFS Hollow Columns



	SL- C	SL- H	SL- O	SL - E	DL- Z	DL- L	DL- C
E L 25%	404	419	412	328	359	295	302
E L 100%	375	258	410	337	359	291	312

Fig. 11 Ultimate Load Comparison Chart of Single and Double Loop CFS Columns under Eccentric Loading

Finite element analysis of single and double loop CFS columns was conducted. Seven different cross sections were analyzed with ANSYS. Among single loop (SL) CFS columns hexagonal hollow section (SL-H) has best performance with high load carrying capacity under eccentric loading with an eccentricity of 25%. When the eccentricity is increased to maximum value (e = 100%), octagonal hollow section (SL-O) is the best performance section in terms of compression behaviour. Among double loop (DL) CFS hollow stub columns, Z section (DL-Z) has high load carrying capacity under eccentric loading. For a biaxial eccentricity of 25% and 100%, Z section was the best performance section. Among single loop (SL) and double loop (DL) CFS columns, hexagonal hollow section (SL-H) has best performance with high load carrying capacity under eccentric loading with e = 25%.

When the eccentricity is increased to the maximum (e =100%), octagonal hollow section (SL-O) has high load carrying capacity among single and double loop CFS columns.

The percentage difference in ultimate load of hexagonal (SL-H) and Z section (DL-Z) was 16.7% under biaxial eccentricity of 25%. Similarly, the ultimate load of octagonal hollow section was 14.2% more than that of double loop Z section under biaxial eccentricity of 100%.

5. CONCLUSIONS

Eccentric compressive behaviour of single and double loop CFS hollow steel stub columns has been presented. Seven different cross sections from single and double loop cold-formed steel columns were studied analytically. A total of 14 non-linear analysis were conducted.

- Among single loop (SL) CFS columns, hexagonal hollow section (SL-H) has best performance with high load carrying capacity and strength index under eccentric loading with an eccentricity of 25%
- When the eccentricity is increased to maximum value (e = 100%), octagonal hollow section (SL-O) is the best performance section in terms of compression behaviour among single loop (SL) sections
- Among double loop (DL) CFS hollow stub columns, Z section (DL-Z) has high load carrying capacity and strength index under eccentric loading. For a biaxial eccentricity of 25% and 100%, Z section was the best performance section
- Among single loop (SL) and double loop (DL) CFS columns, hexagonal hollow section (SL-H) has best performance with high load carrying capacity under eccentric loading with e = 25%
- When the eccentricity is increased to the maximum (e =100%), octagonal hollow section (SL-O) has high load carrying capacity among single and double loop CFS columns
- The percentage difference in ultimate load of hexagonal (SL-H) and Z section (DL-Z) was 16.7% under biaxial eccentric loading of 25%
- The ultimate load of octagonal hollow section was 14.2% more than that of double loop Z section under biaxial eccentric loading of 100%

REFERENCES

[1] **Junbo Chen, Tak-Ming Chan and Amit H. Varma** (2020), "Stub Column Behaviour of Cold-Formed High-Strength Steel Circular Hollow Sections under Compression", *Journal of Structural Engineering*, 146 (12): 04020277.

[2] **Han Fang, Tak-Ming Chan and Ben Young** (2020), "Experimental and Numerical Investigations of Octagonal High-Strength Steel Tubular Stub Columns under Combined Compression and Bending", *Journal of Structural Engineering*, 147(1): 04020282.

[3] **Ju Chen, Man-Tai chen and Ben Young** (2019), "Compression Tests of Cold-Formed Steel C- and Z-Sections with Different Stiffeners", *Journal of Structural Engineering*, 145(5): 04019022.

[4] **Boshan Chen, Krishanu Roy, Asraf Uzzaman, Gary M. Raftery, David Nash, G. Charles Clifton, Pouya Pouladi and James B. P. Lim** (2019), "Effects of edge-stiffened web openings on the behaviour of cold-formed steel channel sections under compression", *Thin-Walled Structures*, 144 (2019) 106307.

[5] **Jiong-Yi Zhu, Tak-Ming Chan and Ben Young** (2019), "Cross-Sectional Capacity of Octagonal Tubular Steel Stub Columns under Uniaxial Compression", *Engineering Structures*, 184 (2019) 480-494.

[6] **Jia-Lin Ma, Tak-Ming Chan and Ben Young** (2015), "Experimental Investigation on Stub-Column Behaviour of Cold-Formed High-Strength Steel Tubular Sections", *Journal of Structural Engineering*, 04015174.

[7] **Man-Tai Chen and Ben Young** (2020), "Tests of Cold-Formed Steel Semi-Oval Hollow Section Members under eccentric Axial Load", *Journal of Structural Engineering*, 146(4): 04020027.

[8] **Jia-Lin Ma, Tak-Ming Chan and Ben Young** (2019), "Cold-Formed High-Strength Steel Rectangular and Square Hollow Sections under Combined Compression and Bending", *Journal of Structural Engineering*, 145(12): 04019154.

[9] **Jun Ye, Iman Hajirasouliha and Jurgen Becque** (2018), "Experimental Investigation of Local-Flexural Interactive Buckling of Cold Formed Steel Channel Columns", *Thin-Walled Structures*, 125 (2018) 245-258.

[10] **Junbo Chen and Tak-Ming Chan** (2020), "Material Properties and Residual Stresses of Cold-Formed High-Strength-Steel Circular Hollow Sections", *Journal of Constructional Steel Research*, 170 (2020) 106099.

[11] **Han Fang, Tak-Ming Chan and Ben Young** (2018), "Material Properties and Residual Stresses of Octagonal High Strength Steel Hollow Sections", *Journal of Constructional Steel Research*, 148 (2018) 479-490.

[12] **Jia-Lin Ma, Tak-Ming Chan and Ben Young** (2015), "Material Properties and Residual Stresses of Cold-Formed High Strength Steel Hollow Sections", *Journal of Constructional Steel Research*, 109 (2015) 152-165.

[13] **Indian Standard Code of Practice for Metallic Materials-Tensile Testing at Ambient Temperature** (Fourth Revision), IS 1608 (Part 1): 2018, *Bureau of Indian Standards*, New Delhi.