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Analytical and Experimental Investigation of Cold Formed Steel Sections under Bending

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Abstract**—*The primary interest of this project is to study the possible buckling occurrence on various cold formed steel closed sections like Box section, front to front Sigma and front to front Z-sections used as beams. Since the flexural load carrying capacity of the above mentioned sections under bending varies greatly with respect to its shape. In order to study different load capacity initially, a reliable finite element model was generated using the ANSYS software package to predict the flexural load above mentioned cold formed structural sections and to obtain a better understanding of the buckling failure behavior. For this purpose, a finite element model was developed using ANSYS. Theoretical study is done by using Euro code (EN1993 Part1-3) to determine the buckling behavior. Experimental study is performed by testing the specimen under bending. The Experimental investigation, theoretical investigation by Euro code (EN1993 Part1-3) and numerical investigation has been compared and concluded.*

Keywords**—** *Cold Formed Steel, various CFS section, Flexural Load.*

I. Introduction

Cold Formed thin sheet steel products are extensively used in building industry, and range from purlins to roof sheeting and floor decking. Generally these are available for use as basic building elements for assembly at site or as prefabricated frames or panels. The thickness of steel sheet used in cold formed construction is usually 1 to 3 mm. Much thicker material up to 8 mm can be formed if pre-galvanized material is not required for the particular application. The method of manufacturing is important as it differentiates these products from hot rolled steel sections. Normally, the yield strength of steel sheets used in cold-formed sections is at least 280 N/mm^2, although there is a trend to use steels of higher strengths, and sometimes as low as 230 N/mm^2. The behavior of various CFS section subjected to bending is discussed in this paper.

1.1 Objective

- To carry out the Experimental and analytical investigation of cold formed steel sections of sigma, z and box section under bending.
- To study the structural performance of cold formed steel sections.
- To reduces the dead load of the structure.

1.2 Scope

The scope of the project is to reduce the dead weight. Theoretical, experimental results are compared with the ANSYS results and other scopes are

- To obtain high performance structure on low cost.
- To use a cost effective and light- weight materials in construction for easy fabrication and installation.

II. Literature Review

2.1 Anna green Antony (2016)**.** Cold formed steel sections are currently widely used as primary framing components and secondary structural systems. They are used as purlins and side rails or floor joist, and after that in the building envelops. The geometry can significantly influence the stability response of cold-formed steel members and their failure patterns. The section selected for the study is CFS sigma section. The behaviour of the sigma section and the effect of providing stiffeners are studied. Providing stiffeners can influence the ultimate load of the section. In this paper, inclined and transverse stiffeners are provided at the flange and their effect on the ultimate load is studied.

2.2 JunYe, ImanHajirasouliha, JurgenBecque (2018).This paper presents the results of a comprehensive experimental program aimed at studying the interaction of local and overall flexural buckling in cold-formed steel (CFS) plain and lipped channels under axial compression. The results were further used to verify the accuracy of the current design procedures in Euro code 3, as well as to evaluate the effectiveness of a previously proposed optimization methodology. A total of 36 axial compression tests on CFS channels with three different lengths (1 m, 1.5 m and 2 m) and four different cross-sections were conducted under a concentrically applied load and pin-ended boundary conditions. The initial geometric imperfections of the specimens were measured using a specially designed set-up with laser displacement transducers. Material tests were also carried out to determine the tensile properties of the flat parts of the cross-sections, as well as the cold-worked corner regions. A comparison between the experimental results and the Euro code 3 predictions showed that the effective width approach combined with the P–M interaction equation proposed in Eurocode 3 to take into account the shift of the effective centroid consistently provided safe results. Furthermore, the experimental data confirmed the results of an optimization study and demonstrated that the optimized CFS columns exhibited a capacity which was up to 26% higher than the standard

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channel with the same amount of material taken as a starting point.

2.3 V.Priyadarshini, MdHasan Khan, Murugesan.P, Kiran Krishna, MdRiyas (2018). The aim of the project is to study the behavior of cold formed steel frames made using channel sections. From the review of literature it has been found that much work has not been done on cold formed steel hollow section frames. Therefore this study on cold formed steel channel section frames is undertaken. The study involves hollow section tests on cold-formed steel frame are two specimens of single bayed two story frames of 3mm thickness are tested along both the major and minor axis. Cold formed steel hollow section frames connected along to major and minor axes connections are tested experimentally under concentrated loading. Stress strain curves are plotted and compared with that of hot rolled steel. It was found out that frames connected along major axis exhibit 38% higher load carrying capacity than that of the frames connected along minor axis.

III. SPECIMEN DETAILS

TABLE 1: Physical Properties CFS Section

Density of steel	7850 kg/m^3
Modulus of elasticity	2x10^5 N/mm^2
Poisson ratio	0.3
Modulus of rigidity	0.769 x10^5 N/mm^2
Yield Strength	210 N/mm^2

Fig. 1 Specimen for Experimental study

TABLE 2: Specimens Dimension

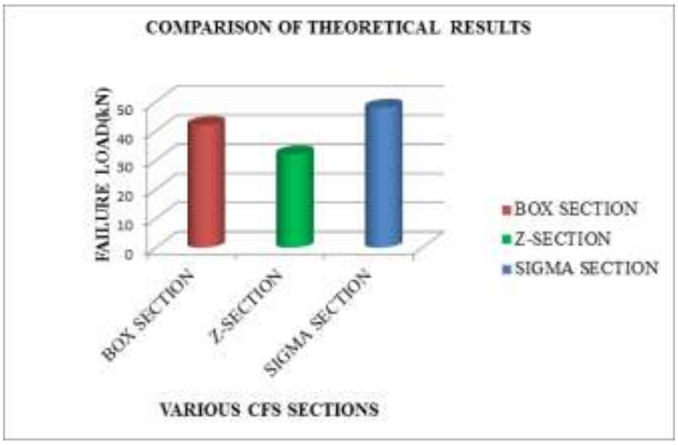
Specimen	Length mm	Section Dimensions		
		A mm	B mm	Thickness Mm
Box section	1000	400	400	3
Z-section	1000	95	375	3
Sigma section	1000	100	500	3

IV. THEORETICAL STUDY

The present study is carried out to understand the flexural behaviour of cold formed steel using Eurocode (EN1993 part1-3)

TABLE 3: Theoretical Results

SPECIMEN	AREA (mm^2)	FLEXURAL LOAD (kN)
Box Section	4800	42
Z-Section	3702	32
Sigma Section	3780	48



V. EXPERIMENTAL STUDY

The main objective of experimental work is to get an insight of the behavior and modes of failure of various cold form steel sections under bending. Three specimens namely Box section, Z-section, Sigma section in which each thickness were tested to determine the flexural load for steel.

5.1 Experimental Procedure

Loading frame is the apparatus which is used to test the beam until it reaches the ultimate load. The sections are tested by applying the uniformly disturbed loading condition. These investigations were done with the help of loading frame load carrying of 50 tonne capacity. Load is applied using hydraulic jack gradually and uniformly. Load and corresponding deflection are recorded. The load is applied till the specimen attains complete failure. The failure mode is completely recorded and studied.

5.2 Experimental Test Result for Box Section

TABLE 4: Test Results for Box section

Load (kN)	Deflection (mm)
5	0.05
10	0.18
15	0.33
20	0.42
25	0.51
30	0.74
35	0.86
40	0.97
45	1.15

Fig. 2 (i) Specimen before loading

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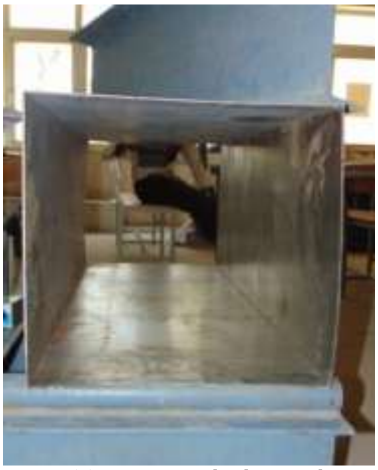
Fig. 2 (ii) Specimen in loading condition


Fig. 2 (iii) Failure mode shape of Box section

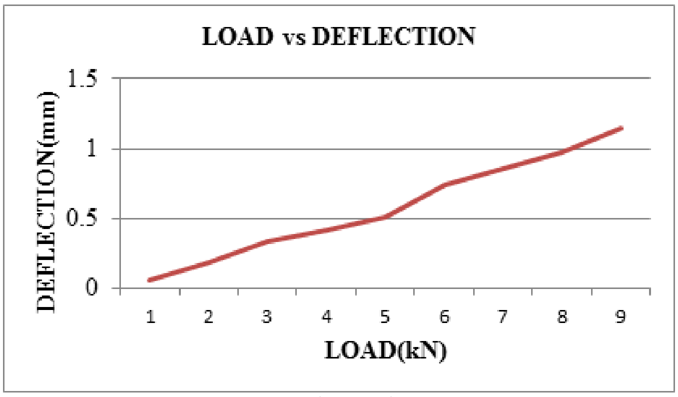

Fig. 3 Load vs Deflection for Box section

5.3 Experimental Test Result for Z- Section

TABLE 5: Test Results for Z-section

Load (kN)	Deflection (mm)
5	0.10
10	0.49
15	1.00
20	1.55
25	3.25
30	4.15


Fig. 4 (i) Specimen before loading


Fig. 4 (ii) Specimen in loading condition


Fig. 4 (iii) Failure mode shape of Z-section

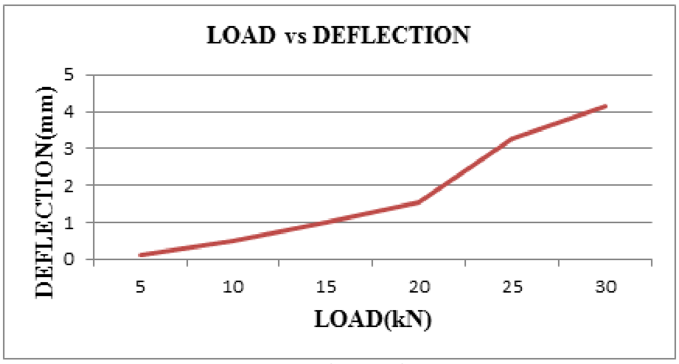

Fig. 5 Load vs Deflection for Z-section

5.4 Experimental Test Result for Sigma Section

TABLE 6: Test Results for Sigma section

Load (kN)	Deflection (mm)
5	0.05
10	0.25
15	0.60
20	0.80
25	1.00
30	1.50
35	2.12
40	2.17
45	3.97
50	6.12


Fig. 6 (i) Specimen before loading


Fig. 6 (ii) Specimen in loading condition


Fig. 6 (iii) Failure mode shape of sigma section

Fig. 7 Load vs Deflection curve for Sigma section

TABLE 7: Experimental Investigation Results

SPECIMEN	AREA (mm^2)	FLEXURAL LOAD (kN)
Box Section	4800	45
Z-Section	3702	30
Sigma Section	3780	50

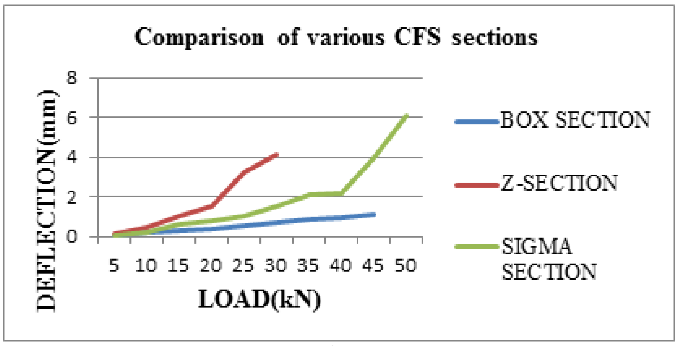

Fig. 8 Comparison of Various CFS Sections

VI. ANALYTICAL PROCEDURE

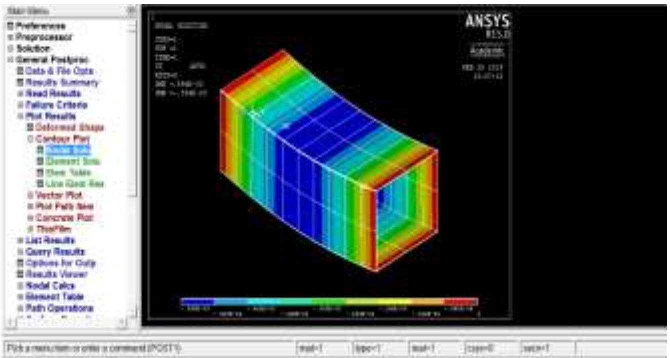

Fig. 9 Failure of Box section

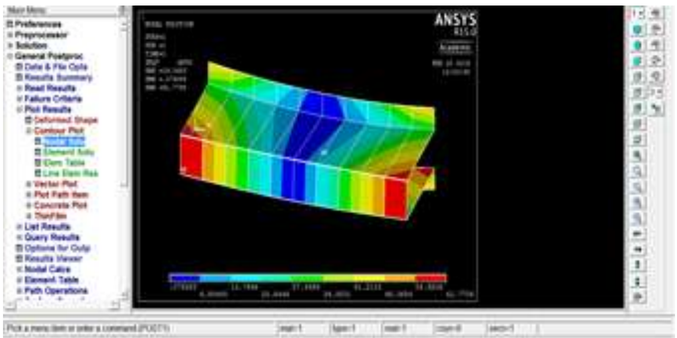

Fig. 10 Failure mode of Z-section

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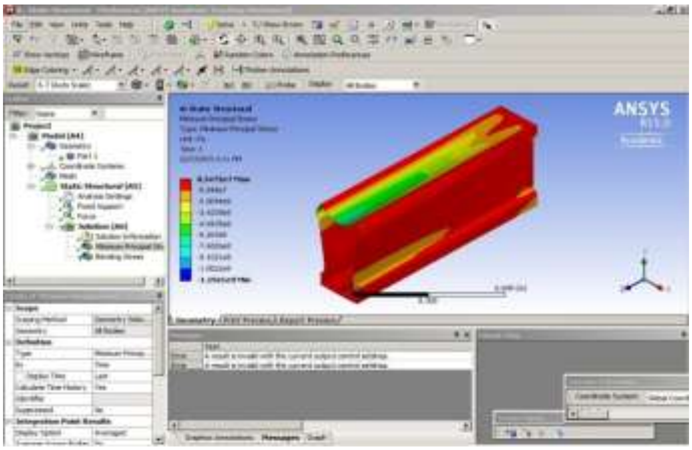

Fig. 11 Failure mode of Sigma section

TABLE 8: Analytical Investigation Results

SPECIMEN	AREA (mm^2)	FLEXURAL LOAD (KN)
Box Section	4800	48
Z-Section	3702	37
Sigma Section	3780	56

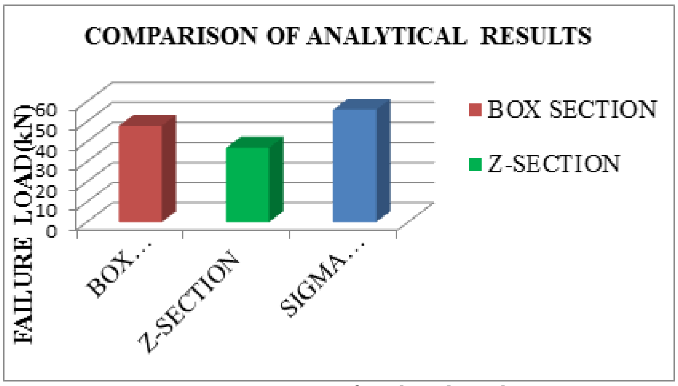

Fig. 12 Comparison of Analytical Result

VII. Methodology

1. Literature Review
2. Selection of various cold formed steel section
3. Fabrication of various CFS section
4. Theoretical Study using Euro code
5. Experimental investigation of various CFS section under bending
6. Analytical study on various CFS section under bending using ANSYS
7. Comparison of flexural strength of various CFS sections
8. Results and discussion
9.Conclusion

VIII. Results and Discussions

The value derived from experimental results, ANSYS results, theoretical values are tabulated below. The table also gives the modes of failure of each specimen. The comparison of results is tabulated below.

TABLE 9: Comparison of Results

Specimen	Experimental kN	Theoretical kN	Analytical kN	Mode of failure
Box section	45	42	48	Lateral Torsional buckling
Z-section	30	32	37	Web local buckling & Distortional buckling
Sigma section	50	48	56	Web local buckling & Distortional buckling

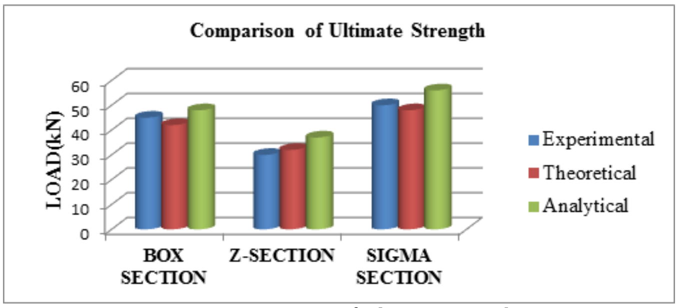

Fig. 13 Comparison of Ultimate Strength

IX. Conclusion

- By increasing the thickness of the specimen load carrying capacity increases.
- Behaviour of thin walled cold formed steel Beams requires consideration of local, Distortional and Euler (i.e., flexural or flexural- torsional) buckling.
- Flexural test on thin walled closed sections has been carried out and investigation of flexural, flexural- torsional and mixed with local- distortional mode of buckling.
- Theoretical results are compared with euro code method. Theoretical results agree well with FEM ANSYS results as well as Experimental results.
- Experimental failure modes of buckling shapes are obtained and has a good agreement with ANSYS and theoretical failure modes.
- Distortional buckling mode has lower post- buckling capacity than local buckling and higher imperfection sensitivity than local buckling.
- If the failure is known to occur in the distortional mode, then the elastic distortional buckling stress (local) is used to predict the ultimate strength.
- Load carrying capacity decreases with increases in w/t ratio.

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