EXPERIMENTAL AND ANALYTICAL STUDY OF BEHAVIOR OF LIGHT GAUGE STEEL COLUMN SECTION

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ABSTRACT

The light gauge steel is used at large number of products. For example; in metal building construction, for wall coverings, floor decking, Cold-formed steel is a basic component in construction of lightweight prefabricated structures like stud frame panels, trusses and portal frames. Cold formed steel term itself make it differ from hot rolled steel because of different manufacturing method. Typically columns, beams and angles etc. are different globally. At room temperatures cold formed steel members are formed by bending flat sheets. Therefore they can be easily available at any place where hot rolled sections are not available. These components can be used for more large and complex structures.

In this report ultimate compressive strength of built up cold formed steel column I section is assessed also, the parametric study of cold formed steel built up I column section is carried out. Comparison work of hot rolled and cold formed steel for the same built up column I section is done in this report. Secondly a suitable finite element model is developed and compared with experimental results.

Keyword - *Ultimate compressive strength, buckling, cold formed steel, stress, strain.*

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1. INTRODUCTION

The motivation of the present work is IS-801:1975 code for cold formed light gauge steel design is under revision. Ultimate compressive strength of built up cold formed steel column I section is not assessed. The parametric study of cold formed steel built up I column section is not done in the literatures referred. Study of failure modes for built up I section is done in very few literatures, also comparison work of Hot rolled and Cold formed steel for the same built up column I section is not worked before. Therefore it is essential to work on this subject and parameters; therefore I selected this subject for my proposed work.

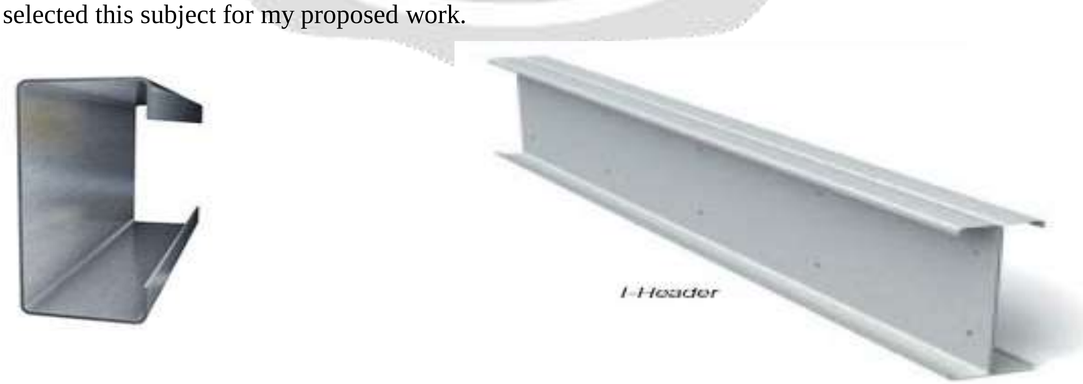


Fig.1.1: Cold formed steel sections.

2. TEST PROCEDURE AND INSTRUMENTATION:

To find out ultimate compressive strength of cold formed steel light gauge section both ends fixed boundary condition has been selected, considering this test set up has created. Column of 700mm overall length tested in universal testing machine. Dial gauges and LVDT were attached to measure deflection in each direction. Figure below shows schematic diagram of test set up.

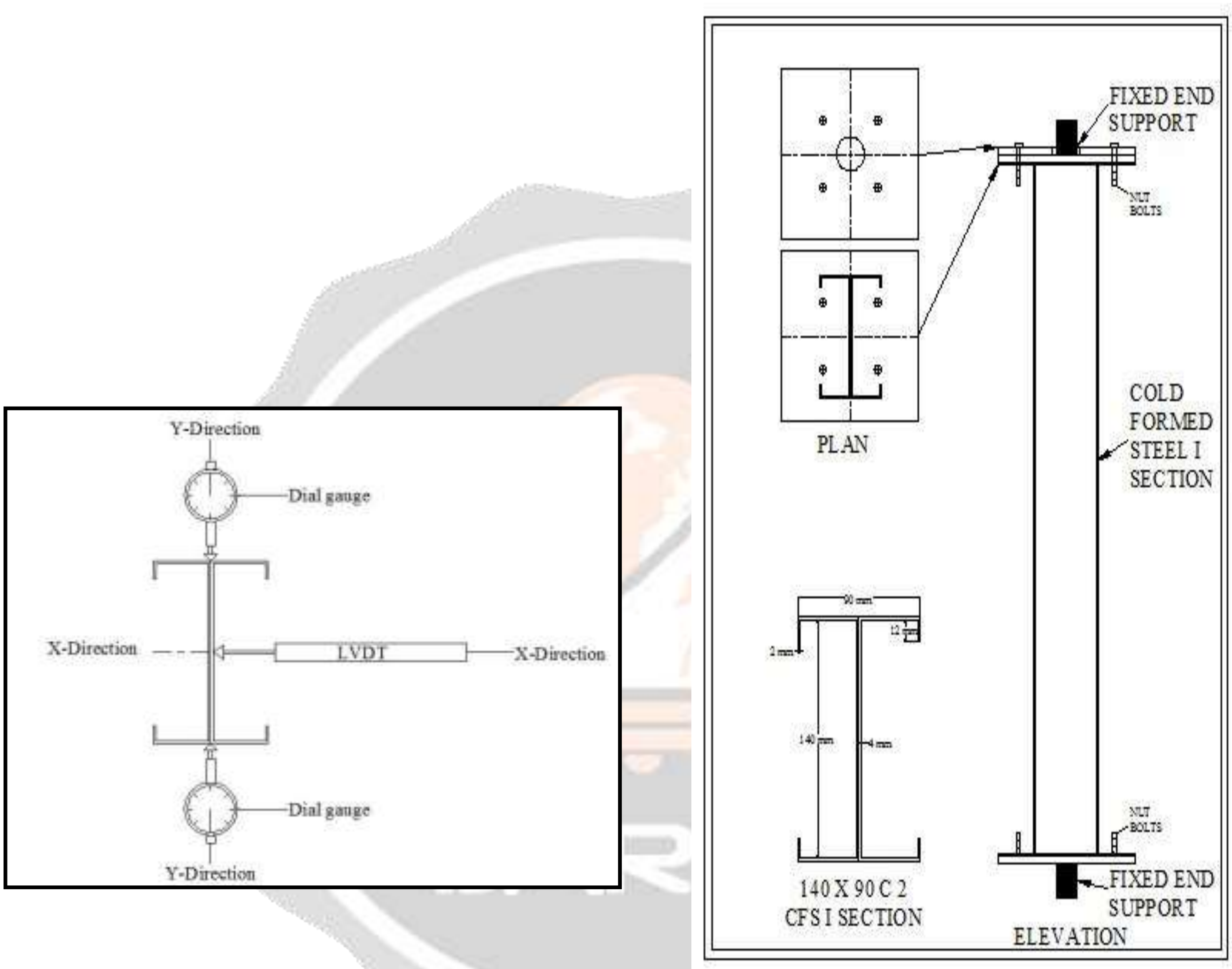


Fig. 2.1 a) Plan b) Elevation

2.1 MATERIAL USED:

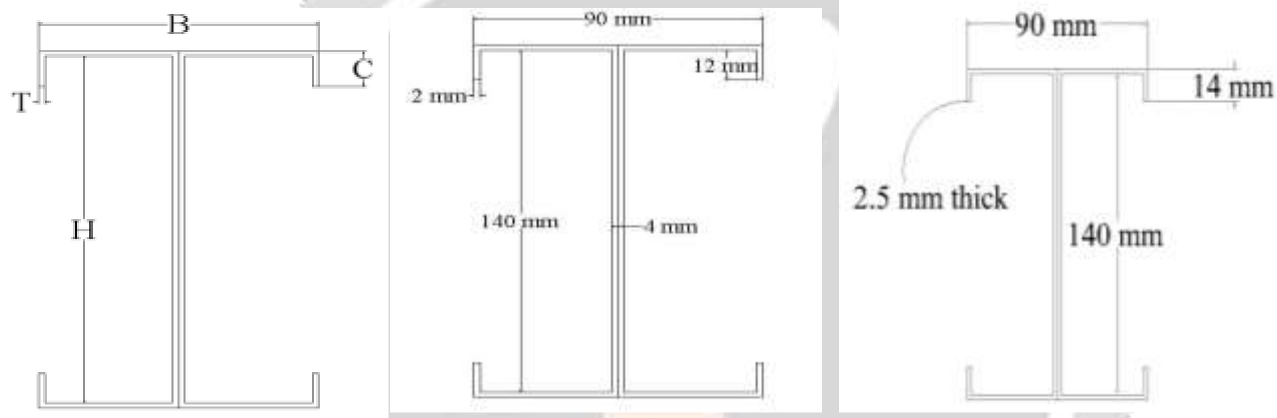
Material used for experimentation is given below,

2.2.1 Cold formed steel sections

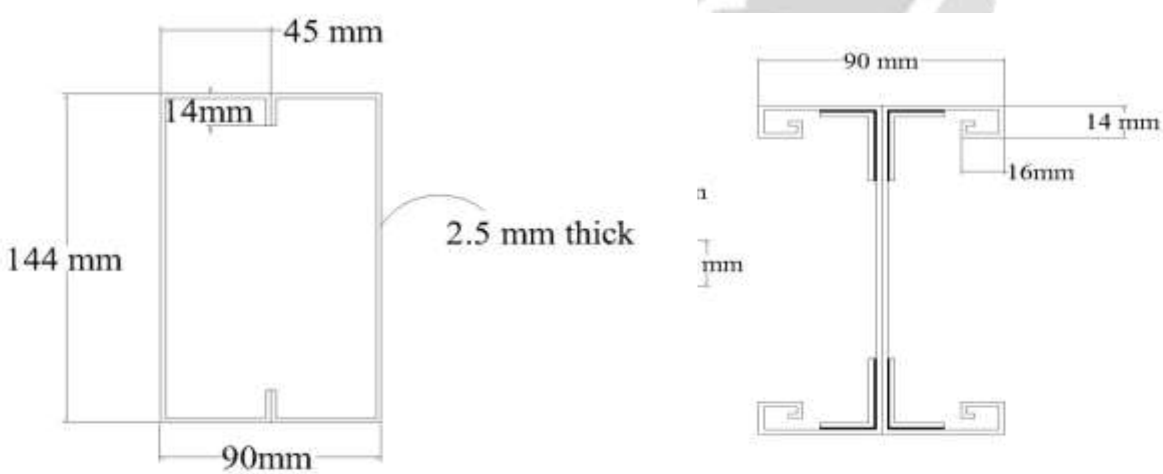
a. 140C2, b.140CA-2,

Table 2.1: Cross sectional properties of sections used for testing

Sections to be tested	**Length (mm)**	**Area (mm^2)**	**H (mm)**	**B (mm)**	**C (mm)**	**T (mm) (W-web, F-flange)**	**Ixx (mm^4)**	**Iyy (mm^4)**
140C-2	700	1016	140	90	12	W-4, F-2	3.12×10^6	2.61×10^6
140CA-2	700	1528	140	90	12	W-4, F-2	4.93×10^6	4.37×10^5



a. Section details b. 140C-2 b. 140c-2.5



b. 140H-2.5 **Fig. 1.2** Section Details b. 140CA-2

3. ANALYTICAL CALCULATIONS:

Load carrying capacity of cold formed steel section with working stress method is calculated below,

3.2.1 Calculations for cold formed steel column Section:

By using Effective width method-

Area of the section =**1016 mm^2**

Moment of inertia- Ixx = 3.1239 x 10^6 mm^4, Iyy = 2.61 x 10^6 mm^4

Radius of gyration,
$$rxx = \sqrt{\frac{3.1239\ x\ 10^{\wedge}6}{1016}} = 55.45\ mm$$

$$ryy = \sqrt{\frac{2.61x\ 10^{\wedge}6}{1016}} = 50.68\ mm$$

$$\frac{w}{t} = \frac{90}{2} = 45$$

$$C_c = \sqrt{\frac{2\ \pi^2 \times 2\ \times 10^5}{250}} = 128.3$$

Basic design stress, $f\ = 0.6 f_y = 0.6\ \times 250 = 150\ Mpa$

$$\frac{454}{\sqrt{f}} = \frac{454}{\sqrt{150}} = 37.07\ < 45$$

For flange of I section-

$$\therefore \frac{b}{t}\ = \frac{671}{\sqrt{150}}\left[1 - \frac{147}{45\sqrt{150}}\right] = 40.17$$

Effective width, b = 40.17 x 2 = 80.35 mm

For web of I section-

$$\frac{w}{t} = \frac{140}{4} = 35 < 37.07$$

Hence, b = w

$$A_{eff}\ = 945..4\ mm^2$$

$$Q = \frac{A_{eff}}{A} = \frac{945.4}{1016} = 0.93$$

$$\frac{C_c}{\sqrt{Q}} = \frac{128.3}{\sqrt{0.93}} = 130.27$$

$$\frac{KL}{r} = \frac{455}{50.68} = 8.97\ < 130.27$$

$$\therefore f_a = \frac{12}{23} \times 0.93\ \times 250 - \frac{3(0.93\ \times 250)^2}{23\ \pi^2\ \times 2\ \times 10^5} \times 8.97^2 = 122\ MPa$$

The buckling load carrying capacity in compression = 1016 x 122.

= **<u>123.95 kN</u>**

4. DEVELOPMENT OF FINITE ELEMENT MODEL IN ABAQUS SOFTWARE:

To study the cold formed steel column under compressive loading S4R shell element is selected. It is selected considering efficiency, memory and processing time. Mechanical properties are inserted as input for the software. Those are Yield strength E = 2 x 10^5, Poisson's ratio was assumed to be 0. . The boundary conditions used for Finite element analysis are both ends fixed i.e. these ends are restrained about all three types of deflection and rotations. For loading and boundary condition application MPC(Multi point constraint) is used.

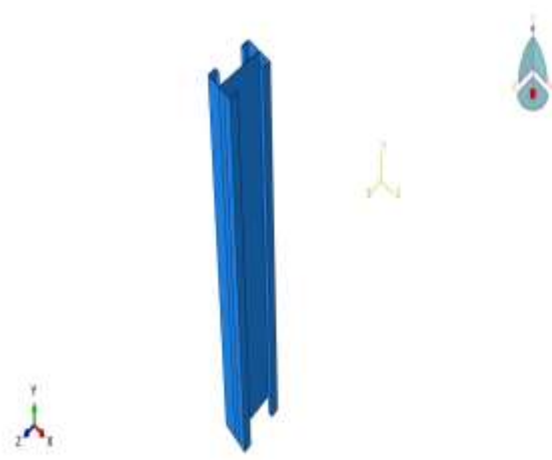


Fig. 4.1: Element model in ABAQUS

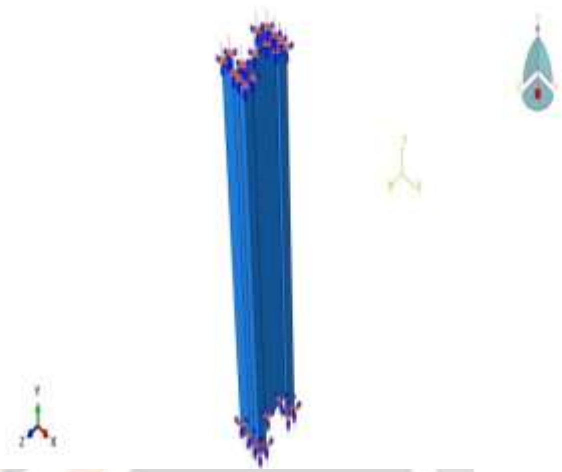


Fig.4.2: Loading and boundary condition

Fig.4.3: Meshing of FE model

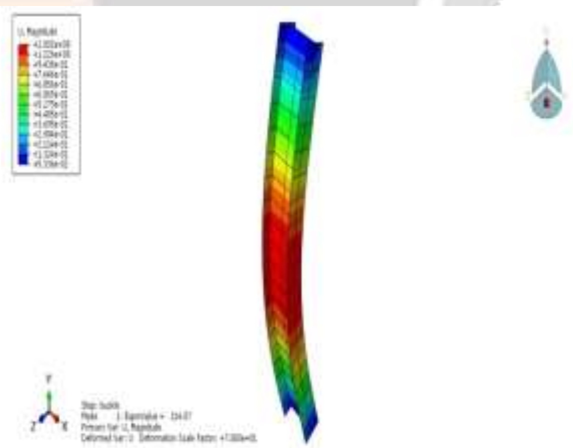


Fig.4.4: Deformed shape of FE model

5. RESULTS AND DISCUSSION

Tables and graph below show obtained results from tests on hot rolled and light gauge steel sections. Significant variation is observed in HRS and CFS sections.

5.1 Results obtained for Cold formed Steel section 140C2:-

5.1.1 Experimental results

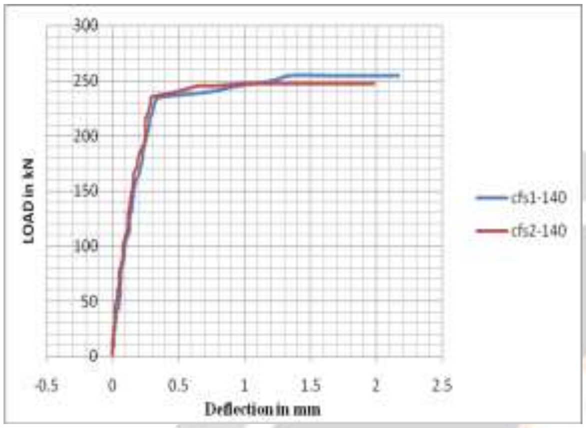


Fig.5.1: Load vs. Axial. Deflection graph 140C2

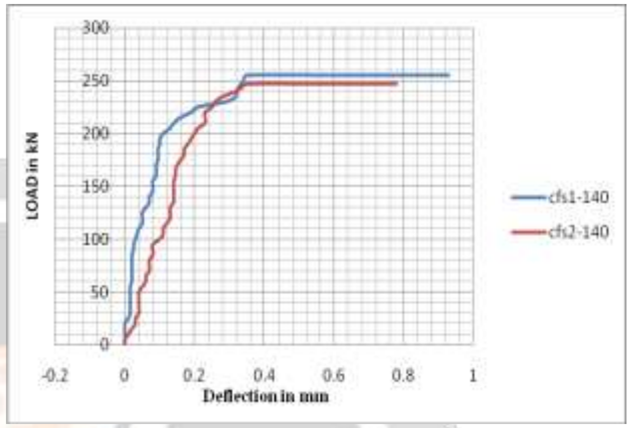


Fig.5.2: Load vs. Lateral. Deflection graph 140C2

Closure:-

The chart shows distinct elastic, elasto-plastic zones with some strain hardening phase and then constant deformation, fig shows linear variation from 0 kN to 225 kN for axial deflection and 0 to 245 kN for lateral deflection till it reaches to deflection of 0.3 mm then it changes its slope. Now, rate of change of deflection is more than rate of change of load from 225 kN to 255 kN. This shows strain hardening giving the ultimate load of 255 kN from 1.38 mm to 2.1 mm deflection.

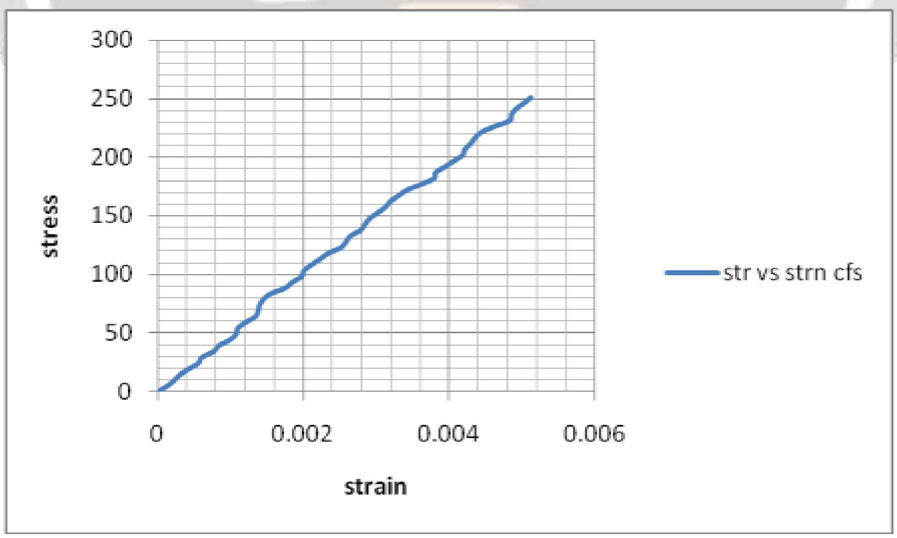


Fig.5.3: Stressvs. strain graph for Cold formed steel section (140C2)

Closure:-

Stress vs. Strain graph shows linear proportionality up to 250 N/mm2 stress, section remains in elastic state up to the failure. The maximum stress value obtained is 250 N/mm2 for strain value 0.00512

5.1.2 Finite element method results:-

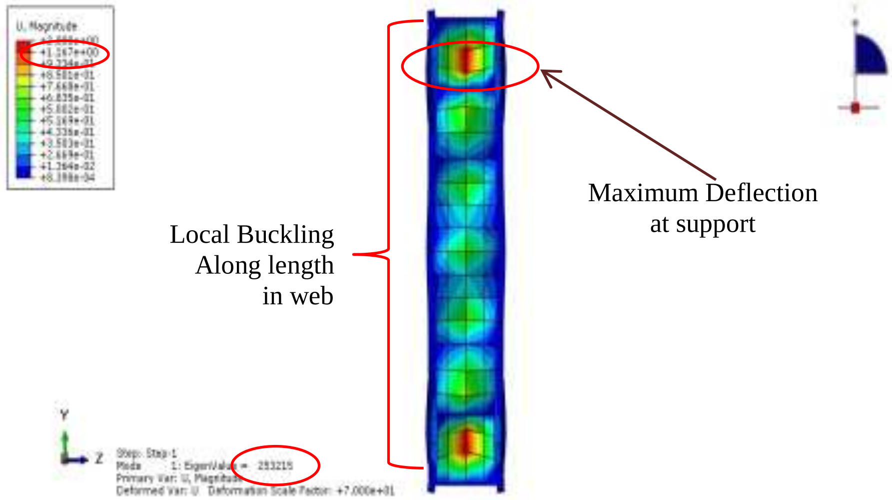


Fig. 5.4: Deflection for Cold formed steel section in ABAQUS (140C2)

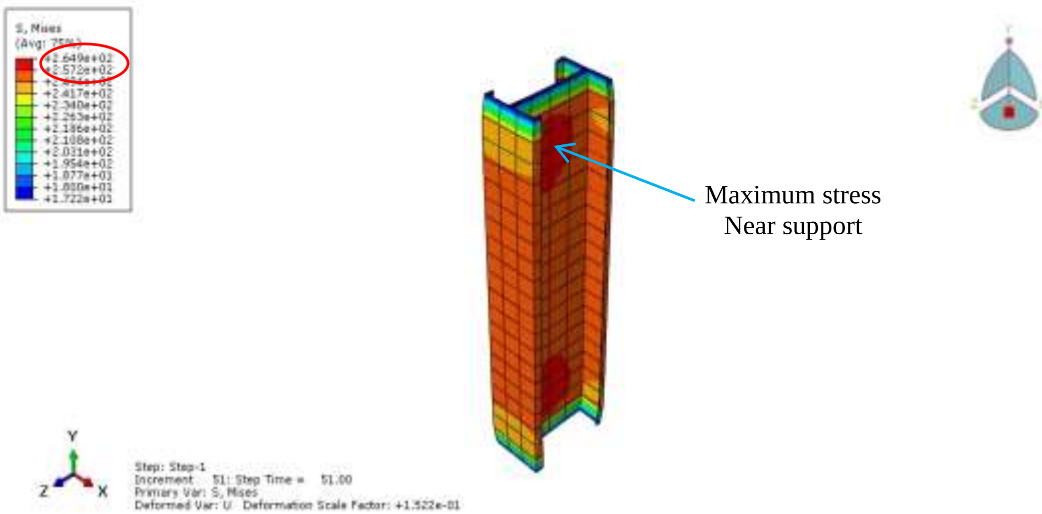


Fig.5.5 : Stress distribution for Cold formed steel section in ABAQUS (140C2)

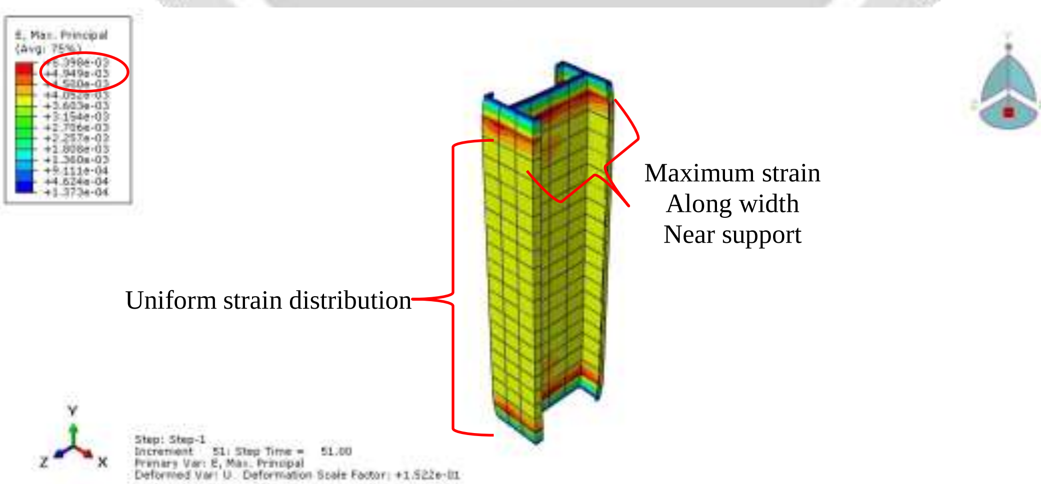


Fig.5.6: Strain distribution for Cold formed steel section in ABAQUS (140C2)

Closure:-

In fig 5.4 it is observed that failure of cold formed steel section is irregular, it shows convex and concave failure pattern and it fails near the support. The deflection obtained from ABAQUS is 2.00 mm with ultimate buckling load 253.21 kN. From fig5.5 it is clearly seen that stress distribution of cold formed steel section is not uniform over the length of the column, it is concentrated near the support in the web. Also it is observed that stress is concentrated in the web only, this means flange has less contributed for load carrying. Similarly fig5.6 shows strain is uniformly distributed along the width of the section near the support, it shows uniform distribution of the strain within the length of the column.

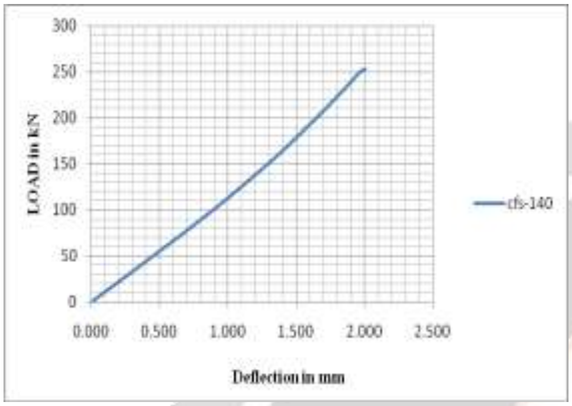


Fig.5.7: Load vs. Axial defl. in ABAQUS (140C2)

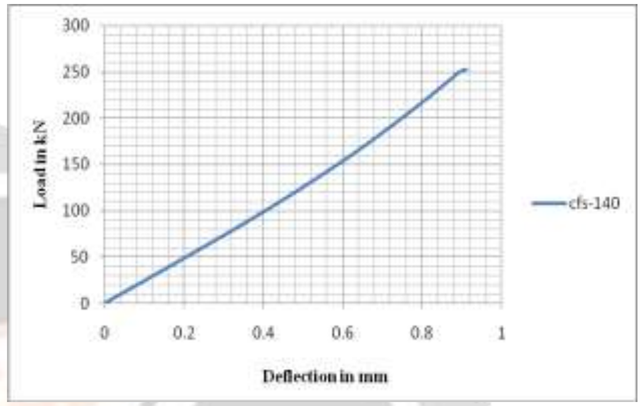


Fig.5.8: Load vs. Lateral defl. in ABAQUS (140C2)

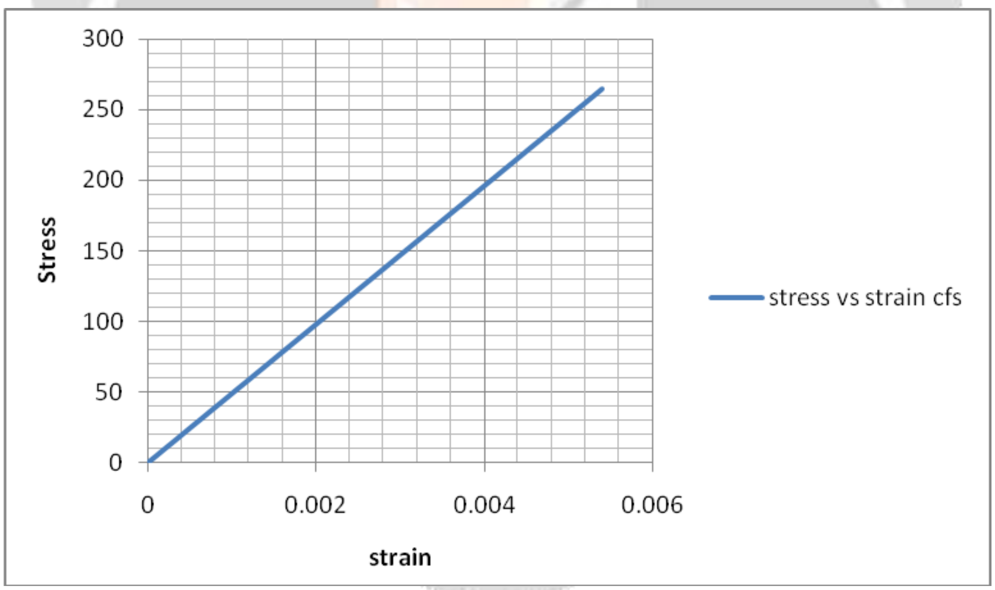


Fig.5.9: Stress vs. Strain graph for Cold formed steel section in ABAQUS (140C2)

Closure:-

The graph shows linear variation in load and deflection, it is observed that section remains in elastic state up to the failure load occurs, with final axial deflection as 2.009 mm and lateral deflection 0.900 mm. In stress vs. strain graph maximum stress observed is 264.878 N/mm2 and strain value is 0.005395

5.2 Results obtained for Cold formed Steel section 140C2:-

5.2.1 Experimental results:-

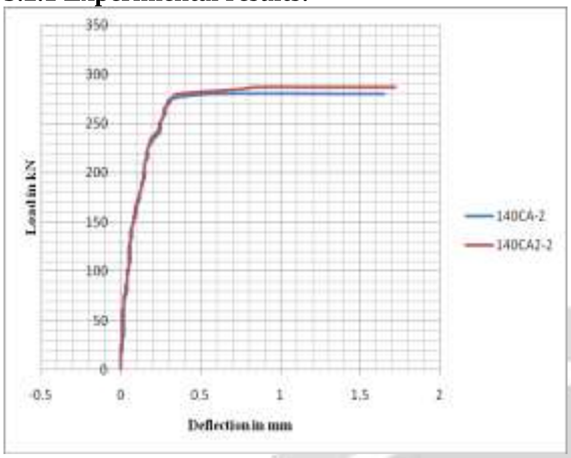


Fig.5.10: Load vs. Axial. Deflection graph(140CA2)

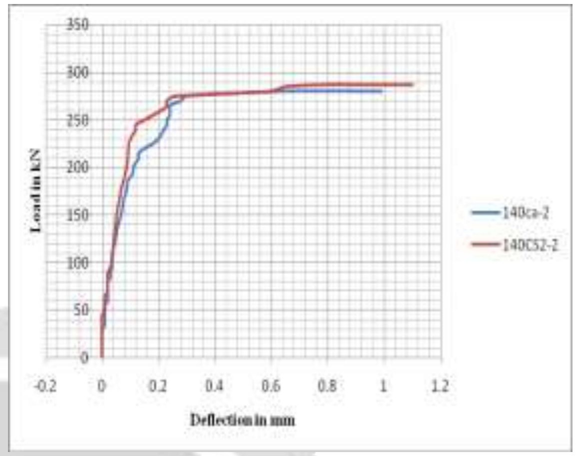


Fig.5.11: Load vs.Lateral Deflection graph (140CA2)

Closure:-

The chart shows distinct elastic, elasto-plastic zones with some strain hardening phase and then constant deformation, fig shows linear variation from 0 kN to 275 kN for axial deflection and 0 to 270 kN for lateral deflection till it reaches to lateral deflection of 0.26 mm then it changes its slope. Now, rate of change of deflection is more than rate of change of load from 275 kN to 287 kN.

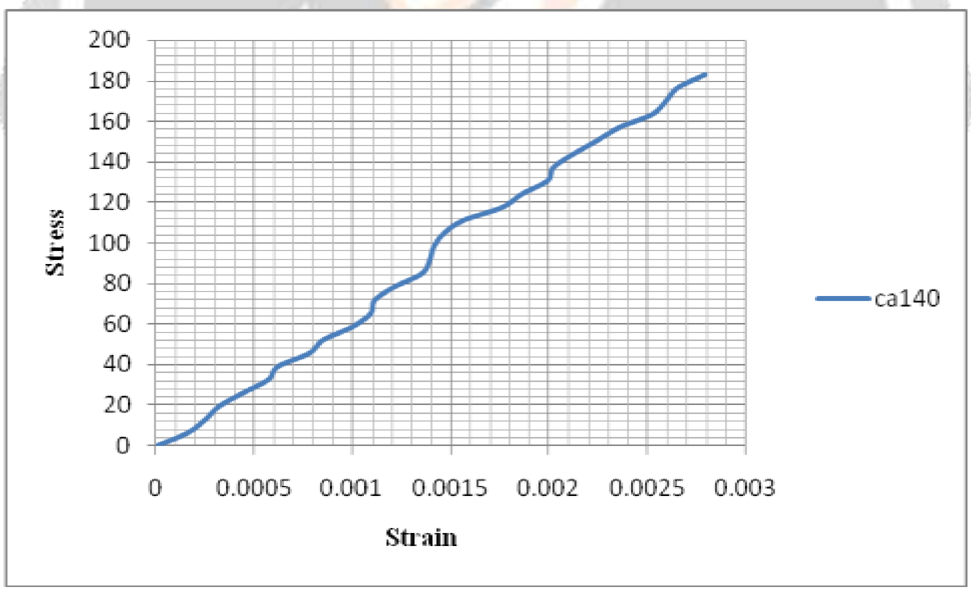
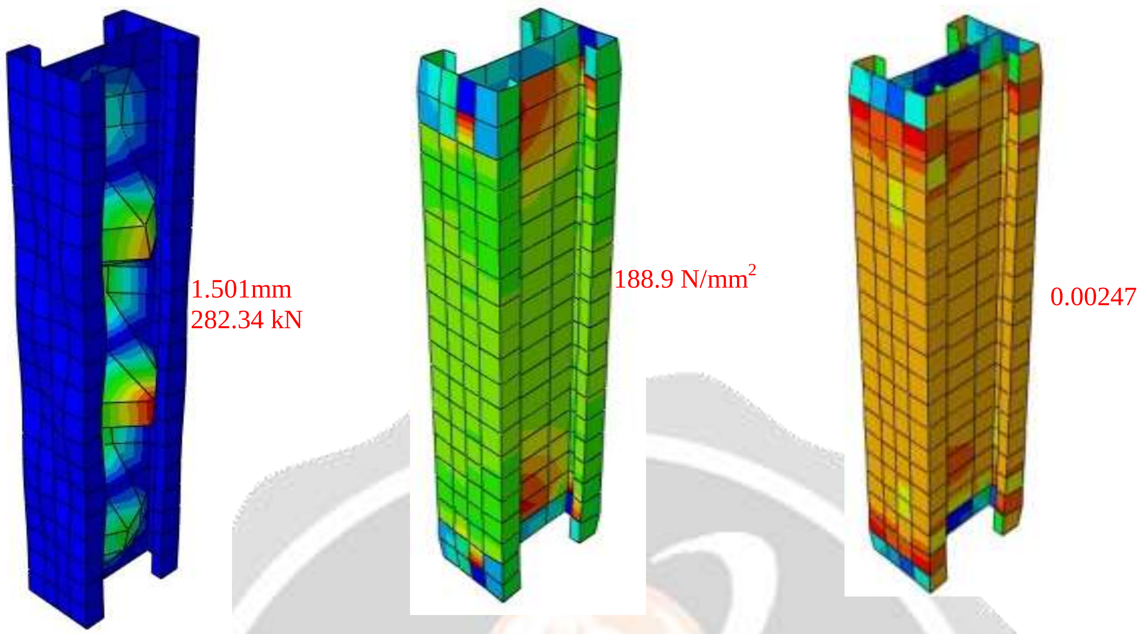


Fig.5.12: Stressvs. strain graph for Cold formed steel section (140CA2)

Closure:-

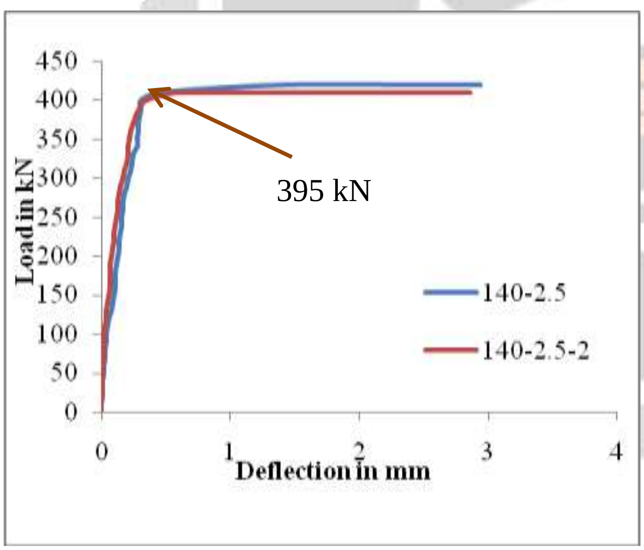
Stress vs. Strain graph shows linear proportionality up to 183.24 N/mm2 stress, section remains in elastic state up to the failure. The maximum stress value obtained is 183.24 N/mm2 for strain value 0.00279

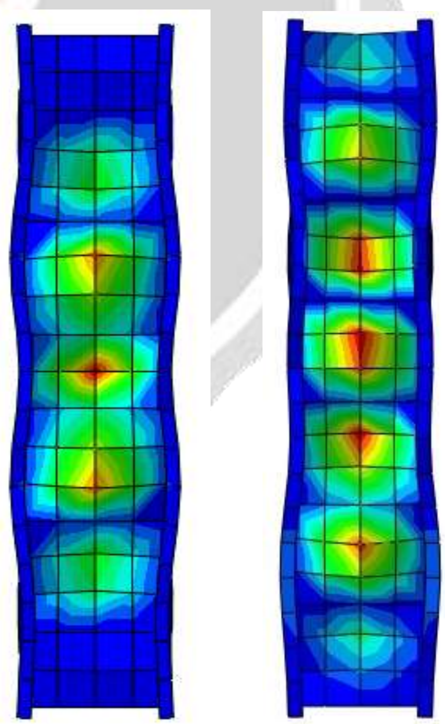


a) Deflection b) Stress Distribution c) Strain Distribution

Fig.5.13: Deflection, stress and strain for Cold formed steel section in ABAQUS (140CA2)

5.3 Elastic and Inelastic Behaviour of CFS section:





Elastic load – 395 kN
Inelastic load- 414.5 kN

Elastic load Deformation **Inelastic load Deformation**

Fig. 5.14: Elastic and Inelastic Behaviour of CFS section 140C2

Table 5.1: Elastic and Inelastic loads, stresses and strains

section	Elastic load (kN)	Inelastic load (kN)	Elastic stress (N/mm^2)	Inelastic stress (N/mm^2)	Elastic strain	Inelastic strain
140C2	225	251	221.45	250.98	0.00444	0.00512
140CA2	270	283	176.70	183.24	0.00265	0.00279

5.4 Comparison of Cold formed and Hot rolled steel section:

Comparison of results obtained for cold formed steel sections and hot rolled sections by experimental analysis are presented in the table below.

5.8 Results obtained by experimentation and finite element software:

Table5.2 Experimental and finite element method results

Sections		**140C2**	**140CA2**
LOAD (kN)	Experiment	251	283.5
	ABAQUS	253.21	282.34
AXIAL DEFLECTION (mm)	Experiment	2.075	1.685
	ABAQUS	2.009	1.501
LATERAL DEFLECTION (mm)	Experiment	0.855	1.045
	ABAQUS	0.909	1.059
STRESS (N/mm^2)	Experiment	250.9843	183.2461
	ABAQUS	264.878	188.9
STRAIN	Experiment	0.00512	0.00279
	ABAQUS	0.005395	0.002475

5.8 Comparison of Experimental and ABAQUS results of buckling capacity:

Table 5.3: Comparison of Experimental and ABAQUS results of buckling capacity

Sections Tested	Buckling capacity (kN)		% Error
	Experiment	ABAQUS	
140C-2	251	253.21	0.88
140CA-2	283.5	282.34	0.41
Average % error			1.15

6. CONCLUSION

The cold formed steel section shows distinct variation in stress distribution. It is clearly seen that stress distribution of cold formed steel section is not uniform over the length of the column; it is concentrated near the support in the web. Also it is observed that stress is concentrated in the web only, this means flange has less contributed for load carrying. Similarly strain is uniformly distributed along the width of the section near the support; it shows uniform distribution of the strain within the length of the column.

7. REFERENCES

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