COMPARATIVE STUDY OF BEHAVIOUR OF COLD-FORMED STEELAND HOT ROLLED STEEL SECTION UNDER COMPRESSIVE LOADING

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Abstract

Cold-formed steel is used in large number of products. For example in metal building construction, for wall coverings, floor decking etc. Cold-formed steel is a basic component in construction of lightweight prefabricated structures like stud frame panels, trusses and portal frames.The Cold formed steel term itself make it different from hot rolled steel due to difference in manufacturing methods. Typically columns, beams and angles etc. are different globally. At room temperature cold formed steel members are formed by bending flat sheets. Cold formed steel sections mainly created using two methods those are break press through and rolling. Where hot rolled steel members are precasted. Therefore cold formed steel sections can be easily available at any place where hot rolled sections are not available. The cold formed steel components can be used for larger and complex structures. The Comparison of cold formed steel section and Hot rolled steel section of equal cross sectional area is done in this research paper. Sections were experimentally tested under axial compression in universal testing machine. Simultaneously, ultimate compressive strength of cold formed members and hot rolled members has been investigated. Also, different properties of the sections such as stresses induced in the sections, strain in the section, axial deflection, and lateral deflection are obtained experimentally. For measuring strain experimentally strain gage foils were used. The validation of results is done by preparing finite element model in ABAQUS software. From experimental work it is observed that cold formed steel sections has more load carrying capacity as compared to hot rolled steel section.

Keywords: *Ultimate compressive strength, buckling, cold formed steel, deflection, stress, strain, ABAQUS*

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1. INTRODUCTION

The use of cold formed steel as a structural member is started recently in the pre-engineered building design method. In structural industry products such as wall cladding, purlins are created using light gauge steel. The acceptance of cold formed steel as a structural material is limited because there is no adequate design method and limited information on use of material.

Most important difficulty in cold formed steel design is prevention of buckling of member. Due to its low thickness

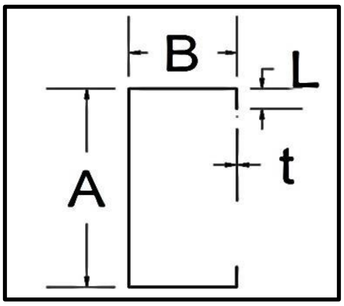

Fig -1: Details of Cold formed steel section

to width ratio, member buckles before the yield stresses occur during the compression of short column. Mainly it fails in elastic buckling mode. It is then classified as overall, distortional and local buckling. Further it is classified as flexural, torsional and flexural-torsional buckling. It is expected that member buckles at lower stress value than yield stress value. Therefore buckling behavior is most important in design of cold formed steel members, which is opposite form of behavior of hot rolled steel members.

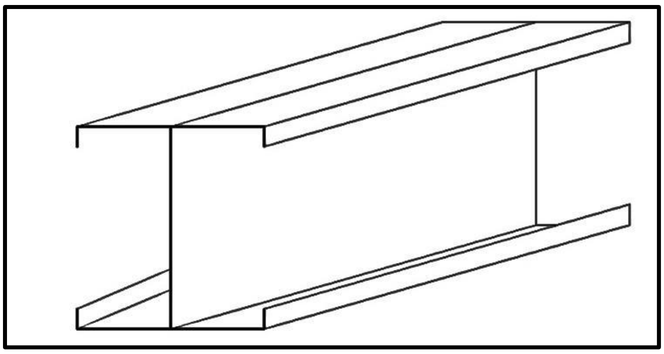

Fig -2: Built up I section of Cold formed steel

2. EXPERIMENTAL WORK AND CALCULATION

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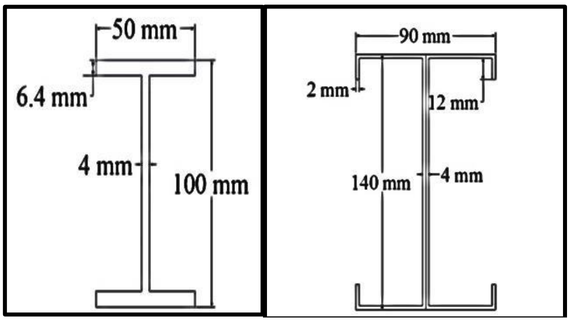
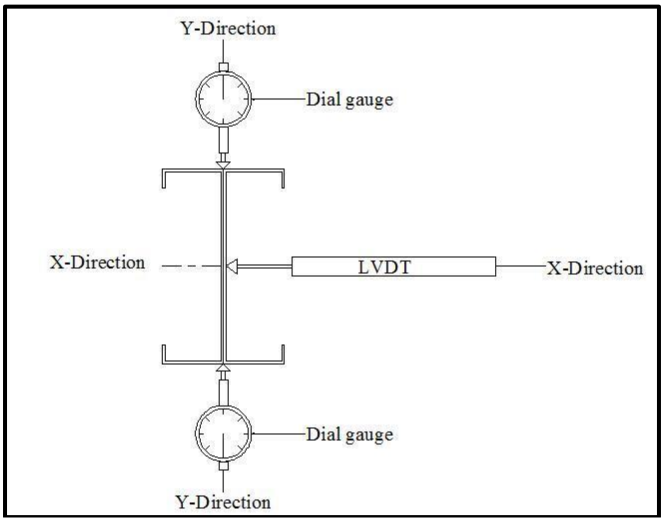
2.1 Test Procedure and Material Used

Forexperimental work sections of equal cross sectional area were selected as shown below. To find out ultimate compressive strength, cold formed steel light gauge section of 2 mm thickness with both ends fixed boundary condition have been selected. Considering this, the test set up has been done. Column of 700 mm overall length is tested in universal testing machine. Dial gauges and LVDT were attached to measure deflection in each direction. Figure 2(c) below shows schematic diagram of test set up. To get accurate strain intensity, strain gauges foils were mounted on column web at 0.5 times of length i.e. at 350 mm from fixed end. Two sections of each were tested in lab, average results are considered for research.



a) ISLB-100 b) 140C-2(Cold Formed steel section)



c) Test set up

Fig.3 Sections tested and test set up

2.2 Analytical Calculation

2.2.1 Calculations for Hot Rolled Steel Column Section:

a) Using limit state method- (IS800:2007)
Data required:-
Section - **ISLB100,** Area of the section =1021 mm^2,$\varepsilon = 1$,Moment of inertia-Ixx = 1.68 x 10^6 mm^4,r_{min} = 11.2 mmIyy = 1.27 x 10^{6}mm^4,f_y = 250 MPa,length = 700 mm,l_{eff} = 0.65 x 700 = 455 mm, Boundary Condition - Fixed – Fixed

Calculation: -Slenderness ratio is,$\frac{kl}{r} = \frac{455}{11.2} = 40.62$

$\frac{b}{2t_f} = \frac{50}{2\ x\ 6.4} = 3.91 < 9.4\ \varepsilon$Therefore flange is plastic;$\frac{h_1}{t_w} = \frac{100}{4} = 24.3 < 42\ \varepsilon$ Therefore web is semi compact,Section is plastic -semi compact.

Buckling class of cross section- $\frac{h}{b_f} = \frac{100}{50} = 2 > 1.2$, $t_{f=}$ 6.4 mm < 40 mm, Therefore Z-axis in a class and Y-axis in b class,For,Fy = 250 MPa and$\frac{kl}{r} = 40.62$, Class a - fcd = 213 and class b - fcd = 206

Buckling Capacity of section= 206 x 1021=**<u>210.326 kN</u>**

b) Using working stress method- (IS800:1987)
Solution: -Slenderness ratio, λ = 40.62, Fy = 250 N/mm^{2,}
Permissible stress = 139 N/mm^2 (from IS800:1987)
Buckling capacity = 1021 X 139 = **<u>141.91 kN</u>**

2.2.2 Calculations for Cold Formed Steel Column Section:

By using Effective width method- (IS801:1975)

Data required:-
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,$rxx = 55.45\ mm$, r$yy = 50.68\ mm$

Calculation: -$\frac{w}{t} = \frac{90}{2} = 45,\ C_c = \sqrt{\frac{2\,\pi^2 \times 2 \times 10^5}{250}} = 128.3,$ 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- $\frac{b}{t} = \frac{671}{\sqrt{150}}\left[1 - \frac{147}{45\sqrt{150}}\right] = 40.17,$ 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 = **123.95 kN**

For calculation of buckling capacity of cold formed steel section using Indian standards there is no limit state method is available as of now. Using effective width method, cold formed steel section shows lesser load carrying capacity, but it is obtained using effective width method. Thus it reserves some more strength which has been founded experimentally.

3. RESULTS AND DISCUSSION

3.1 Experimental Results

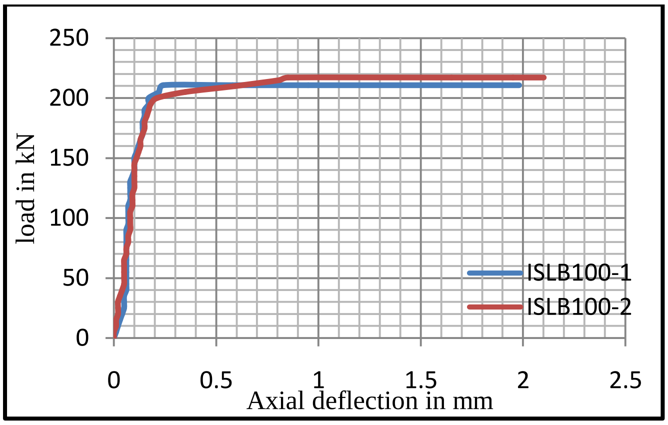


Chart -1: Load vs. Axial Deflection graph for ISLB-100

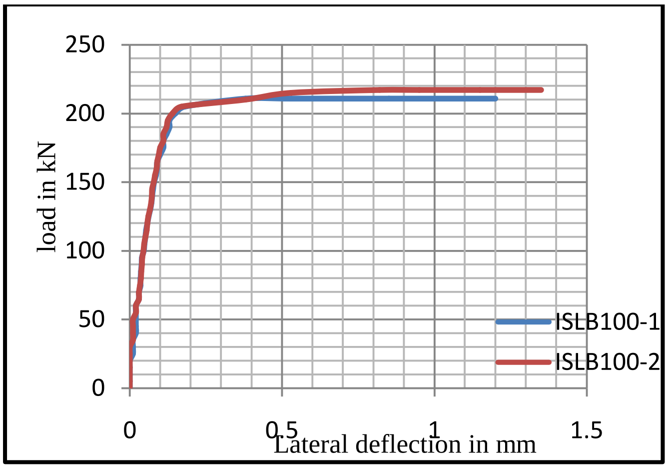


Chart -2: Load vs. Lateral Deflection graph for ISLB-100

The chart shows distinct elastic, elasto-plastic zones with some strain hardening phase and then constant deformation, chart 1 and 2 shows linear variation from 0 kN to 200 kN for axial deflection and lateral deflection till it reaches to deflection of 0.2 mm then it changes its slope. Now, rate of change of deflection is more than rate of change of load from 215 kN to 217 kN. This shows strain hardening giving the ultimate load of 217 kN from 0.85 mm to 2.1 mm deflection.

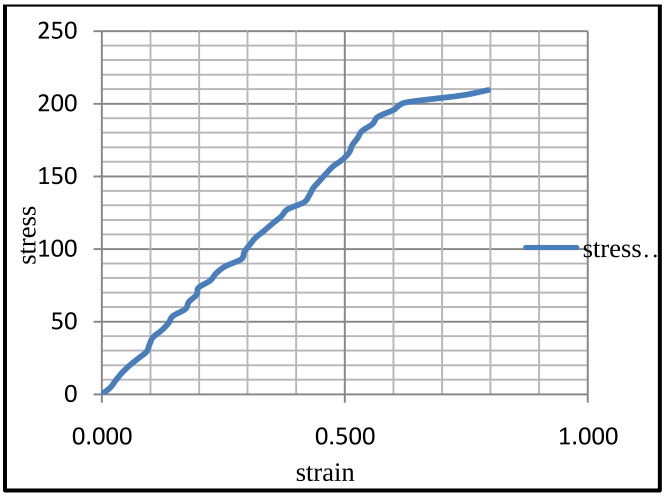


Chart -3: Stress vs. Strain graph for ISLB100

Similarly stress vs. Strain graph shows linear proportionality up to 200 N/mm2 stress, then slope of the line changes as section changes elastic state to elasto-plastic state. The maximum stress value obtained is 209.45 N/mm2 for strain value0.795

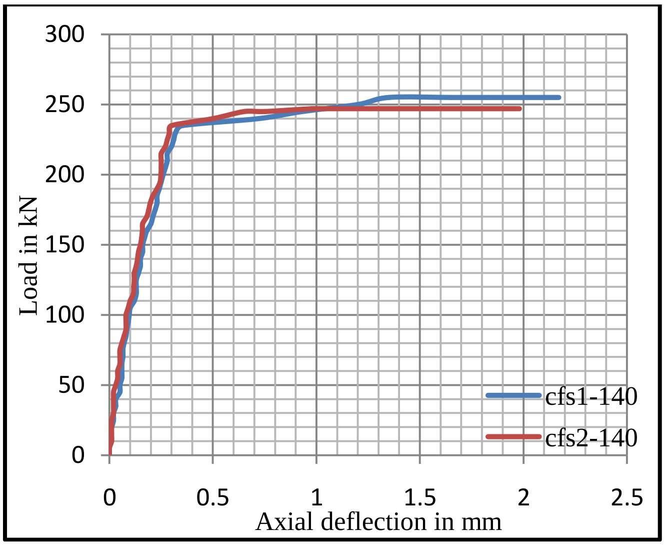


Chart -4: Load vs. Axial Deflection graph for 140C-2

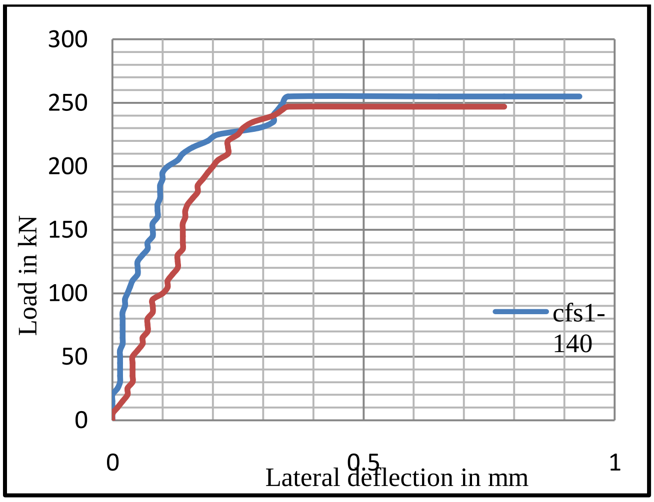


Chart -5: Load vs. Lateral Deflection graph for 140C-2

In chart4 it is seen that section shows linear behavior till it reaches 200 kN load with 0.29 mm axial deformation. Then it changes state from elastic state to plastic state at 200 kN to 255 kN. It shows more rate of change of deflection than rate of change of load. Finally section fails at 2.17 mm axial deflection with 255 kN ultimate load. In chart5 it is observed that from 0 kN load to 247 kN load, it shows complex behavior, increment in load as well as in deflection till it reaches to 247 kN then with constant load 255 kN it failed up to 0.93 mm lateral deflection.

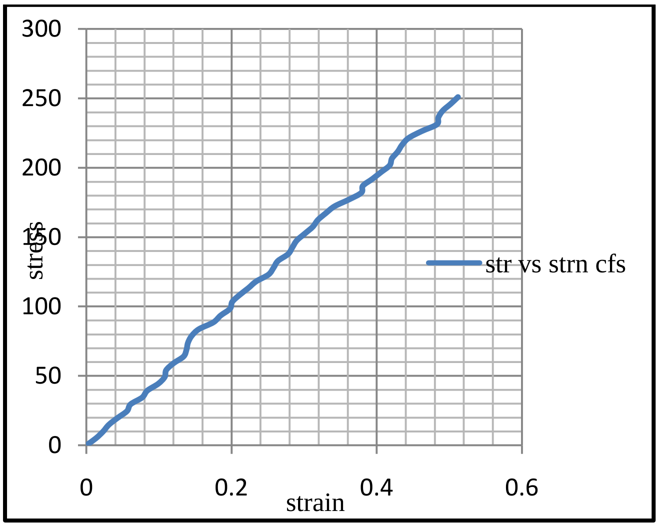


Chart -6: Stress vs. Strain graph for 140C-2

Stress vs. strain graph shows linear proportionality up to the ultimatestress. As it is cold formed section, it remains in elastic state up to the failure load. The maximum stress value obtained is 250.98 N/mm2 for strain value 0.512

3.2 Finite Element Method Results

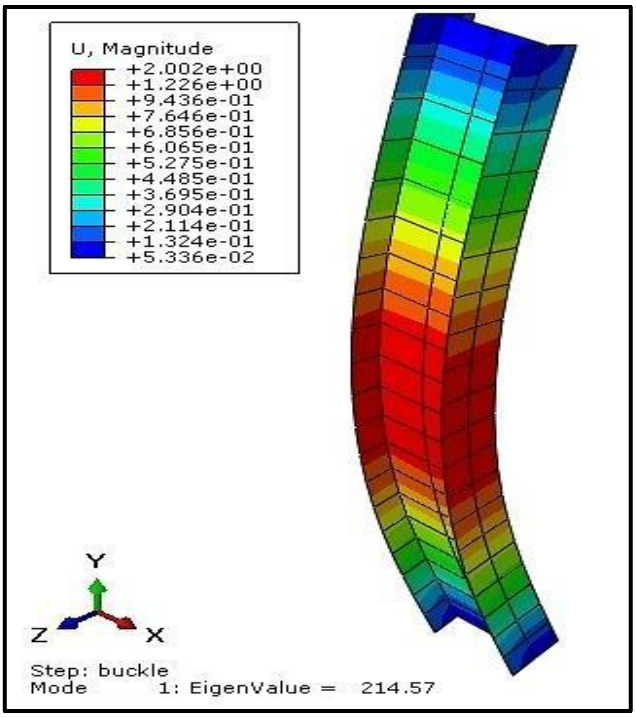


Fig. 4 Deflection of ISLB-100

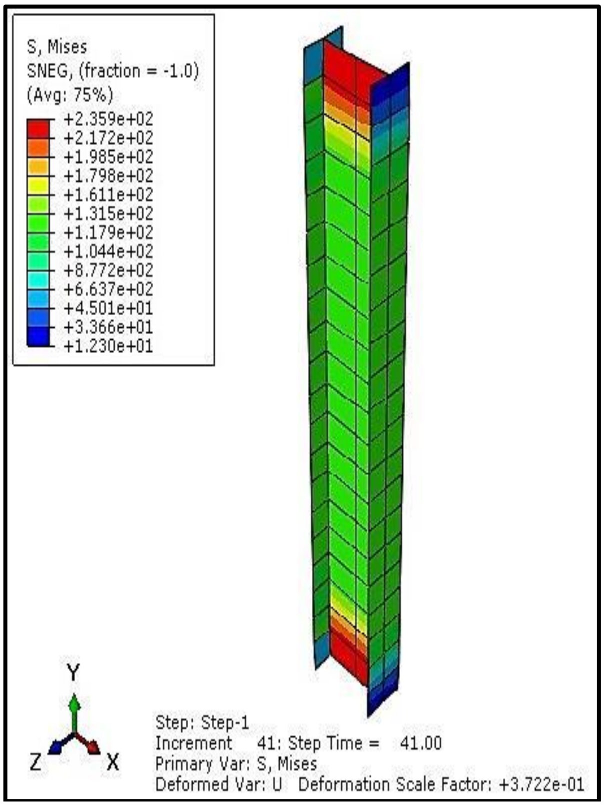


Fig. 5 Stress distribution of ISLB-100

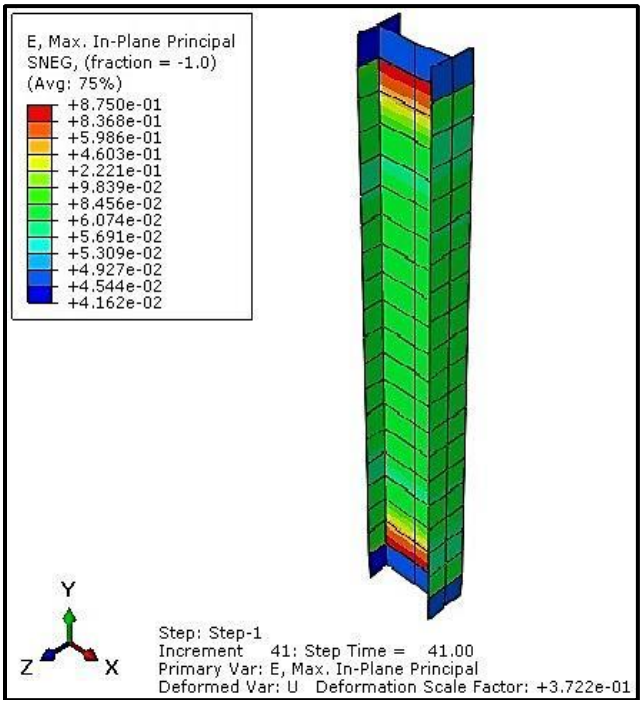


Fig. 6 Strain of distribution ISLB-100

The maximum deflection investigated from ABAQUS software is 2.002 mm with ultimate buckling load 214.57 kN. The maximum stress is observed near fix end support; within the effective length of the column, uniform stress distribution observed is shown in green colour, which causes bending of the section. Therefore the failure pattern observed of ISLB-100 is bending failure. The maximum stress value obtained from ABAQUS software is 235.90

N/mm^2, it shows much lesser value of stresses developed at the edges of the section. Similarly strain distribution is observed in ISLB-100 section, it gives maximum value of strain 0.875

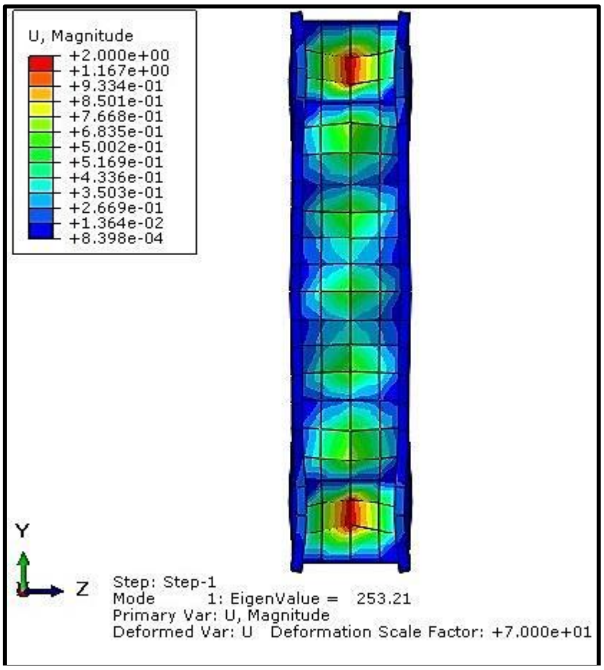


Fig. 7 Deflection of 140C-2

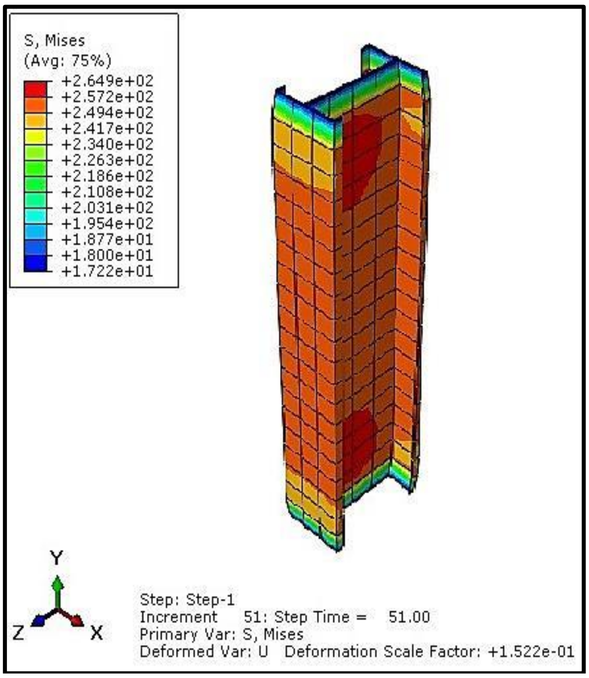


Fig. 8 Stress distribution of 140C-2

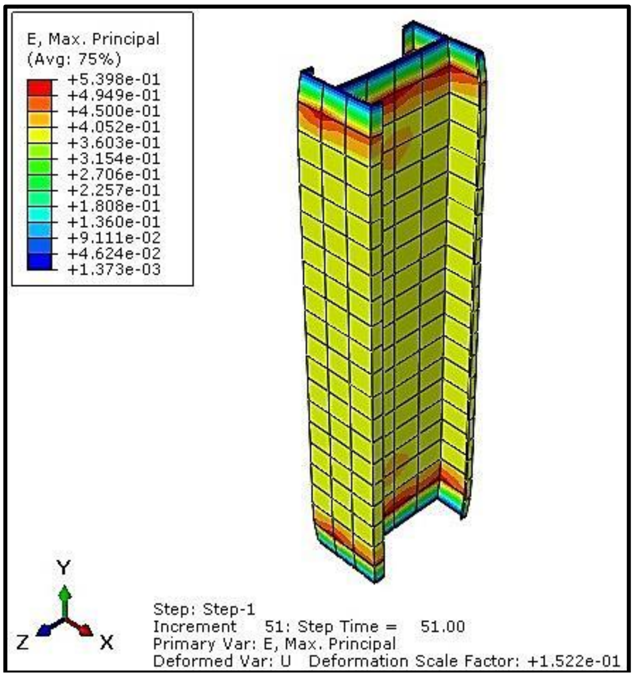


Fig. 9 Strain of distribution 140C-2

In figure 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 figure13 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 figure14 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.

Table -1: Results comparison from experimental and ABAQUS software

Sections Tested		Experiment	ABAQUS	% error
Axial deflection (mm)	ISLB100	2.04	2.00001	1.99
	140C-2	2.075	2.009	3.28
Lateral deflection (mm)	ISLB100	1.275	1.345	5.2
	140C-2	0.855	0.9099	6.03
Stress (N/mm^2)	ISLB100	209.45	235.9	11.21
	140C-2	250.98	264.878	5.24
strain	ISLB100	0.795	0.875	9.14
	140C-2	0.512	0.539	5

From table 1 and 2 the experimental values and ABAQUS software values are nearly equal with much less error so software gets validated.

Table -2: Load carrying capacity software validation

Sections Tested	Load carrying capacity (kN)		% Error
	Experiment	ABAQUS	
ISLB100	213.85	214.57	0.33
140C-2	251.00	253.21	0.88

Table -3: Load carrying capacity comparison of ISLB100 and 140C-2 from experimental results

Sections	**Area**	**Buckling capacity**	**Average buckling capacity**	**% increase in capacity**
HRS1	$1021mm^2$	217 kN	213.85kN	**17. 37 %**
HRS2	$1021mm^2$	210.7 kN		
CFS1	$1016mm^2$	255 kN	251 kN	
CFS2	$1016mm^2$	247 kN		

4. CONCLUSION

It can be interpreted that the cold formed steel sections shows 17.37 % more load carrying capacity as compared to hot rolled sections and it gives 33% lesser lateral deformation as compared to hot rolled section. It also shows little variation in axial deflection of both cold formed steel section and hot rolled steel section.

The stress distribution of hot rolled steel section is much uniform throughout the length, on the contrary cold formed steel section shows distinct variation in stress distribution. The finite element software ABAQUS gives results nearer to experimental results up to 0.6 % for load carrying capacity calculation.

While comparing failure pattern, hot rolled steel member shows bending failure and cold formed steel shows distortional local buckling failure

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BIOGRAPHIES

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