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Behaviour of Cold Formed Steel Starred Section Subjected to Axial and Eccentric Load Condition

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Abstract

Objectives: This paper presents the ultimate load carrying capacity and behaviour of Cold Formed Steel (CFS) starred section with different end conditions and the specimens are subjected to axial compression. **Methods:** Theoretical study is carried out by using Euler's load equation. Six plain sections of different sizes of 2mm thickness were tested as short columns. The analytical study is carried out using FEM software. The specimen used for testing have different dimensions, 60×60×2mm and 50×50×2mm with welded end condition, balled end condition and bolted end condition. The specimens are also tested experimentally by applying axial compression loading. **Findings:** The analysis is numerically carried out using FEM software and the results are compared. The experimental investigation of the cold-formed steel column is carried out by testing the column under loading frame with load applied manually and the test results are found match with the theoretical values. Compression tests were carried out on cold-formed steel starred angles under different end connections. As a result, welded end condition provides more strength than balled end condition where balled end condition provides more strength than the bolted end condition. **Applications:** This results can be further used with different section size or with different end condition under different loading conditions to find the ultimate strength of cold formed steel.

Keywords: Axial Deformation, Axial Load, Cold–formed Steel, Eccentric Load, Starred Section

1. Introduction

There are basically two types of structural steels in building construction: hot-rolled steel shapes and cold-formed steel shapes. The hot rolled steel shapes are formed at elevated temperatures while the cold-formed steel shapes are formed at room temperature. Cold-formed steel structural members are shapes commonly manufactured from steel plate, sheet metal or strip material. The manufacturing process involves forming the material by either press-braking or cold roll forming to achieve the desired shape. When steel is formed by press-braking or cold rolled forming, there is a change in the mechanical properties of the material by virtue of the cold working of the metal. When a steel section is cold-formed from flat sheet or strip the yield strength, and to a lesser extent the ultimate strength, are increased as a result of this cold working, particularly in the bends of the section. The term cold-formed distinguishes this category of material from hot rolled steel sections, typically universal beams, columns, angles etc., by the manufacturing methods used. Cold-formed sections are produced by bending and shaping flat sheet steel at ambient temperatures. There is great flexibility in the design using cold-formed steel. A number of innovative engineers and architects have been very successful in producing systems that are both innovative and practical.

Cold-formed steel in either flat plates or coils is the primary raw material for a wide range of industries. We are surrounded by applications, in washing machines, filing cabinets, storage systems, heating and ventilation and cars. About 40% of sheet steel production is used in the construction industry, in cladding, light structural frames and components such as purlins and lintels. The steel sheets can be cold-formed into many different shapes and forms by a variety of manufacturing processes. The different fabrication

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and forming processes available allow great flexibility in the design of both standard and customized building components and systems. The use of cold-formed steel has played a major part in the development of Hi-tech architecture. The cold-formed sheet is also known as Light gauge steel because of its minimum thickness when compared to hot rolled section. The paper, summarize the studies on the behavior of cold-formed steel starred section subjected to axial and eccentric load condition.

2. Analytical Investigation

ANSYS Version 14.5 was used to stimulate the mode and to find the buckling mode and the strength of cold formed steel columns under compression loading. Using shell element the cold formed steel are modelled and also for bolts, the solid element is used. To get correct presentation of complex geometry, also the easy representation of the total solution and for capturing the local effect meshing option is used in the FEM software[1]. Meshing is done by giving the required size of mesh or it can also be done by giving number of the parts and then mesh is created. Meshing is done manually in the FEM software[2]. The cold formed starred sections are tested analytically by compression loading and the axial deformation of the starred section is studied. The properties of the light gauge section are shown in the Table 1 as follows:

Finite element analysis in structure is normally used to find the structural behaviour of the structure by con-

Table 1. Properties of the Light Gauge Section

Density	**7850 kg/mm^3**
Modulus of elasticity	2×10^5 N/mm^2
Poission's Ratio	0.3
Modulus of rigidity	76900 N/mm^2
Co-efficient of thermal expansion	0.000012

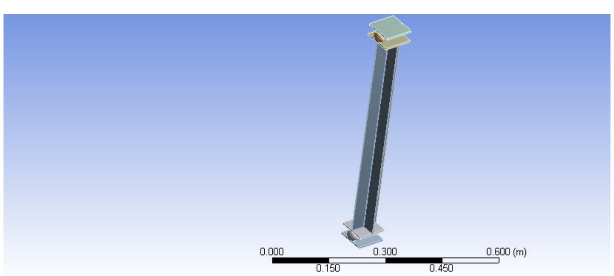

Figure 1. Geometry of ball end condition.

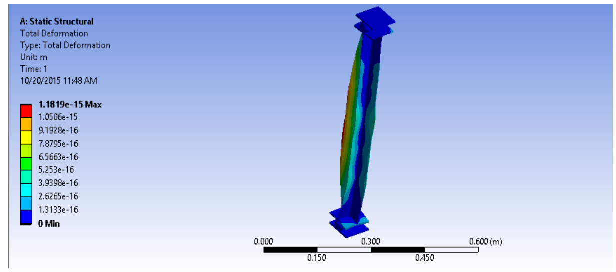

Figure 2. Deformation of ball end condition.

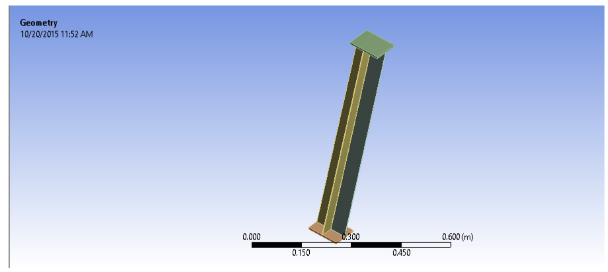

Figure 3. Geometry of bolt end condition.

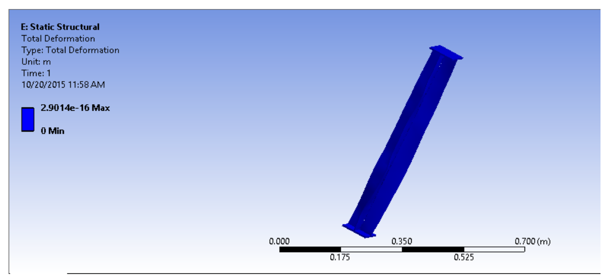

Figure 4. Deformation of bolt end condition.

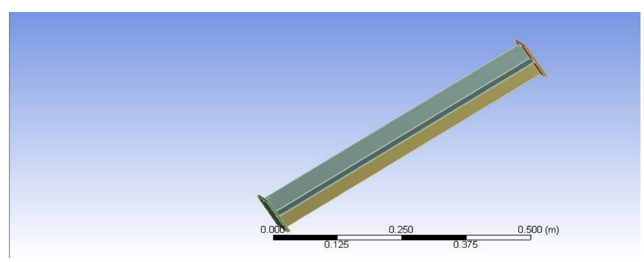

Figure 5. Geometry of weld end condition.

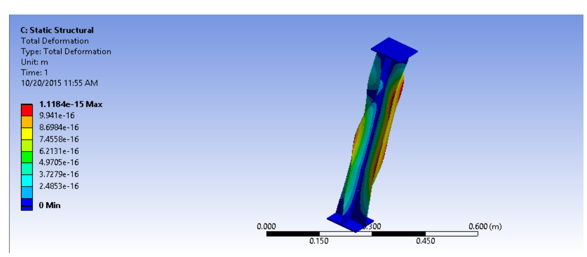

Figure 6. Deformation of weld end condition.

sidering the loading conditions applied on it[3]. Figure 1 and Figure 2 shows the modelling and Figure 3, Figure 4, Figure 5 and Figure 6 shows the total deformation of starred section that is analysed using the FEM software. The results from the analytical investigation is shown in the Table 2 as follows.

2.1 Analytical Results

The analytical results from FEM software are used to find the maximum deflection for each of the specimen and the maximum deflection are shown in Table 2.

Table 2. Maximum deflection by analytical study

DIMENSIONS OF SPECIMEN (mm)	TYPE OF END CONDITION	MAXIMUM DEFLECTION (mm)
60×60×2	Weld end condition	1.16
50×50×2	Weld end condition	1.11
60×60×2	Bolt end condition	1.717
50×50×2	Bolt end condition	1.601
60×60×2	Ball end condition	1.43
50×50×2	Ball end condition	1.39

3. Theoretical Investigation

This study is carried out to study the behaviour of cold formed light gauge steel using Euler's equation to find the buckling load for the column. This equation is used for finding the buckling load of the short column. Columns fail by buckling when their critical load is reached[4]. Theoretically buckling is caused by bifurcation in the solution to the equation of static equilibrium[5]. From the Euler's equation for fixed end and pinned end condition column, the critical load for each of the specimen under different end conditions can be found. Maximum deflection by theoretical study is shown in Table 3 as follows:

For fixed end condition, critical load

$$P = \frac{4\pi^2 EI}{l^2}$$

For Pinned end condition, critical load

$$P = \frac{\pi^2 EI}{l^2}$$

where, P- Critical Load,

E - Elastic Modulus,

Table 3. Maximum deflection by theoretical study

I - Moment of Inertia,

l - Length of the column.

DIMENSIONS OF SPECIMEN (mm)	TYPE OF END CONDITION	MAXIMUM DEFLECTION (mm)
60×60×2	Weld end condition	2.77
50×50×2	Weld end condition	2.6
60×60×2	Bolt end condition	2.9
50×50×2	Bolt end condition	2.88
60×60×2	Ball end condition	2.98
50×50×2	Ball end condition	2.75

4. Experimental Investigation

The experimental work was conducted on a compression testing machine. Strain gauges are connected to both the section of the specimen while testing. Deflectometers were placed at three positions 1/4th distance, mid span and at the support. Strain readings were taken in the mid span and 1/4th of the web under elongation[6]. The load and corresponding buckling of the short columns observed. Compression loading was gradually applied till the specimen become unstable[7]. The experiment results are shown in Table 4 as follows. Figure 7, Figure 8, Figure 9 shows the load versus strain graph for the specimens tested experimentally.

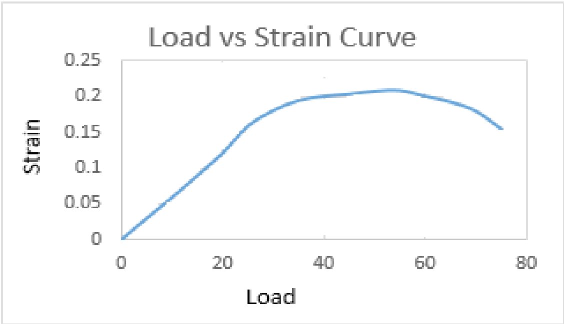

Figure 7. Load vs strain curve for 50×50×2mm under bolt end condition.

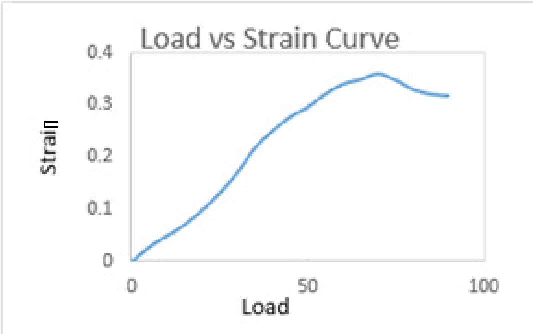

Figure 8. Load vs Strain curve for 50×50×2mm under ball end condition.

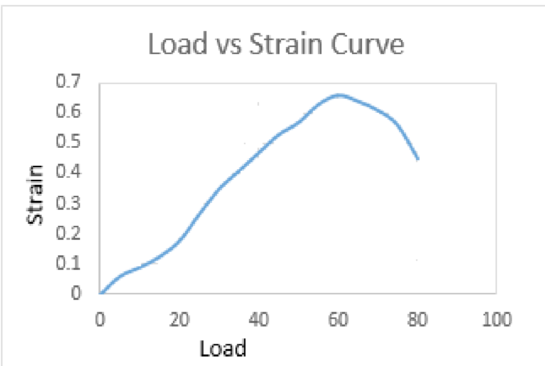

Figure 9. Load vs Strain curve for 50×50×2mm under weld end condition.

The size of the different starred section is 50×50×2mm and 60×60×2 mm under weld end condition and 50×50×2 mm and 60×60×2 mm under bolt end condition and 50×50×2mm and 60×60×2 mm under ball end condition are used for testing[8]. Here 50mm is the length of the angle section used and thickness of the section is 2mm.The specimens were experimented under fixed end condition and pinned end condition with compression loading[9]. Strain gauges are used for getting strain values by connecting it to the strain indicators. Strain gauges are fixed at both sections of the specimens and the strain values are

Table 4. Maximum deflection by experimental study

DIMENSIONS OF SPECIMEN (mm)	TYPE OF END CONDITION	MAXIMUM DEFLECTION (mm)
60×60×2	Weld end condition	2.04
50×50×2	Weld end condition	1.97
60×60×2	Bolt end condition	2.7
50×50×2	Bolt end condition	2.67
60×60×2	Ball end condition	2.32
50×50×2	Ball end condition	2.11

taken from strain indicator during the process of testing of the specimen[10].

The experimental setup and specimen under different end conditions are shown in Figure 10, Figure 11, Figure 12, Figure 13.

The comparison of theoretical, analytical and experimental study is shown in Figure 14. Welded end condition provides more strength than balled end condition where balled end condition provides more strength than the bolted end condition.

The comparison of theoretical, analytical and experimental study is shown in Table 5 as follows:

This table explains that the comparison of theoretical, analytical and experimental study where the welded end condition provides more strength than balled end condition where balled end condition provides more strength than the bolted end condition. Also results from experimental values is 40% lesser than that of theoretical values and 50% lesser than that of analytical values.

Table 5. Comparison of results from theoretical, analytical and experimental study

S.NO	SECTIONAL DIMENSION (mm)	CONDITION OF SUPPORT	ULTIMATE LOAD (KN)		
			THEORETICAL	ANALYTICAL	EXPERIMENTAL
1	60×60×2	Weld end condition	251.6	198	98.9
2	50×50×2	Weld end condition	235.8	185	94.2
3	60×60×2	Bolt end condition	234.7	183.5	94.2
4	50×50×2	Bolt end condition	215	179	88.7
5	60×60×2	Ball end condition	238.7	193.5	95.6
6	50×50×2	Ball end condition	233.7	188	92.2

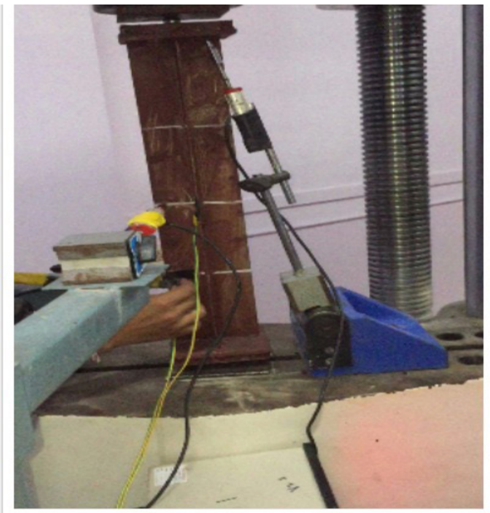

Figure 10. Ball end condition.

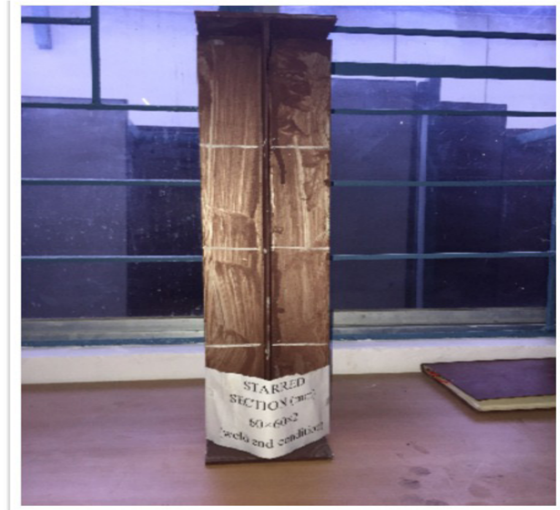

Figure 11. Weld end condition.

Figure 12. Bolt end condition.

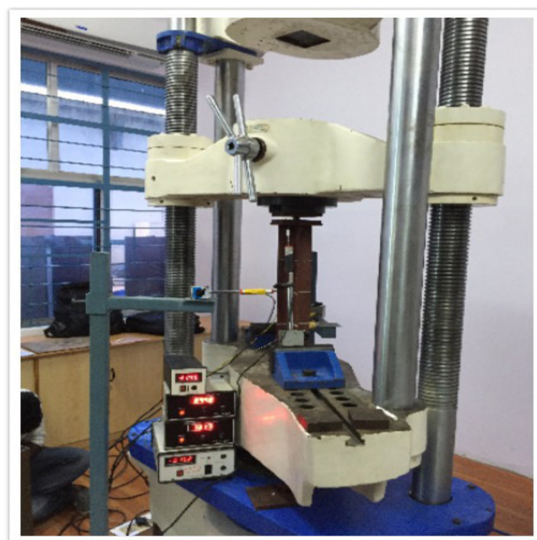

Figure 13. Experimental setup using deflectometers and strain gauges.

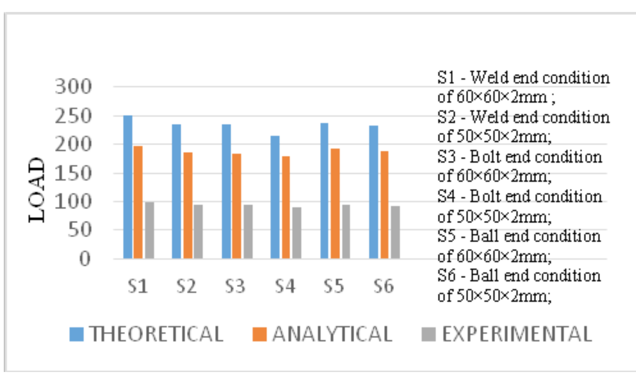

Figure 14. Comparison chart for theoretical, analytical and experimental study.

The variation of strain values due to increase in the load that is applied on the specimen of cold formed steel starred section 50×50×2mm with bolt end condition is shown in fig(2). The strain keeps on increasing with respect to the load till it reaches the maximum load of 55 KN.

The variation of strain values due to increase in the load that is applied on the specimen of cold formed steel starred section 50×50×2mm with ball end condition is shown in fig(3). The strain keeps on increasing with respect to the load till it reaches the maximum load of 70 KN.

The variation of strain values due to increase in the load that is applied on the specimen of cold formed steel starred section 50×50×2mm with weld end condition is shown in fig(4). The strain keeps on increasing with respect to the load till it reaches the maximum load of 60KN.

5. Result and Discussion

In this paper, the studies on axial deformation in cold formed steel starred section are presented. The starred section with welded, balled and bolted end condition are analysed using FEM software analytically and tested by applying load to the specimen in compression testing machine experimentally. And buckling load of the short column is found theoretically by making use of Euler's load equation. FEM software is used to test the specimens with compression loading by applying load. The specimens are created by meshing in the FEM software and then the loads are applied on both sides of the column. Experimentally the loads are applied from compression testing machine and the axial deformation along with strain and ultimate load carrying capacity is found. While applying load, the column displaces vertically. Strain values are obtained from the strain indicators. There are two strain gauges fixed on both the sections of the specimen used for testing and these strain indicators are connected with the strain gauges that gives the strain values while testing. And the failure of the column takes place by axial compression of the material. The column deforms near the mid-span and axial deformation is the mode of failure. Welded end condition provides more strength than balled end condition where balled end condition provides more strength than the bolted end condition.

6. Conclusion

For weld end condition the specimen having dimension of 60×60×2 shows ultimate load is 52.78KN which is higher when compared to specimen having dimension of 50×50×2 with the ultimate load is 52KN.

- For ball end condition the specimen having dimension of 60×60×2 shows ultimate load is 60.99KN which is higher when compared to specimen having dimension of 50×50×2 with the ultimate load is 56.41KN.
- For bolt end condition the specimen having dimension of 60×60×2 shows ultimate load is 53.43KN which is higher when compared to specimen having dimension of 50×50×2 with the ultimate load is 49KN.
- From the results, the ultimate load of specimen having dimension of 60×60×2mm is higher when compared with ultimate load of specimen having section size of 50×50×2mm analytically and experimentally.
- Welded end condition provides more strength than balled end condition where balled end condition provides more strength than the bolted end condition.
- Balled end condition shows more deflection than welded end condition where bolted end condition shows more deflection than the balled end condition.

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