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Experimental Study on the Flexural-Torsional Behavior of Cold-Formed Steel Channel Section Connected Back to Back

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Abstract

Cold-formed steels are made by rolling or pressing steel into semi-finished or finished goods at room temperatures. Cold-formed steel products are made by the working of steel billet, bar or sheet using stamping, rolling and including roll forming or presses to deform it into a usable product. **Objective:** By flexural-torsional behaviour channel section connected back to back. Four specimen of built up I section formed by using symmetric channel section connected back to back with the help of bolts provided in the web part of section. All the specimens were tested for flexural-torsional strength under two point loading. For this analytical study of cold-formed channel section four specimen of dimension of a 230 mm × 100 mm × 3 mm with a lip of 30 mm and 4 specimens of dimension of 180 mm x 50 mm x 1.6 mm with a lip of 20 mm and 1.8 m length were loaded vertically were unrestrained to allow flexural buckling. **Method:** The analytical investigation of the built up I section will be carried out using FEM modelling ANSYS. The theoretical values are calculated using IS 801:1975 and BS-5:5950. **Findings:** For the selected channel section with 230 mm and 180 mm depth the difference in theoretical, analytical and experimental results are found to be 2.5% and 4%. **Application:** Further this study can be carried out for steel section with increased or decreased depth of web and lip. It can also be used as a roofing sheet in warehouses etc.

Keywords: Back to Back Connection, Cold–Formed Steel, Flexural and Torsional Behaviour, Lipped Channel Section, Torsoinal Behaviour

1. Introduction

In Steel structures generally two types of steel members are used i.e. hot-rolled and cold-formed steel members. Hot-rolled steel members are manufactured at high temperatures and cold-formed steel members are manufacture at room temperatures. Until recently, the HR steel members have been recognized as the most popular and are widely used steel group, but since then the use of CR steel members are being used at a greater rate. Open CR Steel sections are relatively common but they suffer from certain buckling modes due to their mono-symmetric or point symmetric, high plate slenderness, eccentricity of shear centre and low torsional rigidity.

In general, cold-formed steel beams have open where the centroid and shear centre do no coincide. When a transverse loaded is applies away from the shear centre it causes torque. Because of open nature of the section, it is subjected to torsional induces warping in the beam. The thickness varies from 1.2 mm to 3.5 mm. The typically design strength for cold formed steel section are 350 N/mm^2, 450 N/mm^2 and 550 N/mm^2.

The cold-formed steel sections are manufactured from steel sheets. By cutting and bending into desired shapes. In the same way, the specimen chosen here is a channel lipped section connected back to back with bolts. The cold-formed sheet is also known as light gauge steel because of its minimum thickness when compared to hot rolled section.

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The paper, summarize the analytical, experimental and theortical investigation on CR steel members. The selection of the section is done on the basis of the slenderness. The details of specimen used in experimental and analytical studies are shown in Table 1.

2. Analytical Investigation

The finite element modelling of the chosen specimen is modelled using ANSYS Version 14.5 to stimulate the mode and to find the buckling mode along with the strength of beams under flexure or torsion. Meshing is used for correct presentation of complex geometry, easy representation of the total solution and capture of local effect. The cold formed channel sections are tested analytically by two point loading the beam section are loaded incrementally and the flexural torsional behaviour is studied. The properties of the light gauge section are given in Table 2.

A commonly employed methodology to create model in software is by using the solid model available. To investigate the structural behaviour of the structure due to various loading conditions Finite element analysis in structure is carried out. Hence accurate of the modelling is vital. There are secured way of application of load on steel structure, displacement, structural force or pressure onto either geometric entities or a set of nodes in the finite element model, if investigation is pure structural analysis.

During the analysis process, ANSYS program performs various analysis using a system of simultaneous equations generated from the Finite element model and corresponding results are given. Figure 1, Figure 2 and Figure 3 shows the modelling of built up I section in ANSYS 14.5.

Table 1. Specimen detail

Specimen (mm)	Dimension (mm)	Length (mm)
CLASS A	230 × 100 × 2	1800
CLASS B	230 × 100 × 25 × 2	1800
CLASS C	180 × 50 × 1.6	1800
CLASS D	180 × 50 × 20 × 1.6	1800

Table 2. Properties of the light gauge section

Density	7850 kg/mm^3
Modulus Of Elasticity	2×10^5 N/mm^2
Poisson's Ratio	0.3
Modulus of Rigidity	76900 N/mm^2

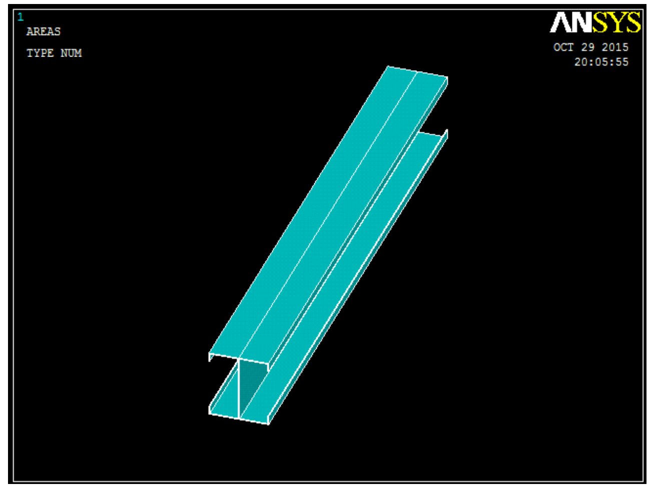


Figure 1. Modelling of built up I section.

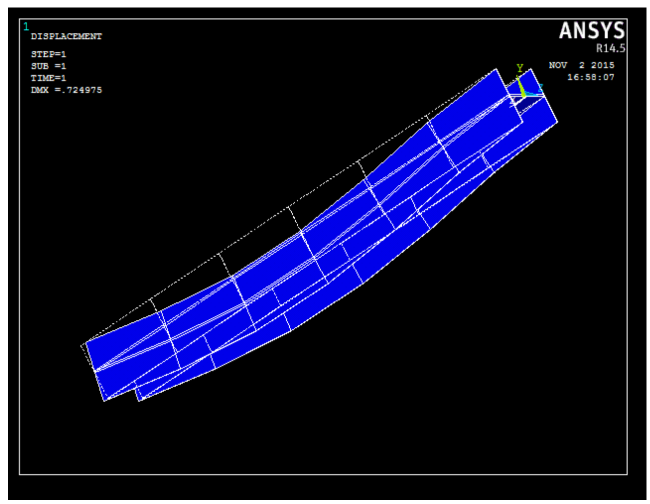


Figure 2. Bending of beam.

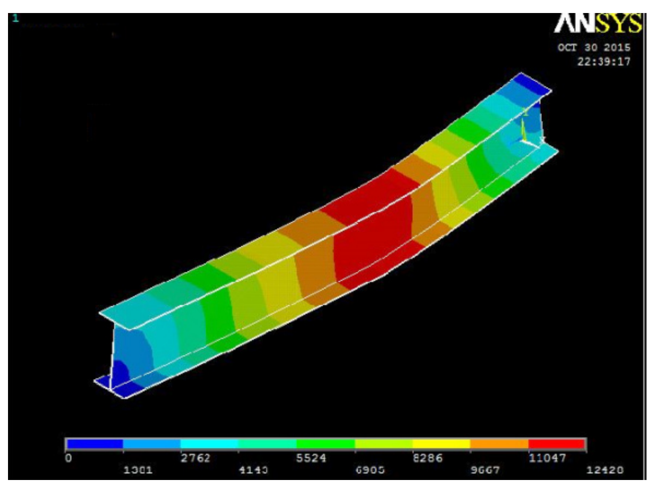


Figure 3. Deflection of beam.

3. Theoretical Investigation

The investigation is done to understand the Flexure and torsional behaviour of CR steel members using IS: 801-1975 and BS 5950-5:1998. Different countries use different codes as per Indian Standard IS 875, code of practice generally used for CR steel members by working stress method whereas the BS: 5950:1998 Part 5. Code practice for design of cold formed thin gauge sections, here the design of members is carried by limit state method. Thus, results for both IS code and BS codes obtained are then compared with the results obtained from analytical investigation.

In[1–4] evaluated the comparative study of different codes. The different codal provisions used for the design in this study are:

- IS: 801-1975
- BS 5950-5:1998

3.1 IS801:1975

Effective width calculation of compression elements If $\frac{w}{t} > (\frac{w}{t})_{lim}$ effective width can be calculated from:

$$\frac{b}{t} = \frac{2120}{\sqrt{f}}\left(1 - \frac{456}{\frac{w}{t}\sqrt{f}}\right)$$

Where, w – width of member, t – thickness of member, b – effective width, f – design stress.

$$\left(\frac{w}{t}\right)_{lim} = \frac{1435}{\sqrt{f}}$$

The depth of the lip can be checked by the given below formula:

$$d_{min} = 2.8t\sqrt{\left(\frac{w}{t}\right)lim - \frac{281200}{fy}} > 4.8t$$

3.2 British Standard (5950-5:1998)

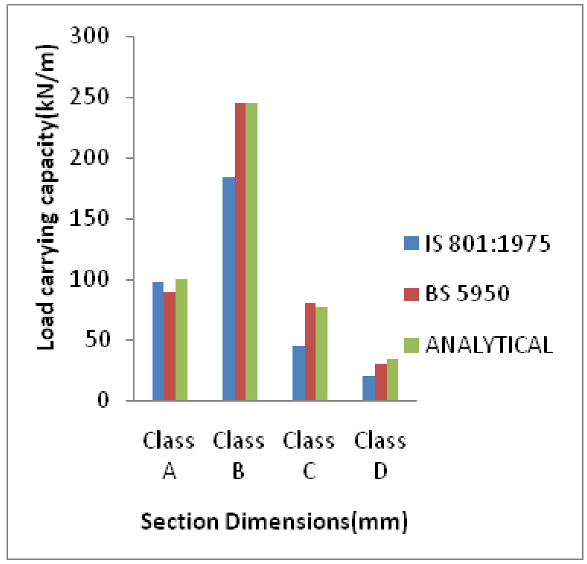
The moment carrying capacity of CR member is given by:

$$M_c = P_o \times Z_c$$

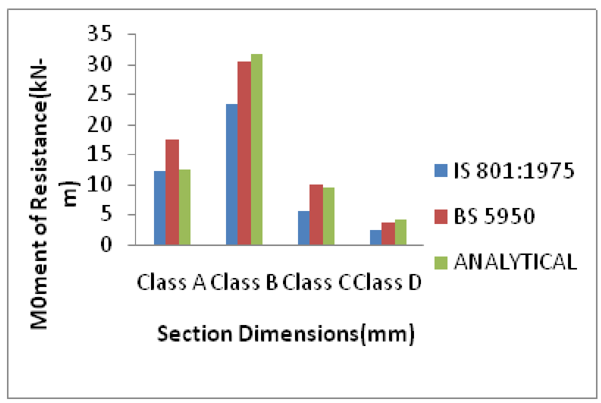
Where,

P_o = Compressive stress (maximum).
$= \{1.13 - 0.0019\frac{D}{t}(\frac{Ys}{280})^{0.5}\}py$
D = Depth/width of the element.
P_y = Yielding stress.
Z_c = Section modulus of the section.

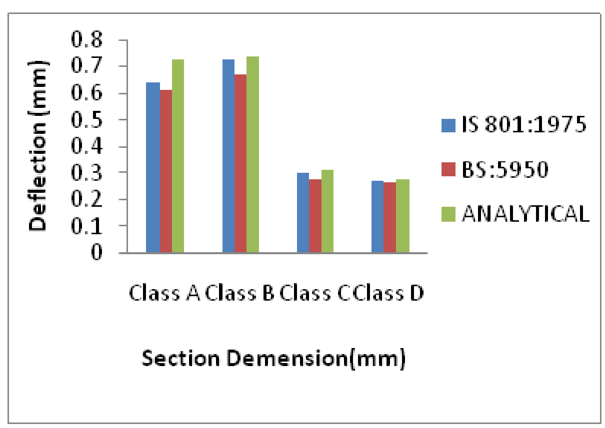
Theoretical Investigations of Built-Up Channel Section by the code of Practice, Load Carrying Capacity given below for the different section:



Theoretical Investigations of Built Up Channel Section by the Code of Practice, Moment of Resistance given below:



Deflection of Built Up Channel Section by the Code of Practice and analytically are given below:



4. Experimental Investigation

[6]Presented the experimental set up for the steel specimens. The experimental investigation was carried out on a self straining frame. The experimental investigation includes two different types of test:

- Flexural test.
- Torsion test.

4.1 Flexural Test

In[7] shows the flexural behaviour of light gauge steel sections. The size of the channel section with and without lip is 230 × 100 × 2 mm, 230 × 100 × 25 × 2 mm, 180 × 50 × 1.6 mm and 180 × 50 × 20 × 1.6 mm. Here 230 and 180 mm is the web of the section, 100 and 50 mm is flange portion of the section and 25 and 20 mm is lip of the section. The Figures 4, 5, 6 and 7 shows the specimen. The four point bending test set up for experimental investigation. The length of the beam is kept constant to 1800 mm.

The data are recorded from the three LVDT (Linear Variable Deflection Transducer). One is placed at the middle of the beam and other two are placed on the beam line with the supporting points of the beam. The experimental work was carried out on a self straining frame[8]. Strain readings were taken on the top flange and on the bottom flange. The arrangement of specimen for flexural test in the self straining loading frame of 100 Ton capacity is shown in Figures 8 and 9. The various results obtained by experimental investigation are given in Table 3.

Figure 4. Built-up I section (230 × 100 × 2 mm).

Figure 5. Built-up I section (230 × 100 × 25 × 2 mm).

Figure 6. Built-up I section (180 × 50 × 20 × 1.6 mm).

Figure 7. Built-up I section (180 × 50 × 1.6 mm).

Figure 8. Experimental arrangement of 180 mm depth beam for flexural.

Figure 9. Experimental arrangement of 230 mm depth beam for flexural.

Figure 10. Experimental arrangement of 180 mm depth beam for torsional.

Figure 11. Experimental arrangement of 230 mm depth beam for torsional.

Table 3. Summary of experimental results

Specimens (in mm)	Maximum Moment (in kN-m)	Maximum Load (in kN)	Deflection (in mm)
230 × 100 × 2	8.1	18	0.524
230 × 100 × 25 × 2	8.91	22	0.60
180 × 50 × 1.6	4.86	12	0.35
180 × 50 × 20 × 1.6	6.48	16	0.30

[9,10]The critical behaviour of CR steel beams under restrained end conditions is presented with a constant length of 1.8 m. It was observed for class A beams, the difference in the flexure or bending capacity is found to be decreased by 18.5% as compared with the theoretical calculation. With the increment of load the deflection values are obtained which is shown in Figure 12. It was also observed for class B beams, the difference in flexural capacity is found to be decreased by 13.5% with a lip size of 25 mm and 2 mm thickness. The load versus deflection curve for class B is shown in Figure 13. Further, it was observed for class C beams the difference in the flexural capacity is found to be decreased 27% with 1.6 mm thickness. The variation in deflection value with respect to load is shown in Figure 14. And also for class D beams, the difference in the flexural capacity is found to be decreased by 17.5% with a lip size of 20 mm and 1.6 mm thickness. The variation in deflection value with respect to load is shown in Figure 15. The variation of strain in the compression and tension flange with the increment of load for specimen class (A, B, C, D) is shown in Figure 16.

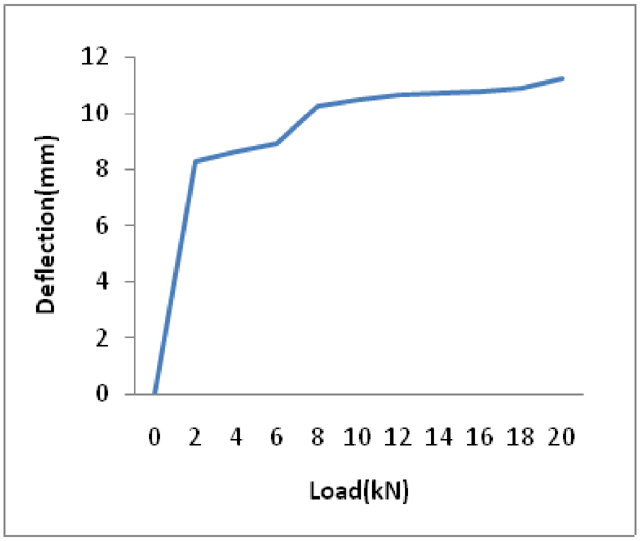


Figure 12. Load vs. deflection for 230 mm depth beam.

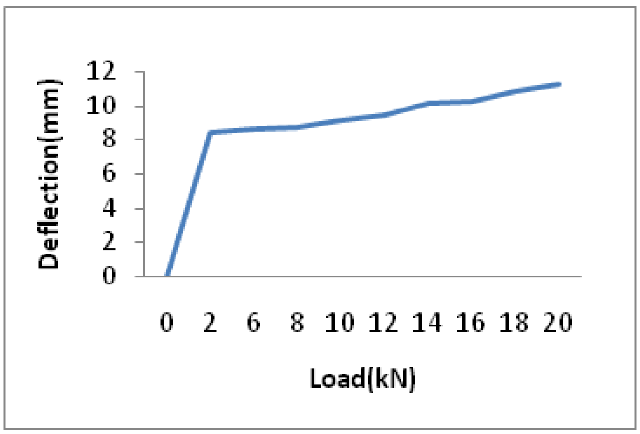


Figure 13. Load vs. deflection for 230 mm depth beam with lip.

4.2 Torsion Test

After complete fabrication of specimen with 230 mm and 180 mm depth, strain gauges are placed in the correct position such as strain gauges are placed in the mid portion where the deflection attains due to the twisting of the section. After placing the strain gauges, the steel beam should be placed in the loading frame. Then the loading beam which is having two steel rod at the desired distance for applying load to the angle section was placed over the angle section in loading frame. Then the hydraulic jack and proving rings are placed over the loading beam.

In[11] describes the torsional behaviour of cold-formed steel channel section. Then load was applied through

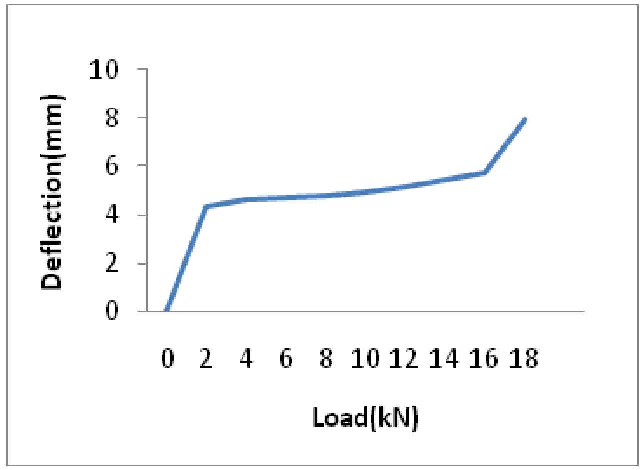


Figure 14. Load vs. deflection for 180 mm depth beam.

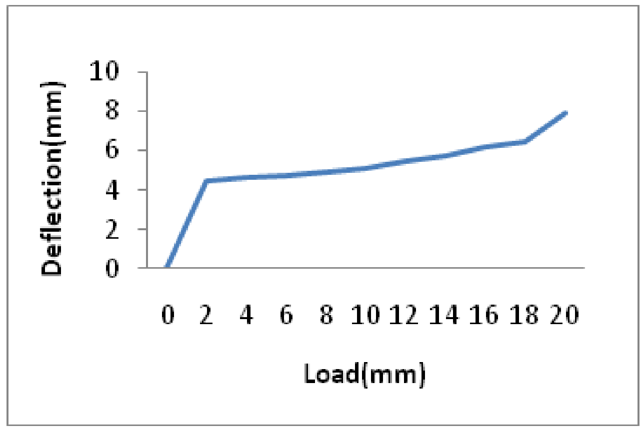


Figure 15. Load vs. deflection for 180 mm depth beam with lip.

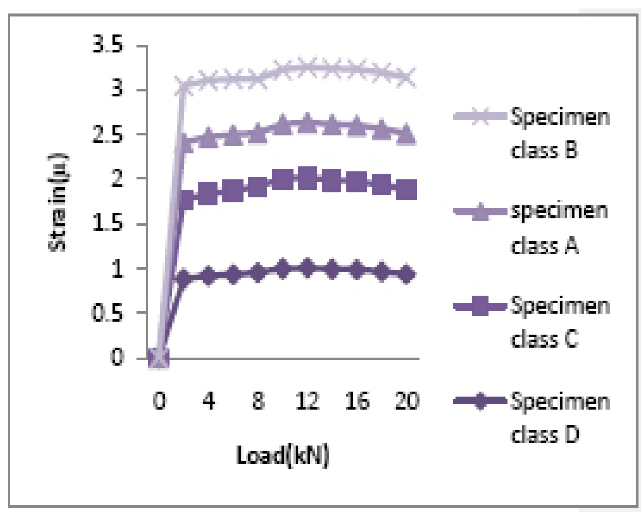


Figure 16. Load vs. strain curve for class (A, B, C, D) beam for flexural.

hydraulic jack and applied load was determined by the proving ring. The strain gauges are used to note the result. The load is applied till the section attains ultimate load capacity and buckles. The arrangement of the specimen with 230 and 180 mm with and without lip in the loading frame is shown in Figure 10 and 11. The strain gauges are provided at the web part of the beam with is connected to the strain indicator in order to take the strain value. The variation of strain with the increment of load for specimen class (A, B, C, D) is shown in Figure 17. The angle of twist obtained from experimental and theoretical investigations are compared in Table 4.

5. Result and Discussion

In[12,13] gives the different buckling modes and deflections of beams. The deflection and the angle of twist were compared with the results obtained by analytically, theoretically and experimentally. The theoretical and experimental results were found to be precise with analytical results.

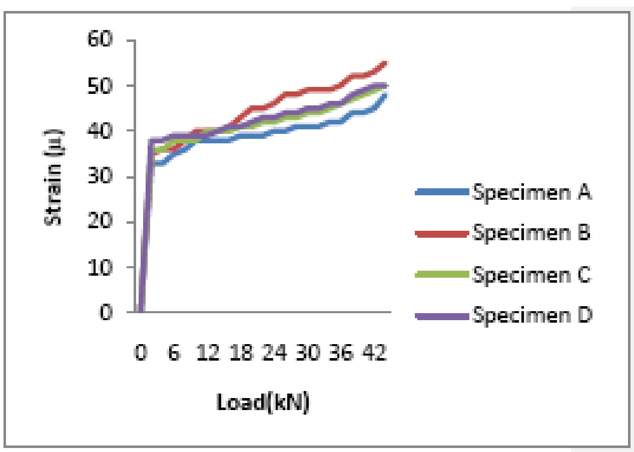


Figure 17. Load vs. strain for beam of class (A, B, C, D) for Torsion.

Table 4. Comparison of angle of twist values

Specimen (mm)	Theoretical angle of twist (radian)	Experimental angle of twist (radian)
230 × 100 × 2	34.95	23.49
230 × 100 × 25 × 2	38.44	25.66
180 × 50 × 1.6	15.47	14.15
180 x 50 x 20 x 1.6	14.90	12.032

Table 5. Comparison of deflection values

Specimen (mm)	IS-801: 1975 (mm)	BS-5950: 1998 (mm)	Analytical (mm)	Test Results (mm)
230 × 100 × 2	0.639	0.610	0.68	0.524
230 × 100 × 25 × 2	0.627	0.6701	0.70	0.60
180 × 50 × 1.6	0.296	0.273	0.41	0.35
180 × 50 × 20 × 1.6	0.273	0.260	0.36	0.30

5.1 Comparison of IS and BS Code, Analytical Studies and Experimental Studies

The deflection value obtained from IS and BS code has been specified in the below Table 5.

6. Conclusion

- A comparative study on the flexure or bending strength along with the torsional strength of lipped and without lipped cold formed sections using IS and BS codal provisions and the results are compared with analytical results.
- For the selected channel section with 230 mm depth analytical study shows 2% difference with theoretical data.
- For the selected channel section with 180 mm depth analytical study shows 3.5% difference with theoretical data.
- With the increment of depth the strength and stiffness of the beam also increases. The average maximum moment resistance of beam with depth 230 mm is 30.57 kN-m and that of 180 mm depth is 9.97 kn-m.
- The top flange part of CR sections failed due to local buckling. This type of buckling is can easily seen in cold formed members.
- From experiment we came to know that the deflection increases gradually till the specimen undergoes local buckling.
- The determined ultimate load value is compared to the numerical values. These values helps to use the light gauge angle sections as secondary beams.

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