Effect of Transverse Web Stiffeners for Cold Formed Light Gauge Steel Beam Under Flexure

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ABSTRACT

Cold-formed steel lipped I-beam are extensively used in the industrial, commercial and the residential projects as a load bearing structural element. Their flexural strength considerably reduces due to the less thickness of the web. The failure occurred is mainly due to the shear buckling of the web and the lateral torsional buckling. From previous studies, as the thickness of the web reduces the contribution of post-buckling in its failure increases. So to resist it, transverse web stiffeners are used to strengthen the web. This work investigates the flexural strength and failure pattern of the light gauge cold formed I beam with and without web stiffener. In this work, flexural test is carried out on the CFS I section with and without rectangular shapes of transverse web stiffeners using FEA based software ANSYS. The software analysis results give load carrying capacity of beam under four point bending.

Keywords: Cold formed steel, lateral torsional buckling, transverse web stiffeners, web shear buckling etc.

I INTRODUCTION

From 1930’s light gauge is evolved as building material but has got more importance during World War II. Light gauge can be used extensively in industries as purlins to roof sheeting, metal building construction, wall coverings and floor decking. The cold formed Light Gauge Steel structures differ from hot rolled sections by its less thickness (resulting in light weight) and its manufacturing process. These sections are cold formed i.e. they are manufactured in the cold state by rolling metal sheet of 1 to 3mm thickness. The steel sheets of yield strength at least 280 N/mm^2 are used to manufacture cold-formed sections. India uses the light gauges for bus body construction, railway couches, cladding, metal building construction, etc. with sheet of thickness 1 to 1.32 mm.

The section is made by bending the sheet of thickness 1 to 3 mm under room temperature is called as cold-formed light gauge steel section. There are two main types of manufacturing cold formed section i.e. cold rolling and press braking (Up to 6 mm). For simple shape, repetitive and large work cold rolling is used and for the small work press-braking is used. India uses both the cold rolling as well as press braking. These can be connected using fillet welds, spot welds and screws. Due to flexibility in cross-section of it can be used in cladding frames, industrial buildings, fabricated products and for pre-fabricated structures. Due to its thin walled nature and open cross sections, it has high structural instability. Due to which, CFS can undergo local buckling, distortional buckling and large lateral torsional buckling. To resist this instability many types of stiffened elements can be used. Following are advantages of cold formed steel section,

1. Due to cold working, there is an increase in yield stress up to 15% to 30%.
2. Cold rolling of galvanized sheet is possible, hence can be more corrosion resistant.
3. The strength to weight ratio of cold formed steel is much higher as compared to other building materials. So high strength and stiffness they can be used for wide spans.

   As cold forming is light weight and can be manufactured on site, the speed of construction is higher.

A. Different modes of buckling

There are different modes of buckling occurring in the cold formed steel sections. Some of those are as explained below;

I. Web local buckling

In case of light gauge member, width to thickness ratio is much higher. Hence the failure of plate is generally by buckling. Contrast to that, in hot rolled members the width to thickness ratio is less, hence the buckling is neglected and the failure is by the yielding. The buckling in light gauge member occurs due to the stress produced by compression, bending or bearing.

II. Flange local buckling

When the bending stress exceeds critical stress in the flange, the flange of the beam can buckle locally. The flange buckling is exactly same as web local buckling except width-thickness ratio is in terms of flange not the web. This type of buckling occurs when width to thickness ratio is not large enough to withstand a moment in the beam.

III. Lateral torsional buckling

When applied load causes both lateral displacement and twisting of a member then lateral torsional buckling occurs. Lateral torsional buckling may occur in an unrestrained beam. A beam is said to be unrestrained if its compression flange is free to displace laterally and rotate.

IV. Distortional buckling

Distortional mode of buckling initially involves rotation of flange about web/flange junction. This type of buckling generally occurs in cold-formed sections. When deflection of top flange is more as compared to deflection of bottom flange then distortional buckling occurs.

B. Types of stiffeners

There are different types of stiffeners used in cold formed beams namely

I. Intermediate stiffener

Cold formed members are less in thickness, which results in slenderer member. Generally cold formed beams undergo failure by distortional buckling of flange followed by lateral-torsional buckling of web. These slender and ineffective members can be transformed to highly effective members by providing the intermediate stiffeners. Intermediate stiffeners are made by bending the street in desired shape in original section.

II. Web plate stiffeners

As cold formed members are less in thickness they may undergo lateral torsional buckling. To overcome this, it is necessary to stiffen the web of the beam. For this purpose, extra plates are welded to web using fillet welds. These welded plates may orient in both longitudinal as well as transverse direction. As these types of stiffeners resist torsional buckling of the beam, these are also called as Torsional Stiffeners.

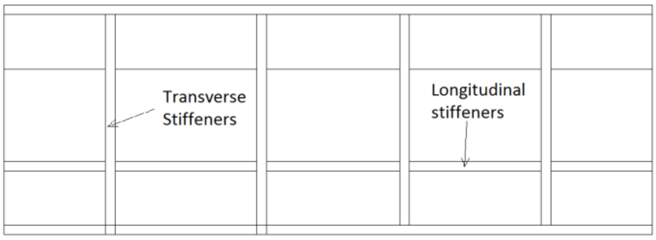

Figure 1 Web Plate Stiffeners

III. Bearing stiffeners

At the point of support and at the point of concentrated load, there are chances of load concentration. In such cases bearing stiffeners can be used. Bearing stiffener is nothing but plates welded to web. Thickness of these welded plates is more as compared to thickness of web. For connecting these plates continuous fillet weld is used. The thickness of this weld may be 8 to 10 mm.

IV. Extra plates welded to web and flanges

In case of cold formed sections, the thickness of web and flanges is less as compared to hot rolled sections. Therefore, there is distortional buckling of flanges and lateral torsional buckling of web of the beam. To overcome this problem, the thickness of both web and flanges is increased by welding extra plates at some location in both web and flanges.

II METHODOLOGY

In this study, the two lipped channel sections of cold-formed steel are connected back to back to form I section with and without transverse stiffener is used. Four point bending test is carried out for selected beam member. Thickness of transverse web plate stiffener for selected member is varied from 1mm to 4mm and the effect on load carrying capacity of member under flexure is observed. To analyse the load carrying capacity of member ANSYS software is used which done the analysis using finite element method.

A. Type of test

There are two types of tests available that are 3-point bending test and 4-point bending test to get ultimate load carrying capacity of the cold formed steel beam. In 3-point bending test, there is only one concentrated load applied at mid span of the beam but in case of 4-point bending test two concentrated loads are applied each at one third span of the beam. This how 3-point bending test differ from 4-point bending test.

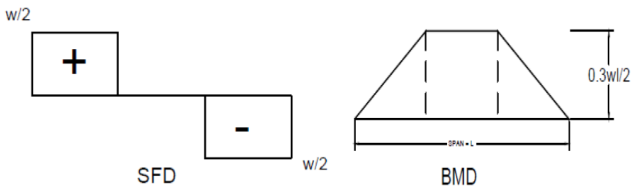

Figure 2 Typical SF and BM diagram for 4-point bending test

For experimental investigation 4-point bending test is preferred over 3-point bending test. In case of 3-point bending test, the entire load is concentrated at the single point. Hence, there may be a premature local failure of the beam and actual load carrying capacity of the beam cannot be obtained. However, in case of 4-point bending test, the entire load is distributed through two anvils, so there is no premature failure of the beam.

From shear force diagram and bending moment diagram, in 3-point bending, there is stress concentration at the point of loading. However, in case of 4-point bending test, there is uniform bending moment and shear stress is zero between loading points, thus it leads to be pure bending condition. Therefore, this 4-point bending test is desirable.

B. Problem for analysis

Sections were simply supported at 900 mm c/c distance with overall length of section 1000 mm. Two-point loads with the use of the spreader beam were applied to the test specimen at distance 300 mm apart. That is section was equally dividing with 300 mm distance giving no shear zone in the middle part to get pure bending at mid span section.

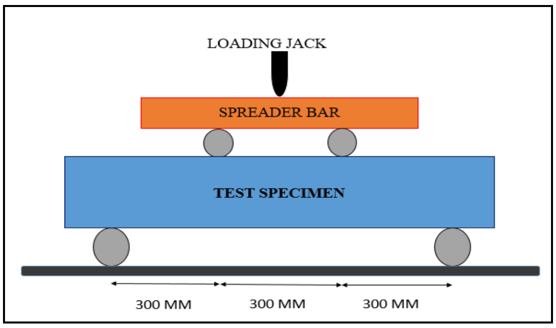

Figure 3 The schematic diagram of test set up for 4-Point bending test

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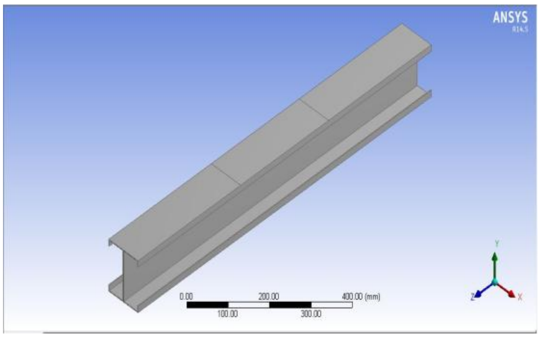
III. MODELING AND ANALYSIS

A. Finite element modeling

To study flexural behavior of section under 4-point bending test, the finite-element analysis-based software, ANSYS is used. The modeling of the beam is done in Design Modeler, and then it is imported to ANSYS Workbench Mechanical. Precise model is developed by actual boundary condition and load application on 3-D model. Results are obtained for displacement at ultimate load of beam and for ultimate load carrying capacity of the beam. To calculate ultimate load carrying capacity of the beam Eigen buckling analysis is done in software ANSYS.



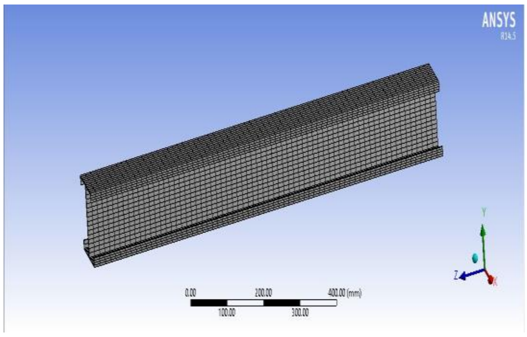


Figure 4 Element model in ANSYS Figure 5 Meshing of finite element model in ANSYS

Table 1 Sections for analysis

Designation of Sections	I Section	Stiffener thickness				
1	120 * 50 * 15 * 2.00	0	1	2	3	4
2	120 * 50 * 25 * 4.00	0	1	2	3	4
3	120 * 60 * 20 * 3.15	0	1	2	3	4
4	140 * 60 * 20 * 3.15	0	1	2	3	4
5	140 * 60 * 25 * 4.00	0	1	2	3	4
6	150 * 50 * 20 * 3.15	0	1	2	3	4
7	150 * 50 * 25 * 4.00	0	1	2	3	4
8	180 * 50 * 20 * 3.15	0	1	2	3	4
9	180 * 80 * 25 * 3.15	0	1	2	3	4
10	180 * 80 * 25 * 4.00	0	1	2	3	4
11	200 * 50 * 20 * 3.15	0	1	2	3	4
12	200 * 50 * 25 * 4.00	0	1	2	3	4
13	200 * 80 * 20 * 3.15	0	1	2	3	4
14	200 * 80 * 25 * 4.00	0	1	2	3	4
15	250 * 50 * 20 * 3.15	0	1	2	3	4

16	250 * 50 * 25 * 4.00	0	1	2	3	4
17	250 * 80 * 20 * 3.15	0	1	2	3	4
18	250 * 80 * 25 * 4.00	0	1	2	3	4

B. Analysis of Member

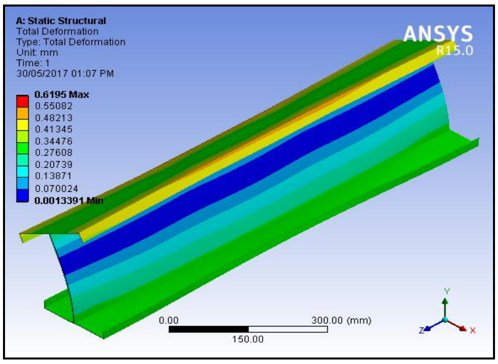


Figure 6 Displacement of finite element model in ANSYS

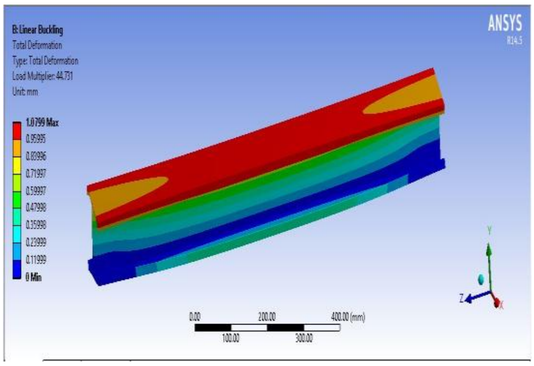


Figure 7 Ultimate LCC of finite element model in ANSYS

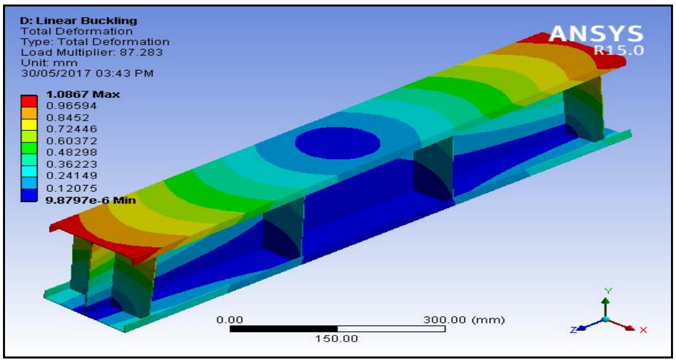


Figure 8 Ultimate LCC of finite element model in ANSYS with transverse stiffeners

IV. RESULTS AND DISCUSSION

Finite element analysis was carried out using ANSYS software to check the ultimate load carrying capacity of members.

A.Load carrying capacity of members

Table 2 Ultimate Load Carrying Capacity of Members

Sr. No.	I Section	Stiffener thickness	Ultimate LCC (kN)
1	120 * 50 * 15 * 2.00	0	18.09

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2	120 * 50 * 25 * 4.00	0	26.45
3	120 * 60 * 20 * 3.15	0	22.87
4	140 * 60 * 20 * 3.15	0	28.26
5	140 * 60 * 25 * 4.00	0	44.54
6	150 * 50 * 20 * 3.15	0	37.96
7	150 * 50 * 25 * 4.00	0	58.8
8	180 * 50 * 20 * 3.15	0	51.25
9	180 * 80 * 25 * 3.15	0	65.32
10	180 * 80 * 25 * 4.00	0	83.16
11	200 * 50 * 20 * 3.15	0	54.96
12	200 * 50 * 25 * 4.00	0	99.78
13	200 * 80 * 20 * 3.15	0	59.29
14	200 * 80 * 25 * 4.00	0	108.48
15	250 * 50 * 20 * 3.15	0	77.33
16	250 * 50 * 25 * 4.00	0	119.14
17	250 * 80 * 20 * 3.15	0	91.58
18	250 * 80 * 25 * 4.00	0	130.32
19	120 * 50 * 15 *	1	29.16

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	2.00		
20	120 * 50 * 25 * 4.00	1	40.47
21	120 * 60 * 20 * 3.15	1	35.81
22	140 * 60 * 20 * 3.15	1	43.57
23	140 * 60 * 25 * 4.00	1	70.13
24	150 * 50 * 20 * 3.15	1	57.47
25	150 * 50 * 25 * 4.00	1	91.61
26	180 * 50 * 20 * 3.15	1	77.05
27	180 * 80 * 25 * 3.15	1	102.53
28	180 * 80 * 25 * 4.00	1	116.45
29	200 * 50 * 20 * 3.15	1	85.93
30	200 * 50 * 25 * 4.00	1	142.99
31	200 * 80 * 20 * 3.15	1	92.67
32	200 * 80 * 25 * 4.00	1	160.35
33	250 * 50 * 20 * 3.15	1	115.92
34	250 * 50 * 25 * 4.00	1	176.63
35	250 * 80 * 20 * 3.15	1	137.20
36	250 * 80 * 25 * 4.00	1	192.43

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37	120 * 50 * 15 * 2.00	2	39.12
38	120 * 50 * 25 * 4.00	2	55.29
39	120 * 60 * 20 * 3.15	2	47.11
40	140 * 60 * 20 * 3.15	2	58.76
41	140 * 60 * 25 * 4.00	2	94.03
42	150 * 50 * 20 * 3.15	2	79.73
43	150 * 50 * 25 * 4.00	2	121.49
44	180 * 50 * 20 * 3.15	2	106.55
45	180 * 80 * 25 * 3.15	2	133.09
46	180 * 80 * 25 * 4.00	2	162.65
47	200 * 50 * 20 * 3.15	2	111.39
48	200 * 50 * 25 * 4.00	2	195.66
49	200 * 80 * 20 * 3.15	2	125.34
50	200 * 80 * 25 * 4.00	2	213.06
51	250 * 50 * 20 * 3.15	2	153.22
52	250 * 50 * 25 * 4.00	2	228.91
53	250 * 80 * 20 * 3.15	2	182.65
54	250 * 80 * 25 *	2	249.35

	4.00		
55	120 * 50 * 15 * 2.00	3	50.16
56	120 * 50 * 25 * 4.00	3	71.19
57	120 * 60 * 20 * 3.15	3	39.16
58	140 * 60 * 20 * 3.15	3	51.04
59	140 * 60 * 25 * 4.00	3	121.77
60	150 * 50 * 20 * 3.15	3	102.31
61	150 * 50 * 25 * 4.00	3	156.25
62	180 * 50 * 20 * 3.15	3	136.28
63	180 * 80 * 25 * 3.15	3	176.23
64	180 * 80 * 25 * 4.00	3	217.26
65	200 * 50 * 20 * 3.15	3	143.38
66	200 * 50 * 25 * 4.00	3	257.35
67	200 * 80 * 20 * 3.15	3	153.48
68	200 * 80 * 25 * 4.00	3	274.76
69	250 * 50 * 20 * 3.15	3	202.61
70	250 * 50 * 25 * 4.00	3	299.465
71	250 * 80 * 20 * 3.15	3	236.58

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72	250 * 80 * 25 * 4.00	3	324.16
73	120 * 50 * 15 * 2.00	4	65.29
74	120 * 50 * 25 * 4.00	4	98.21
75	120 * 60 * 20 * 3.15	4	85.67
76	140 * 60 * 20 * 3.15	4	104.74
77	140 * 60 * 25 * 4.00	4	162.305
78	150 * 50 * 20 * 3.15	4	139.84
79	150 * 50 * 25 * 4.00	4	211.53
80	180 * 50 * 20 * 3.15	4	187.32
81	180 * 80 * 25 * 3.15	4	228.62
82	180 * 80 * 25 * 4.00	4	285.15
83	200 * 50 * 20 * 3.15	4	184.66
84	200 * 50 * 25 * 4.00	4	335.11
85	200 * 80 * 20 * 3.15	4	201.59
86	200 * 80 * 25 * 4.00	4	360.31
87	250 * 50 * 20 * 3.15	4	258.86
88	250 * 50 * 25 * 4.00	4	378.35
89	250 * 80 * 20 *	4	304.35

	3.15		
90	250 * 80 * 25 * 4.00	4	410.29

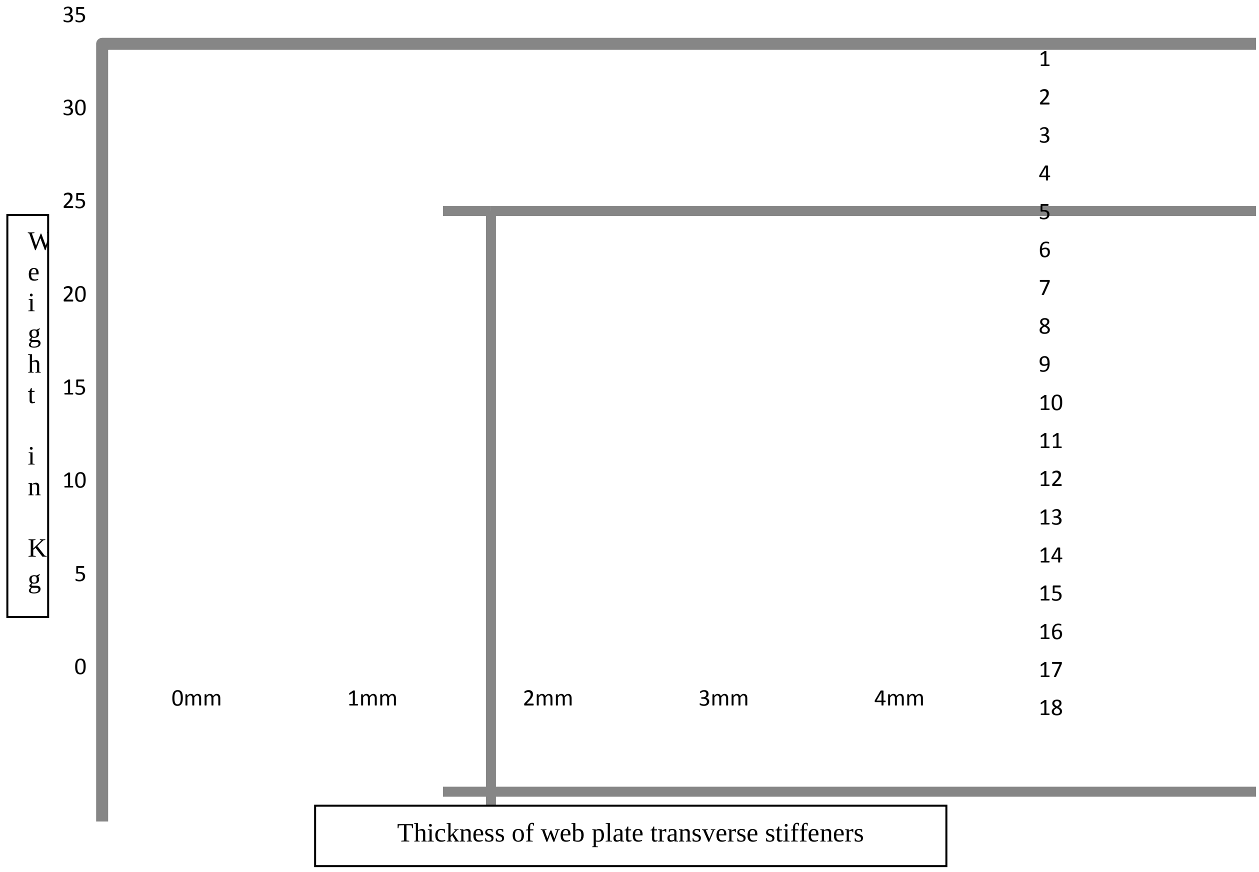

Figure 10 Graph of effect of thickness of transverse web stiffener on weight of member

It is observed that, as transverse web stiffeners are used, the weight of member is increases by 3%, 6%, 9% and 12% for 1mm, 2mm, 3mm and 4mm thick stiffener and there is corresponding increase in ultimate load carrying capacity of member by 50%, 95 %, 145% and 180% respectively.

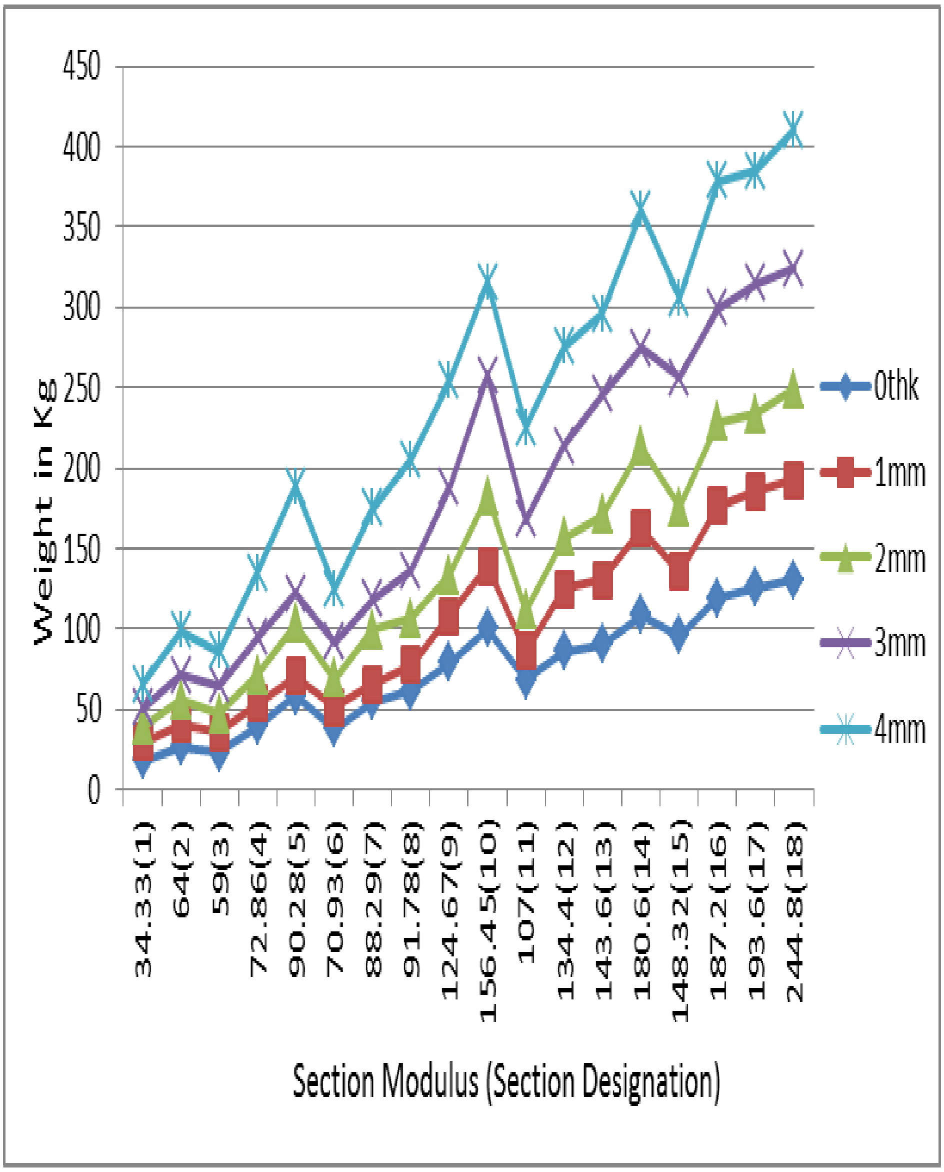

Figure 10 Graph of effect of section modulus on load carrying capacity of member

Stiffeners of thickness ranging from 1mm to 4mm were taken for analytical modeling in ANSYS WORKBENCH. The 0mm thickness in the Figure 11 indicates that no stiffeners were provided. From the above figure it can be concluded that as the section modulus for the member increases there is an increase in the load carrying capacity of the member.

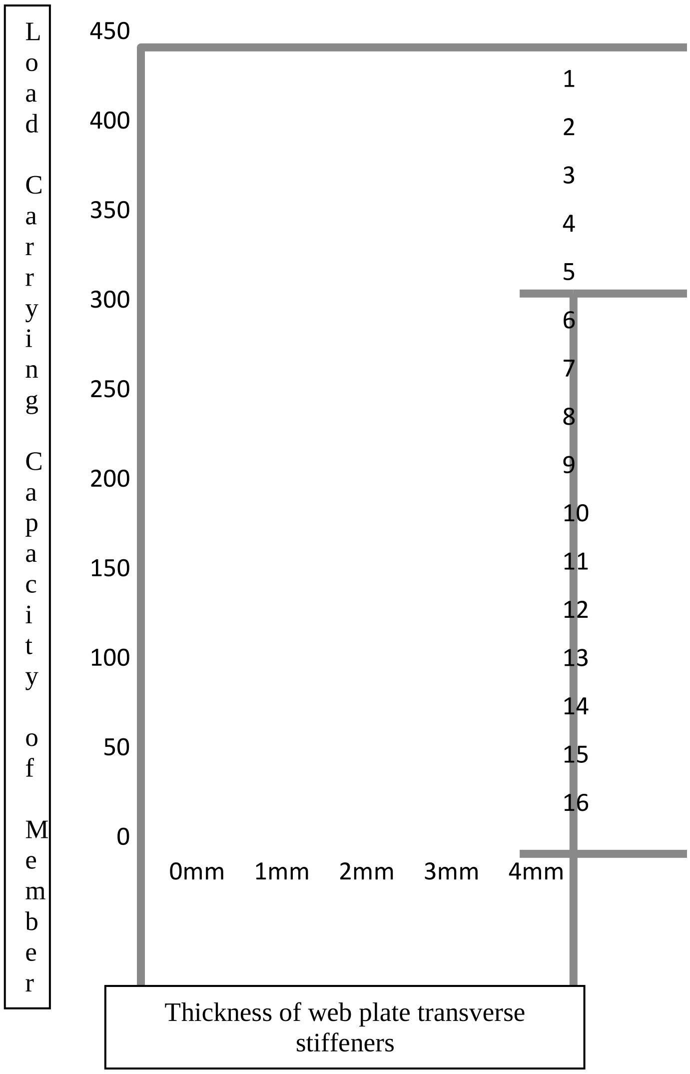

Figure 11 Graph of effect of thickness of transverse web stiffener on load carrying capacity of member

V. CONCLUSION

1. Figure 6 shows that I section of cold formed steel without transverse web stiffeners shows distortional buckling in compression flange and lateral torsional buckling in web. While Figure 8 shows that I section of cold formed steel with transverse web stiffeners shows very less local buckling. So, it can be concluded that transverse web stiffeners increase stiffness of whole section and avoid pre-mature failure due to local buckling. From this study it can be concluded that the transverse web stiffeners are effective for controlling local buckling.

2. Ultimate load carrying capacity of members greatly increases with addition of stiffeners and increase of thickness of stiffener.

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