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Experimental Study of Light-Gauge Steel Beams of Structurally Efficient Shapes

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Abstract—*In recent times light-gauge cold-formed steel beams have been used extensively in residential buildings as primary load bearing structural components. This is because cold-formed steel sections have a very high strength to weight ratio compared to hot-rolled steel sections. Light-gauge steel construction is appropriate and economical where members are subjected to moderate loads and where it is desired load carrying members should also provide useful surface. However these members are susceptible to buckling and their ultimate strength is governed by buckling and hence there is a need to fully evaluate the performance of light gauge cold-formed steel beams. This research is therefore aimed at investigating structurally efficient section of light-gauge cold-formed steel beams. I beam made of two channels connected back to back, box section and I beam made of a channel and two angles connected to channel were experimentally and theoretically studied. The deformations experienced during the testing were measured and observations regarding the failure modes were documented. The parameters considered for determining an efficient section include ultimate bending moment and deflection.*

Keywords: Cold- formed steel, Buckling, Ultimate bending moment, I beam, Box section and Deflection.

1. INTRODUCTION

Light-gauge steel evolved as a building material in the 1930's and reached large scale usage only after 2nd world war. In comparison with conventional steel construction, were hot-rolled shapes are used the cold-formed light-gauge steel structures are a relatively new development. The light gauge steel sections are cold-formed in rolls by rolling the material in cold condition or by bending the steel sheets in press brakes; cold rolling being used for mass production while press brakes are used for economical production of small quantities of small shapes. These are used widely in structures subjected to light or moderate loads or for members of short span lengths. For such structures, the use of conventional hot-rolled shapes is often uneconomical because the stresses developed in the smallest available shape may be very low. Further, a variety of light gauge members can be formed in the cold state with ease & the material can be used in the most effective manner. Cold-formed steel has the advantage of applying protective coatings to the coil before roll forming. The main factor governing the corrosion resistance of cold-formed steel sections is not the base metal thickness but the type of protective treatment applied to the steel. Cold-formed light- gauge steel sections are produced from strips not thicker than 10mm. For specifications of light gauge steel sections IS: 811 and for analysis and design, IS: 801 should be referred.

The thicknesses of individual plate elements of cold-formed sections are normally small compared to their widths, so local buckling may occur before section yielding. However, the presence of local buckling of an element does not necessarily mean that its load capacity has been reached. If such an element is stiffened by other elements on its edges, it possesses still greater strength, called "post-buckling strength." The cold-formed sections also have low torsional stiffness and many of the sections produced by cold-forming are singly symmetric with their shear centers eccentric from their centroids. Since the shear center of a thin-walled beam is the axis through which it must be loaded to produce flexural deformation without twisting, any eccentricity of the load from this axis generally produces considerable torsional deformations in a thin-walled beam. Consequently, beams usually require torsional restraints at intervals or continuously along them to prevent torsional deformations. However even in doubly symmetric sections, accidental eccentricities are present .Web crippling at points of concentrated loads and supports can be a problem in cold-formed steel structural members. Engineers have learned to adopt versatility to advantage in the design of structural members and the main aim is to develop shapes which combine economy of the material with versatility, ease of mass production and provision for effective and simple connection to other structural members or to non structural or both of them. The shapes which can be cold-formed are many and varied. The usual shapes are channels, Z-sections, angles, hat-sections and I sections .The beams included for experimental investigations are I beam made of two channels connected back to back, box section and I beam made of a channel and two angles connected to the channel as shown in Fig1: a, b, c . The beams are primarily designed as flexural members with adequate capacity to resist shear. The section dimensions are chosen arbitrarily and ultimate resisting bending moment is obtained as per IS 801.

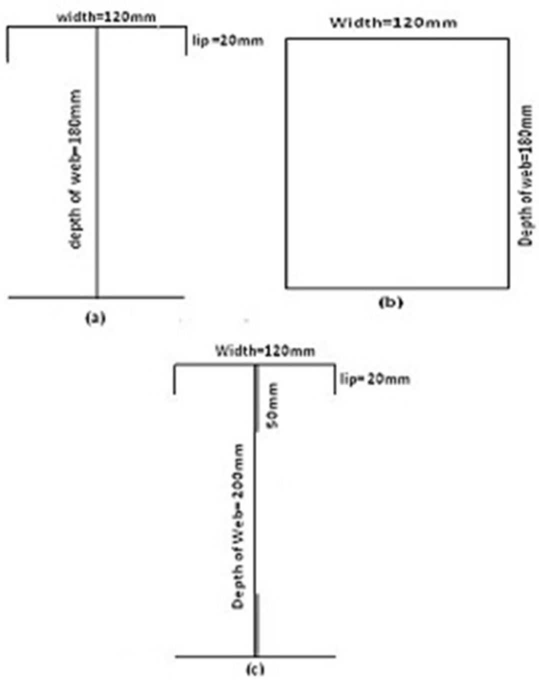


Fig. 1: Cross section of beams: a) I beam made of two channels connected back to back b) Box section c) I beam made of a channel and two angles connected to the channel

2. MATERIALS AND METHOD

2.1 Determination of Yield strength and Modulus of Elasticity

The mechanical properties of steel are determined from tensile coupon tests. The mechanical properties so obtained from the tensile coupon test were used in numerical modeling of steel beams and columns. Tensile test specimen was taken from the same sheet which was used for fabrication of beams. The specimen size is shown in Fig (2.1.1).The coupon was tested in the Universal Testing Machine and the typical stress-deflection curve is shown in Fig (2.1.2).A linear region is followed by a distinct plateau at 400MPa, then strain hardening up to the ultimate tensile strength at 450 MPa. The yield strength (fy) of the material was taken 400MPa conservatively and the modulus of elasticity (E) = 1.77×10^4MPa.

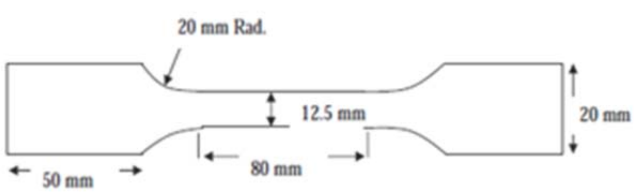


Fig. 2.1.1: Dimensions of tensile test coupon

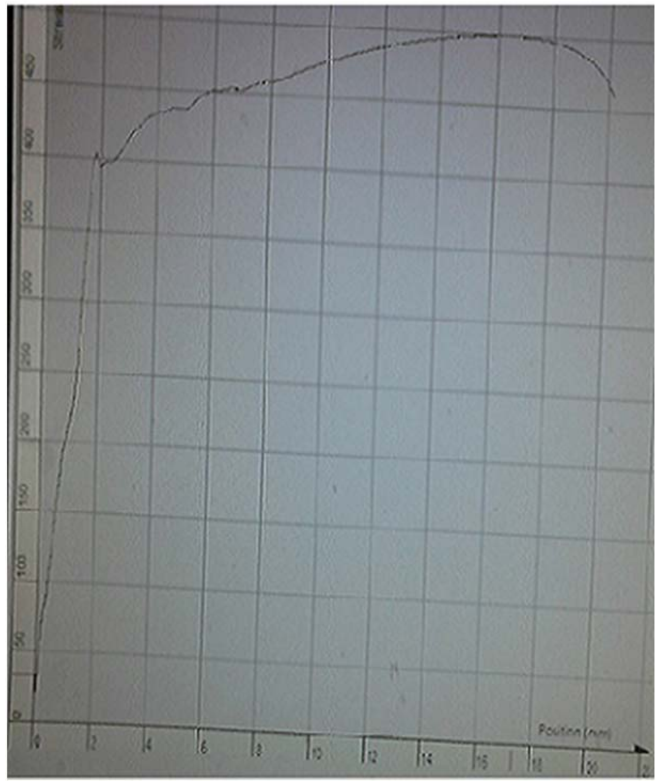


Fig. 2.1.2: Stress (MPa) – Deflection (mm) Curve

2.2 Preparation of Beam Specimens

The light-gauge steel sheets of size 2.4mx1.2m were procured from the market. The sheets were cut into requisite dimensions by sheet shearing machine as shown in Fig. (2.2.1).The cut shapes so obtained were given requisite number of bends by using the mechanical press brake as shown in Fig (2.2.2).I-section made of two channels connected back to back and box section were joined with the help of bolts and the bolt holes were drilled with the help of a drilling machine as shown in Fig(2.2.3).

Fig. 2.2.1: Sheet Shearing

The bolt diameter was 7mm and holes were drilled with 8mm drill bit .I beam made of a channel and two angles connected back to back to channel was joined by welding to prevent the block shear failure (if connected by bolts) because of the smaller end distance.

Fig. 2.2.2: Press Brake for bending of sheets

Fig. 2.2.3: Drilling of bolt holes

2.3 Experimental Set-Up

The finally prepared models of the beams were tested on the loading frame using hydraulic jack of 50 Ton capacity. It provided a suitable arrangement as per the span requirement.

Some packing arrangements were also used for effectively transmitting the load. The dial gauges were used for measuring the deflections at various loads. The least count of dial gauges was 0.01mm and maximum count was 25mm.The total span of the beam was kept as 1.27m and the bearing length was maintained .27m on either side with effective span of 1m. Single point load was applied at the mid-span of the beam. Deflections were measured at the mid-span of the beam. The loading arrangement is shown in Fig (2.3.1)

Fig. 2.3.1: Experimental Set-Up

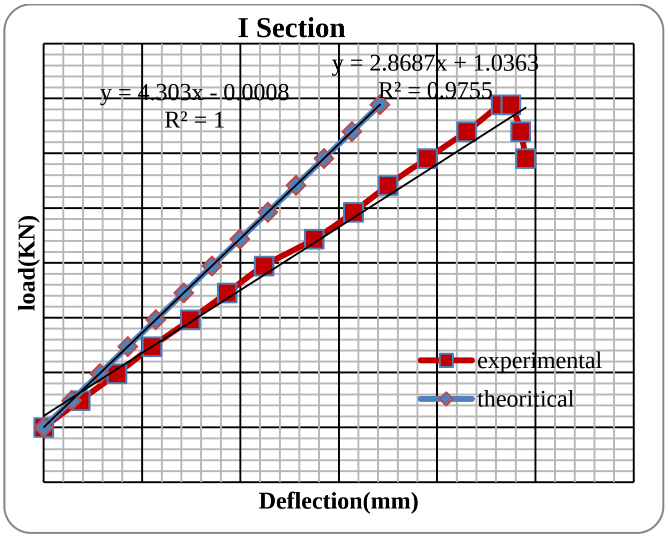
3. TESTING AND OBSERVATIONS

3.1 Testing of I beam made of two channels connected back to back

I beam of requisite dimensions as shown in Fig:1(a) was placed on a loading frame with suitable arrangements in place. The load was increased in intervals of 250 kg. The maximum load and the deflection at the failure were 3000 kg and 9.3mm respectively. The theoretical values of maximum load and deflection were 5200 kg and 11.87 mm respectively. The failure was predominantly torsional in nature associated with local buckling as shown in Fig (3.1.1).

Fig. 3.1.1: Failure of I beam made of two channels

The test results have been plotted in the form of a graph between load and deflection as shown in Graph 1



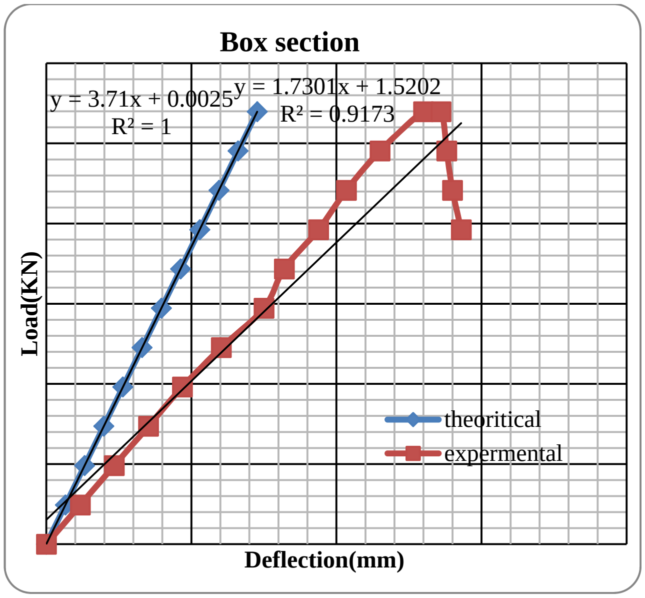
Graph 1: Load-Deflection curve of I beam made of two channels connected back to back.

It is evident from the Graph1 that the theoretical and experimental values are approximately coinciding with each other up to a load of 5KN.Beyond this value beam lost some contact with the supports because of the development of torsion.

3.2 Testing of Box Section

This section was also tested on a loading frame with suitable arrangements. The load was increased in intervals of 250 kg. The maximum load and the deflection at the failure were 2750 kg and 13.6mm respectively. The theoretical values of maximum load and deflection were 4607 kg and 12.19 mm respectively. The failure of the section was due to development of high bearing stresses under the concentrated load as shown in Fig (3.2.1).The test results have been plotted in the form of graph between load and deflection as shown in Graph 2.The disparity between the theoretical and experimental plot is due to the absence of stiffening element under the load

Fig. 3.2.1: Failure of Box Section



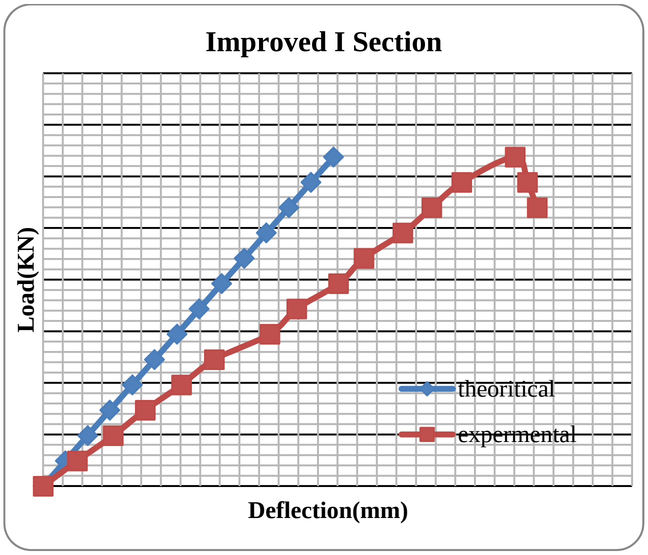
Graph 2: Load-Deflection curve of Box Section

3.3 Testing of I beam made of a channel and two angles connected to channel

I beam of requisite dimensions as shown in Fig1(c) was placed on a loading frame with suitable arrangements in place. The load was increased in intervals of 250 kg . The maximum load and the deflection at the failure were 3250 kg and 9.62mm respectively. The theoretical values of maximum load and deflection were 3268 kg and 5.95 mm respectively. The failure was predominantly torsional in nature accompanied with local buckling as shown in Fig (3.3.1)

Fig. 3.3.1: Failure of I beam made of a channel and two angles connected to channel

The test results have been plotted in the form of a graph between load and deflection as shown in Graph 3



Graph 3: Load-Deflection curve of I beam made of a channel and two angles connected to channel

The behavior of this section was similar to that of I beam made of two channels connected back to back however it resisted larger load and deflections were also reduced .From the Graph 3 it is clearly evident that the theoretical and experimental values are approximately coinciding with each other up to a load of 5KN. Beyond this value beam lost little contact with the supports because of the development of torsion.

4. CONCLUSIONS

The efficiency of sections was judged on the basis of moments and deflections produced. The overall results can be summarized below in Table1 and Table 2.

Table 4: Comparison of experimental and theoretical loads and moments

Section	Theoritical load (kN)	Experimental load (kN)	Theoritical Moment(kNm)	Experimental Moment (kNm)
I Section	51.01	29.43	12.75	7.35
Box Section	45.2	26.98	11.3	6.745
Improved-I Section	32.063	31.88	8.015	7.97

Table 5: Comparison of experimental and theoretical deflections

Section	Max. Theoritical Deflection (mm)	Max.Experimental Deflection (mm)
I section	11.87	9.3
Box Section	12.19	13
Improved-I section	5.95	9.62

Analysis of test experimental results reveals that improved I section (channel and two angles connected back to back with channel) was structurally and economically most efficient. The moment capacity of this section came out to be 8.32% more than I section made of two channels connected back to back and 18.16% more than box section. The amount of steel was almost kept same in all three sections. It was observed there was a linear relationship between load and deformation upto certain limit and beyond that non-linearity came into picture even though material did not reach its yield strength. The possible reasons could be:

- Surface irregularities of metal sheets.
- Non availability of controlled loading arrangement.
- Possible eccentricities leading to torsional failure

5. ACKNOWLEDGEMENTS

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