Experimental Study on Behaviour of Cruciform and Modified Cruciform Steel Section

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Abstract

Steel has become the predominate material for the construction of bridges, buildings, towers, and other structures. Steel exhibits a desirable physical property that makes it one of the most versatile structural materials in use. Its great strength, uniformity, light weight, ease of use, and many other desirable properties makes it the material of choice for numerous structures such as steel bridges, high rise buildings, towers, and other structures. Column is one of the important structural elements in any type of Structures. Steel columns sometimes cannot provide the necessary strength because of buckling. The steel sections manufactured in rolling mills and used as structural members are known as rolled structural steel sections. The steel sections are named according to their cross sectional shapes. Rolled steel Sections the most desirable members are those with large moments of inertia in proportion to their areas can be used into a wide variety of shapes and sizes to avoid torsional buckling.

This paper presents the findings from an experimental study on steel column subjected to constant axial force. Three Different categories of cross-sections such as I section, cruciform section (Plus section) and modified cruciform section (Double Tee-inverted) were designed. Totally Nine scale model columns were fabricated based on the proposed design methodology and were subjected to Axial Loading. Parametric studies such as Load Vs deflection, failure behaviour of short columns were discussed. From the experimental study it was concluded that the cruciform section performed well than modified cruciform section.

Keywords — *Torsional effect, I – section, Cruciform, Modified cruciform, Controlling factor of torsional buckling.*

I. INTRODUCTION

Steel sections have found their development in design of enormous structures over the past years. Steel has high strength per unit mass which enhances the usage of it. Among steel section prevalently used is I -section. Industrial usage of I -section is more than 100 tones. Reasons for such wide practice is effective load transmission and sustain design loads. The section has adequate durability and withstands deformations during and after construction.

I -section is a most influential section because of the universal benefits and economic in all regions. Such powerful section is only used in all the places irrespective of the load requirement.

For many high loads carrying member we can use other sections. One such member is cruciform section. A cruciform section is otherwise known as open cross section. This can also be referred as doubly symmetric section.

The section is formed with the help of two TEE section, in which one is inverted Tee – section appears to be a rectangular hollow section with extended flanges on its four sides. No two extended flanges are in same direction. Hence the section is modified and its torsional rigidity is enhanced. Similarly, the section is rearranged with its own basic elements alone.

The theoretical data are calculated using Indian Standard code IS 875-1975 (part III), IS 800 – 2007 using limit state method, IS 800- 1984 using working stress method and the section properties of the specimens are obtained using steel table.

A. *Objective of study*

The following are the objectives of the present study:

- To increase the usage of cruciform section for various high load requirement situations.
- To enhance usage of economic sections.
- To avoid torsional buckling of steel section.
- To reduce the utilization of raw material to produce economic sections.

B. *Scope of study*

The universe is virtually using concrete in the construction field. Comparatively steel is also growing in construction field for high raised structures. But the usage is limited due to susceptible to corrosion and availability of raw material. Mainly in India steel structures are less in number in universal scale.

Additionally, to find whether the section is torsional resistant and its buckling resistance of those sections in various end connections.

II. LITERATURE REVIEW

Afonso etal., 2015 studied the characterization of the shear behavior of rectangular double column panels attached to beams of unequal depths. In addition, a cruciform finite element that captures the behavior of the proposed mechanical model has been developed. This general cruciform element is also suitable for semi-rigid connections and can be used for global analysis of semi-rigid steel frames.

Mahmood Md Tahir et al., 2009 discussed "Experimental investigation of short cruciform columns using universal beam sections" The cruciform steel column is made up of two universal beam sections where one of the beam sections is cut into two pieces along in longitudinal axis, and connected to the other beam section by fillet welding to form the cruciform shape. This study has concluded that cruciform column using universal beam section provides an alternative column sections that increase the axial capacity, stiffness of the column and reduce the total steel weight.

Nicholas s. Trahar (2012) studied on "Strength design of cruciform steel columns" in enlightening the buckling resistance. Very different strengths are predicted by two different methods of designing steel cruciform columns. Both methods require design against local and flexural buckling, and while one method also requires design against torsional buckling, the other does not.

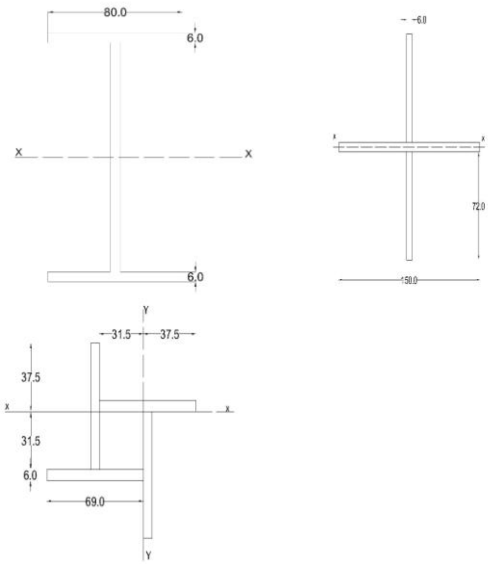
Erling Murtha Smith (1988) et al., discussed the "Restrained Warping in Cruciform Compression Members". The primary parameters controlling torsional buckling mode are the width/thickness ratio of the outstanding legs, and the degree of warping restraint provided by the supports, the interconnectors, and the separation gap between the angles. Results are reported of an analytic and numerical study on the effects of warping restraint on the torsional stiffness and on the torsional buckling capacity.

Erling A. Smith studied the (1988) "Buckling of Four Equal - Leg Angle Cruciform Columns. The elastic and inelastic buckling of cruciform section columns formed from four equal leg angles is examined. The results of this analysis are compared with empirical methods in current specification indicate that the specifications are not conservative for all values of slenderness and width to thickness ratios.

Nicos Makris studied (2003) on "Plastic Torsional Buckling of Cruciform Compression Members" In this paper the plastic torsional buckling of a cruciform column is revisited. He concluded that when the flanges of the column are not perfectly straight, the incremental theory of plasticity predicts that at the onset of plastic torsional buckling, the shear stress and the shear strain are related with the tangent shear modulus. Experimental evidence supporting the theoretical findings is presented.

III. DESIGN OF STEEL SECTION

Theoretical design of three Different categories of cross-sections such as I section, cruciform section (Plus section) and modified cruciform section (Double Tee-inverted) with three support conditions are discussed. The Cruciform section is commonly known as open cross section. It can also be called as doubly symmetric section since it is symmetric about both x-axis and y-axis. Section properties of cruciform formed by rectangular plate are not available in steel table. Hence the section is designed by conventional procedure. Fig. 1. Shows the details of the cross section.



All Dimensions are in mm
Fig 1: I section, Cruciform and modified Cruciform Section

IV. EXPERIMENTAL INVESTIGATION

A. Materials

Light Gauge Steel Physical Properties:

The rolled steel sheet is used. The physical properties of light gauge steel section given in Table 1. The properties of the section taken from the Indian Standard code IS 800-2007.

TABLE I
PHYSICAL PROPERTIES OF LIGHT GAUGE STEEL SECTION

Density of Steel	7850 kg/m^3
Modulus of elasticity	2 x 10^5 N/mm^2
Poisson ratio	0.3
Modulus of rigidity	0.769 x 10^3 N/mm^2
Co Efficient of thermal Expansion	12 x 10^{-6} / ^{0}C

The steel columns for various cross sections are designed according to the three end condition. The results are presented in the Table II.

TABLE III
Crippling Load For Various Sections

Section	End Condition			
	Crippling load for kl= 2.0 Load in kN	**Crippling load for KL=1.0 Load in kN**	**Crippling load for KL=0.65 Load in kN**	**Area of the Section in mm^2**
I section ISLB 150X80	203.84	343.5	380.3	1788
Cruciform	301.22	374.15	394.15	1764
Modified Cruciform	85.3	150.14	298.08	1656

An experimental test was carried on the various sections on the Universal Testing Machine (UTM) of 1000kN capacity. The columns specimens were tested to study the failure load, load strain behavior and ultimate load. The specimens were externally confined by 10mm thick mild steel collars in the top during testing to prevent failure. The test setup for the columns is shown in Figures 2 to Figure 4.

Fig 2: Fabrication, Testing and Buckling of I – section

Fig 3: Fabrication, Testing and Buckling of Cruciform

Fig 4: Fabrication, Testing and Buckling of Modified Cruciform

The analytical and experimental result for both ends hinged are presented in Table III.

TABLE IIIII

Ultimate load of Section

Section	Design Load (kN)	Buckling load (kN)
I-section ISLB 150x80	380.23 kN	560.5 kN
Cruciform	395.72 kN	660 kN
Modified Cruciform	360.37 kN	565.5 kN

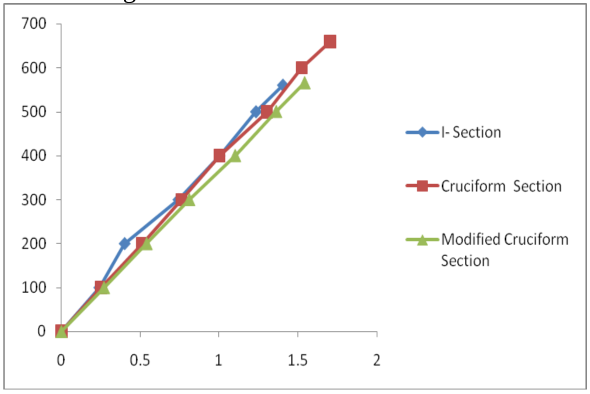
V. RESULTS AND DISCUSSION

The steel structures for various cross sections are designed according to the three end condition. The results are presented in the Table II.

From the results it was observed that the cruciform section gives the highest load for all the end condition. For one end fixed and other end is hinged the percentage decrease in load carrying capacity of I section is 32.25% and 71.68% for modified cruciform section when compared to Crucifrom section . But when the columns are fixed in both end the percentage decrease in load carrying capacity of I section is 3.51% and 24.37% for modified cruciform section when compared to Crucifrom section. When the columns are hinged at both ends the percentage decrease in load carrying capacity of I section is 8% and 59.87% for modified cruciform section when compared to Cruciform section.

From the experimental result presented in Table III When the columns are hinged at both ends the percentage decrease in load carrying capacity of I section is 15% and 14.31 % for modified cruciform section when compared to Cruciform section which is less area of cross section than I section.

The failure modes of all three types of columns are shown in Fig. 2, 3 & 4. The load deflection curve shown in Fig. 5 .The deflections was observed every 100kN increment. From the curve it was noted that larger displacements occurs in axial directions of modified cruciform sections. For first 100kN loading the percentage increase in the deflection in modified cruciform section is 12.5% when compared to I section and 8% when compared to cruciform section. Whereas the percentage increase in deflection in cruciform section is 4.167% higher than I section. When further loading, the deflection in 200kN of loading the percentage increase in the deflection in modified cruciform section is 27.5% when compared to I section and 35% when compared to cruciform section. Whereas the percentage increases in deflection in cruciform section is 5.88% higher than I section. For 300kN of loading, the percentage increase in the deflection in modified cruciform section is 9.45% when compared to I section and 6.57% when compared to cruciform section. Whereas the percentage increases in deflection in cruciform section is 2.702% higher than I section. There were not changes in deflection in 400kN of loading. But the loading at 500kN the percentage increase in the deflection in modified cruciform section is 10.569% when compared to I section and 4.615% when compared to cruciform section. Whereas the percentage increases in deflection in cruciform section is 5.38% higher than I section.



Deflection in mm

Fig 5: Load Vs Deflection Curve for Various Sections

VI. CONCLUSION

From the Design it was concluded that the Cruciform section can be suitable selected for efficient load carrying capacity and Economical usage of steel materials in structural members.

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