

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 5, May 2018

Strength of Flanged and Plain Cruciform Steel Section used as Column Members

Pabbisetty Sai Kiran¹, Dr.M.Usha Rani², J.Martina Jenifer³, S.Kavya⁴

U.G. Student, Department of Civil Engineering, RMK Engineering College, Kavaraipettai, Chennai, India¹

Professor, Department of Civil Engineering, RMK Engineering College, Kavaraipettai, Chennai, India²

Assistant Professor, Department of Civil Engineering, RMK Engineering College, Kavaraipettai, Chennai, India²

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 study involves in examination of theoretical design of Three Different categories of cross-sections such as I section, cruciform section (Plus section) and modified cruciform section (Double Tee-inverted) for the possible use of section as columns members. From the study it was concluded that the cruciform section shows higher load than that of the 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.

Objective of study

The following are the objectives of the present study:

- To increase the usage of modified cruciform section for various high load requirement situations.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 5, May 2018

- To enhance usage of economic sections.
- To avoid torsional buckling of cruciform section.
- To reduce the utilization of raw material to produce economic sections.

Scope of study

The universe is vitally 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.

In order to improve the situation mentioned section and use effectively in our environment.

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

II. LITERATURE REVIEW

Afonsoetal., 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.

MahmoodMdtahir 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.

NicosMakris 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

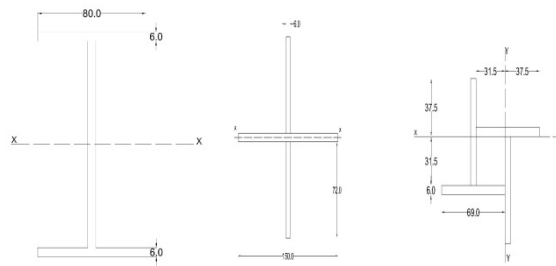
Theoretical design of three Different categories of cross-sections such as I section, cruciform section (Plus section) and modified cruciform section (Double Tee-inverted) with three support conditions are discussed. The Cruciform section is commonly known as open cross section. It can also be called 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.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 5, May 2018



All Dimensions are in mm

Fig.1. I section, Cruciform and modified Cruciform Section

(i) Design of I section

Area of I-section

$$A = (80 \times 6) + (80 \times 6) + (138 \times 6) = 1788 \text{ mm}^2$$

Moment of Inertia along x-axis

$$I_{xx} = (bd^3)/12 + A(y-y_1)^2$$

$$I_{xx} = 6.29 \times 10^6 \text{ mm}^4$$

Moment of Inertia

$$\text{Along X-axis } I_{xx} = 6.29 \times 10^6 \text{ mm}^4$$

$$\text{Along Y-axis } I_{yy} = 0.552 \times 10^6 \text{ mm}^4$$

$$\text{Along Z-axis } I_{zz} = 6.882 \times 10^6 \text{ mm}^4$$

Radius of gyration

$$\text{Along x-axis } r_x = \sqrt{(I_{xx}/A)} = \sqrt{((6.29 \times 10^6)/1788)} = 59.31 \text{ mm}$$

$$\text{Along Y-axis } r_y = 17.5 \text{ mm}$$

$$\text{Along z-axis } r_z = 61.7 \text{ mm}$$

End Condition: (As per IS 800:2007)

Condition 1: Both ends are fixed

$$Kl = 0.65L$$

Here length of I-section = 900mm

$$kl/r_y = 0.65 \times 900 / 17.5 = 33.43$$

(As per IS 800:2007, page number: 34)

$$P_d = A_c \times f_{cd}$$

Calculation of f_{cd}

(As per IS 800:2007, page number: 44 Table: 10)

Type of section: Rolled I-section

Condition: Buckling about y-y axis

$$t_f \leq 40 = 6.8 < 40 = 6.8 < 40$$

Buckling class along 'b'

(from table: 9b page number 41 of IS 800:2007)

$$kl/r_y = 33.43 \text{ and } f_y = 250 \text{ N}/(\text{mm}^2)$$

$$\therefore f_{cd} = 212.56 \text{ N}/(\text{mm}^2)$$

$$\therefore \text{Crippling load } P_d = A_c \times f_{cd} = 1788 \times 212.56 = 380.3 \text{ kN}$$

$$\therefore \text{Working load } P = P_d / 1.5 = 380.3 / 1.5 = 253.37 \text{ kN.}$$

Condition 2: Both ends are hinged

$$Kl = 1.0L$$

Here length of I-section = 900mm

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 5, May 2018

$$kl/r_y = 1.0 \times 900 / 17.5 = 51.43$$

(As per IS 800:2007, page number: 34)

$$P_d = A_c \times f_{cd}$$

Calculation of f_{cd}

(As per IS 800:2007, page number: 44 Table: 10)

Type of section: Rolled I-section

Condition: Buckling about y-y axis

$$t_f \leq 40 = 6.8 < 40 = 6.8 < 40$$

Buckling class along 'b'

(from table: 9b page number 41 of IS 800:2007)

$$kl/r_y = 51.43 \text{ and } f_y = 250 \text{ N}(\text{mm}^2)$$

$$\therefore f_{cd} = 192.14 \text{ N}(\text{mm}^2)$$

$$\therefore \text{Crippling load } P_d = A_c \times f_{cd} = 1788 \times 192.14 = 343.5 \text{ kN}$$

$$\therefore \text{Working load } P = P_d / 1.5 = 343.5 / 1.5 = 229.03 \text{ kN}$$

Condition 3: When one end is fixed and other end is free

$$Kl = 2.0L$$

Here length of I- section = 900mm

$$kl/r_y = 2.0 \times 900 / 17.5 = 102.85$$

(As per IS 800:2007, page number: 34)

$$P_d = A_c \times f_{cd}$$

Calculation of f_{cd}

(As per IS 800:2007, page number: 44 Table: 10)

Type of section: Rolled I-section

Condition: Buckling about y-y axis

$$t_f \leq 40 = 6.8 < 40 = 6.8 < 40$$

Buckling class along 'b'

(from table: 9b page number 41 of IS 800:2007)

$$kl/r_y = 102.85 \text{ and } f_y = 250 \text{ N}(\text{mm}^2) : f_{cd} = 114.01 \text{ N} / \text{mm}^2$$

$$\therefore \text{Crippling load } P_d = A_c \times f_{cd} = 1788 \times 114.01 = 203.84 \text{ kN}$$

$$\therefore \text{Working load } P = P_d / 1.5 = 203.84 / 1.5 = 135.9 \text{ kN}$$

(ii) Design of Cruciform section

$$\text{Area of steel } A_c = (6 \times 72 \times 2) + 150 \times 6 = 1764 \text{ mm}^2$$

Centroid axis (x-x)

$$y_1 = 72 / 2 = 36 \text{ mm}$$

$$y_2 = 72 + 6 / 2 = 75 \text{ mm}$$

$$y_3 = 72 + 6 + 72 / 2 = 114 \text{ mm}$$

Centroid of section $y_0 = 75 \text{ mm}$

$$\text{Moment of Inertia } I_{yy} = (bd^3) / 12 + A (y-y_0)^2$$

$$I_{yy} = 1.629 \times 10^6 \text{ mm}^4$$

Moment of Inertia along x-x axis

$$I_{xx} = (dx^3) / 12$$

$$I_{zz} = 3.37 \times 10^6$$

Radius of gyration

$$\text{Along x- axis } r_x = \sqrt{(I_{xx} / A)} = \sqrt{((1.681 \times 10^6) / 1764)} = 30.96 \text{ mm}$$

$$\text{Along y- axis } r_y = \sqrt{(I_{yy} / A)} = \sqrt{((1.69 \times 10^6) / 1764)} = 30.95 \text{ mm}$$

$$\text{Along z- axis } r_z = \sqrt{(I_{zz} / A)} = \sqrt{((3.37 \times 10^6) / 1764)} = 43.7 \text{ mm}$$

End Condition: (As per IS 800:2007)

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 5, May 2018

Condition 1: Both ends are fixed

$$Kl = 0.65L$$

Length of cruciform section = 900mm

$$kl/r_y = 0.65 \times 900 / 30.95 = 18.9$$

(As per IS 800:2007-page number: 34)

$$P_d = A_c \times f_{cd}$$

Calculation of f_{cd}

(As per IS 800:2007-page number: 44 Table: 10)

Type of section: Solid Sections

Condition: Buckling about y-y axis

Buckling class along 'c'

(from table: 9c page number 42 of IS 800:2007)

$$kl/r_y = 18.9 \text{ and } f_y = 250 \text{ N/mm}^2 = \therefore f_{cd} = 223.44 \text{ N/mm}^2$$

$$\therefore \text{Crippling load } P_d = A_c \times f_{cd} = 1764 \times 223.44 = 394.15 \text{ kN}$$

$$\therefore \text{Working load } P = P_d / 1.5 = 394.15 / 1.5 = 262.76 \text{ kN}$$

Condition 2: Both ends are hinged

$$Kl = 1.0L$$

Length of cruciform section = 900mm

$$\frac{kl}{r_y} = \frac{1.0 \times 900}{30.95} = 29.08$$

(As per IS 800:2007 page number: 34)

$$P_d = A_c \times f_{cd}$$

Calculation of f_{cd}

(As per IS 800:2007 page number: 44 Table: 10)

Type of section: Solid Sections

Condition: Buckling about y-y axis

Buckling class along 'c'

(from table: 9c page number 42 of IS 800:2007)

$$\frac{kl}{r_y} = 29.08 \text{ and } f_y = 250 \text{ N/mm}^2$$

$$\therefore f_{cd} = 212.17 \text{ N/mm}^2$$

$$\therefore \text{Crippling load } P_d = A_c \times f_{cd} = 1764 \times 212.17 = 374.15 \text{ kN}$$

$$\therefore \text{Working load } P = \frac{P_d}{1.5} = \frac{374.26}{1.5} = 249.51 \text{ kN}$$

Condition 3: When one end is fixed and other end is free

$$Kl = 2.0L$$

Length of cruciform section = 900mm

$$\frac{kl}{r_y} = \frac{2.0 \times 900}{30.95} = 58.16$$

(As per IS 800:2007 page number: 34)

$$P_d = A_c \times f_{cd}$$

Calculation of f_{cd}

(As per IS 800:2007 page number: 44 Table: 10)

Type of section: Solid Sections

Condition: Buckling about y-y axis

Buckling class along 'c'

(from table: 9c page number 42 of IS 800:2007)

$$\frac{kl}{r_y} = 58.16 \text{ and } f_y = 250 \text{ N/mm}^2$$

$$\therefore f_{cd} = 170.76 \text{ N/mm}^2$$

$$\therefore \text{Crippling load } P_d = A_c \times f_{cd} = 1764 \times 170.76 = 301.22 \text{ kN}$$

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 5, May 2018

$$\therefore \text{Working load } P = \frac{P_d}{1.5} = \frac{301.22}{1.5} = 200.81 \text{ kN}$$

(iii) Design of modified cruciform section:

$$\text{Area of steel } A_c = (69 \times 6) \times 4 = 1656 \text{ mm}^2$$

$$\text{Centroid Axis } y_0 = 25.94 \text{ mm}$$

Moment of Inertia

$$I_{yy} = (bd^3)/12 + A (y-y_1)^2$$

$$I_{yy} = 209.64 \times 10^3 \text{ mm}^4$$

$$\therefore I_{xx} = I_{yy} = 209.64 \times 10^3$$

Radius of gyration

$$r_x = r_y = \sqrt{\frac{I_{xx}}{A}} = \sqrt{\frac{209.64 \times 10^3}{1656}} = 11.25 \text{ mm}$$

Condition 1: Both ends are fixed

$$Kl = 0.65L$$

Length of cruciform section = 900mm

$$\frac{kl}{r_y} = \frac{0.65 \times 900}{11.25} = 52$$

(As per IS 800:2007 page number: 34)

$$P_d = A_c \times f_{cd}$$

Calculation of f_{cd}

(As per IS 800:2007 page number: 44 Table: 10)

Type of section: Solid Sections

Condition: Buckling about y-y axis

Buckling class along 'c'

(from table: 9c page number 42 of IS 800:2007)

$$\frac{kl}{r_y} = 52 \text{ and } f_y = 250 \text{ N/mm}^2$$

$$\therefore f_{cd} = 180.250 \text{ N/mm}^2$$

$$\therefore \text{Crippling load } P_d = A_c \times f_{cd}$$

$$= 1656 \times 180 = 298.08 \text{ kN}$$

$$\therefore \text{Working load } P = \frac{P_d}{1.5} = \frac{298.08}{1.5} = 198.72 \text{ kN}$$

Condition 2: Both ends are hinged

$$Kl = 1.0L$$

Length of cruciform section = 900mm

$$\frac{kl}{r_y} = \frac{1.0 \times 900}{11.25} = 80$$

(As per IS 800:2007 page number: 34)

$$P_d = A_c \times f_{cd}$$

Calculation of f_{cd}

(As per IS 800:2007 page number: 44 Table: 10)

Type of section: Solid Sections

Condition: Buckling about y-y axis

Buckling class along 'c'

(from table: 9c page number 42 of IS 800:2007)

$$\frac{kl}{r_y} = 80 \text{ and } f_y = 250 \text{ N/mm}^2 \therefore f_{cd} = 136 \text{ N/mm}^2$$

$$\therefore \text{Crippling load } P_d = A_c \times f_{cd} = 1656 \times 136 = 225.23 \text{ kN}$$

$$\therefore \text{Working load } P = \frac{P_d}{1.5} = \frac{225.23}{1.5} = 150.14 \text{ kN}$$

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 5, May 2018

Condition 3: When one end is fixed and other end is hinged

$$Kl = 2.0 L$$

Length of cruciform section = 900mm

$$\frac{kl}{r_y} = \frac{2.0 \times 900}{11.25} = 160$$

(As per IS 800:2007 page number: 34)

$$P_d = A_c \times f_{cd}$$

Calculation of f_{cd}

(As per IS 800:2007 page number: 44 Table: 10)

Type of section: Solid Sections

Condition: Buckling about y-y axis

Buckling class along 'c'

(from table: 9c page number 42 of IS 800:2007)

$$\frac{kl}{r_y} = 160 \text{ and } f_y = 250 \text{ N/mm}^2 \therefore f_{cd} = 51.5 \text{ N/mm}^2$$

$$\therefore \text{Crippling load } P_d = A_c \times f_{cd} = 1656 \times 51.5 = 85.3 \text{ kN}$$

$$\therefore \text{Working load } P = \frac{P_d}{1.5} = \frac{85.3}{1.5} = 57 \text{ kN}$$

IV. 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 1.0.

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 Cruciform section. But when the columns are fixed in both ends the percentage decrease in load carrying capacity of I section is 3.51% and 24.37% for modified cruciform section when compared to Cruciform 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.

Table. 1.0 Crippling Load for various sections

Section	End Condition			Area of the Section in mm ²
	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	
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

V. 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.



ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 5, May 2018

REFERENCES

- [1] Charles king. (2006) 'Design of cruciform section by BS Euro codes'.
- [2] Erling A Smith. (2008) 'Buckling of four equal-leg Angle Cruciform Columns' ASCE volume 107.
- [3] Edwin H, Gaylord. (1992) 'Design of Steel Structures'.
- [4] IS 800-2007 Indian Standard General Construction in Steel - code of practice (3rd Revision).
- [5] N.S. Trahair. (1993) 'Flexural-Torsional Buckling of structures'.
- [6] Nico Makris from ASCE 0733. (2003) 'Plastic Torsional Buckling of Cruciform Compression Members', Journal of Engineering Mechanics- Volume 129, Issue 6.
- [7] N. Subramanian, 'Design of Steel Structures'.
- [8] Seven Eilif Svensson and Carsten Munk Plum.(1983) 'Stiffener effect on Torsional Buckling of columns', Journal of Structural Engineering, Volume 109, Issue 3,.
- [9] S.S. Bhavikatti. (2009) 'Design of Steel Structures'.
- [10] Roger L, Frederick S. (2011) 'Design of Steel Structure Handbook'.