© 2018 IJSRSET | Volume 4 | Issue 9 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology

Comparative Study and Analysis of Cold Formed Steel Columns Subjected to Axial Loading

Priyanka R. Lokhande[1], G. C. Jawalkar[2]
[1]PG. Student, Department of Civil Engineering, N B N Sinhgad College of Engineering, Solapur, Maharashtra, India
[2]Assistant Professor, Department of Civil Engineering, N B N Sinhgad College of Engineering, Solapur, Maharashtra, India

ABSTRACT

Cold formed steel are nowadays used for building construction especially non-load bearing partitions, curved wall etc due to its flexural strength, load carrying capacity and good appearance. In this paper detailed study of cold formed steel has been carried out to predict load carrying capacity of a column using Indian Standard IS 801-1975, British Standard BS 5950-5:1998, finite element software ABAQUS . A series of parametric tests were also carried out to compare the performance of different shapes of channel sections at various lengths (500mm, 600mm and 700 mm).The results indicate that the channel sections with intermediate stiffener carry greater load and show less deformation as compared to plain channel section and lipped channel section. The details of these investigation and the outcomes are presented in this paper.

Keywords: Cold Formed Steel, Load Carrying Capacity, IS 801-1975, BS 5950-5:1998, Finite Element Software, Experimental Tests.

I. INTRODUCTION

Steel can be classified in to two main groups that is hot-rolled steel and cold-formed steel sheet. Cold formed steel are made up of thin sheets which are bent or rolled into required shapes by press brake machines at ambient temperature. The advantages of using Cold formed steel are high length-to-weight ratio, lighter in weight thus reducing the weight of structure, easy for construction and flexibility in fabricating different cross section shapes. Moreover, most of the process is controlled by machine and computer, it is more economic and easy for transportation and handling to site or at confined space. Cold formed steel sections are highly susceptible to instability phenomenon such as local, distortional and global buckling. Depending on columns cross section, length and end support conditions, its post-buckling behaviour and ultimate strength can be significantly affected by interactions involving various buckling modes.

Local buckling occurs where the axis of the member is not distorted, but the strength of the cross section is compromised by the buckling component of the cross section. It is an extremely important factor of cold-formed steel sections on account of the fact that the very thin elements used invariably buckle before yielding. One of the biggest difficulties with cold-formed steel design is the prevention of member buckling. Because of the low thickness to width ratio, it is likely that the members will buckle at stresses that are lower than the yield stress when compressive, bearing, and shear bending forces are applied. Therefore, buckling is a major design consideration for all cold-formed steel, which is unlike the behavior of hot-rolled steel where steel yielding is the leading design consideration.

In this study, a series of column tests were conducted on plain channel sections, lipped channel sections and lipped channel with intermediate stiffener sections by varying lengths (500mm, 600mm, 700mm) of sections. Therefore the Load Carrying Capacity (LCC) of plain channel section, lipped channel section and lipped channel with intermediate stiffener sections as per IS 801-1975, BS 5950-5:1998, ABAQUS and by experimental investigation were determined by applying load at CG of section.

Analytical Calculations:

To find out ultimate compressive strength of cold formed steel light gauge section of 1.6 mm thickness, both ends fixed boundary condition were selected. Considering this, the calulation of ultimate load capacity is done. Using Plain Channel,lipped channel section and lipped with intermediate stiffner of length 500 mm, 600 mm and 700 .

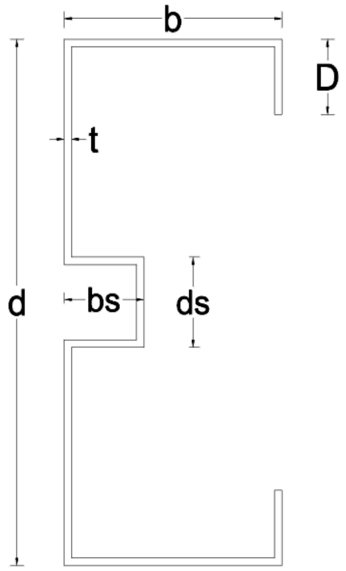


Figure 1. Labeling of different Cross Section

Table 1. Dimension of Models

Specimen Modeling	Lmm	dmm	bmm	tmm	Dmm	Dsmm	bsmm
P-500	500	130	40	1.6	0	0	0
P-600	600	130	40	1.6	0	0	0
P-700	700	130	40	1.6	0	0	0
L-500	500	130	40	1.6	20	0	0
L-600	600	130	40	1.6	20	0	0
L-700	700	130	40	1.6	20	0	0
S-500	500	130	40	1.6	20	20	20
S-600	600	130	40	1.6	20	20	20
S-700	700	130	40	1.6	20	20	20

Computation as per IS Code 801-1975 of practice for use of cold formed light gauge steel structural members in general building construction.

3.1.1 Calculation of Effective Area :

As per clause 6.1, Page No 11, IS 801-1975,

Basic allowable design stress, f = 0.6 Fy

As per clause 5.2.1.1, Page No 6, IS 801-1975,

Flanges are fully effective b = w upto $(\frac{w}{t})\lim = \frac{1435}{\sqrt{f}}$

where,

w = flat width.

b = effective design width.

Fy = yield point or yield strength.

f = Basic allowable design stress.

For flange with w/t larger than (w/t)lim

$$\frac{b}{t} = \frac{2120}{\sqrt{f}}(1 - \frac{465}{(w/t)\sqrt{f}}$$

For flange with w/t lesser than (w/t)lim,

$b_{eff} = w$

3.1.2. Calculation for Load Carrying Capacity (LCC):

As per clause 6.6.1.1, Page No 18, IS 801-1975,

$$\frac{kL}{r} < \frac{Ce}{\sqrt{Q}}$$

Hence, $Fa_1 = \frac{12}{23}QFy - \frac{3(QFy)^2}{23\pi^2 E}\left(\frac{kl}{r}\right)^2$

where,

$$Ce = \sqrt{\frac{2\pi^2 E}{Fy}}$$

A = full unreduced cross-sectional area of the member.

E = modulus of elasticity.

Fa_1 = allowable average compression stress under concentric loading.

k = effective length factor.

L = unbraced length of member.

Q = Ratio between the effective design area and the gross area of the cross section.

r = radius of gyration of full, unreduced cross section.

Load Carrying Capacity = Fa_1X Agross

3.2. Computation as per British Standard 5950-5:1998: Code of practice for design of cold formed thin gauge section.

3.2.1. Calculation of Effective Cross Section Area :

As per Clause 6.1.2, Page No. 27, BS 5950-5:1998,

$$Q = \frac{A_{eff}}{A}$$

where,

A_{eff} = Effective cross sectional area.

A = Gross cross sectional area.

A_{eff} can be calculated as follows :

For stiffened element, k = 4,

For unstiffened element, k = 0.425

The effective width for stiffened element can be calculated as per Clause 4.4.1, Page No. 12, BS 5950-5:1998,

$$\frac{b}{t} = \left(\frac{b}{t}\right)_{actual} X \left(\frac{b}{t}\right)_{modified}$$

$$\frac{b}{t} = \left(\frac{b}{t}\right)_{actual} X \sqrt{\left(\frac{fc}{280}\right)\left(\frac{4}{k}\right)}$$

The effective width for unstiffened element can be calculated as per Clause 4.5.1, Page No. 14, BS 5950-5:1998,

$$\frac{b}{t} = \left(\frac{b}{t}\right)_{actual} X \left(\frac{b}{t}\right)_{modified}$$

$$\frac{b}{t} = \left(\frac{b}{t}\right)_{actual} X \sqrt{\left(\frac{fc}{280}\right)\left(\frac{0.425}{k}\right)}$$

where,

b = Flat width of an element.

fc = Compressive strength on the effective element.

k = Buckling coefficient of an element.

t = material thickness

3.2.2. Calculation of Ultimate Loads:

As per Clause 6.2.3, Page No. 27, BS 5950-5:1998,

The buckling resistance under axial load, P_c, can be calculated as,

$$Pc = \frac{P_E P_{cs}}{\phi + \sqrt{\phi^2 - P_E P_{cs}}}, \text{ where } \phi = \frac{P_{cs} + (1+\eta)P_E}{2}$$

P_{cs} is the short strut capacity

$P_{cs} = A_{eff}$ X P_y

Effective Length L_E = 0.65L foe both ends fixed.

P_E is the minimum elastic flexural buckling load,

$$P_E = \frac{\pi^2 EI}{L_E^{\ 2}}$$

η is the Perry coefficient and is calculated as,

For $L_E/r < 20$, $\eta = 0$

For $L_E/r > 20$, $\eta = 0.002(L_E/r - 20)$

where,

E = Modulus of elasticity of steel.

I = Second moment of area of a cross-section about its critical axis.

r = Radius of gyration.

3.2.3. Calculation of Load Carrying Capacity (LCC):

As per clause 6.2.4, Page No. 27, BS 5950-5:1998,

Load carrying capacity of a column is,

$$P_c^I = \frac{M_c P_c}{(M_c + P_c e_s)}$$

where, e_s is the distance between the geometric neutral axis of the gross cross-section and that of the effective cross-section,

*M*c is the moment capacity determined in accordance with Clause 5.2.2, Page No 17, BS 5950-5:1998,

Mc = Po.Se

where Se = Section Modulus = $\dfrac{I_{xx}}{d/2}$

$$p_o = \left\{1.13 - 0.0019\frac{D_w}{t}\left(\frac{Y_s}{280}\right)^{\frac{1}{2}}\right\}P_y$$

or $p_o = p_y$ whichever is less.

where,

D_w = Equivalent depth of a stiffened element.

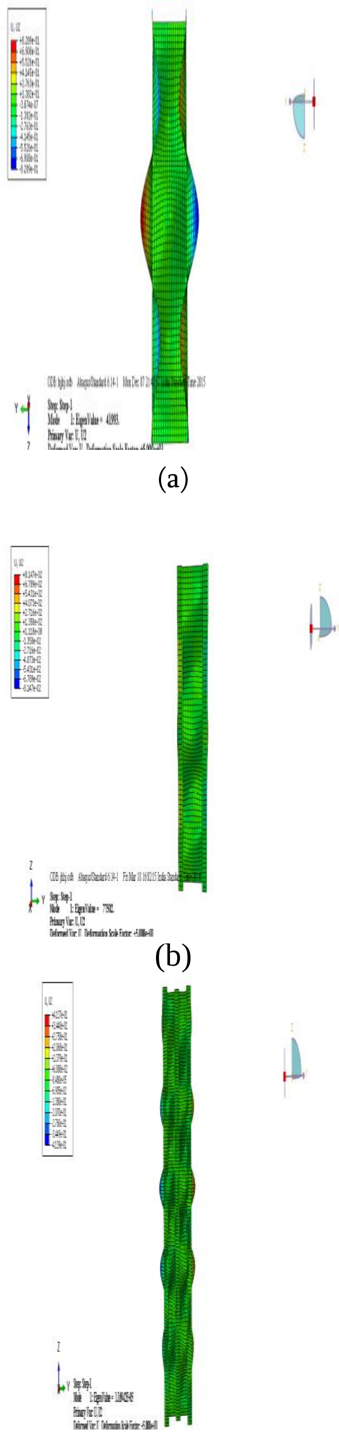
p_o = Limiting compressive stress in a flat web.

Y_s = Nominal yield strength of steel.

4. FINITE ELEMENT ANALYSIS

All the sections were modelled in ABAQUS with both ends fixed. The sections were considered as a thin shell for analysis and both ends were tied with MPC constraints by giving a reference point at a distance of CG of X axis, so that the cross-section act as a one body and hence by assigning the boundary conditions to both ends at tied reference point with 1 N load along Z direction, analysis was performed as shown in Figure 4. So we obtain the Eigen values from analysis. The finer the meshing the accurate would be your results. Load Carrying Capacity of a column is thus given by:

Load Carrying Capacity = Least Eigen value / Applied Load



(a) (b) (c)

Figure 4. Eigen Value for Mode 1 in ABAQUS for (a) Plain Channel section of 500mm length, (b) Lipped Channel section of 500mm length, (c) Lipped Channel with Intermediate section of 500mm length.

5. RESULTS AND DISCUSSIONS

5.1 Failure Load

The ultimate loading capacities of the specimen modelling are presented in Table 2. These numerical values are compared with the theoretical values obtained from the equations that are predicted in accordance with the IS 801-1975, British Standard BS 5950-5:1998, ABAQUS software .

From the numerical investigation results, the difference can be indicated on channel columns without edge stiffeners (plain channel), with edge stiffeners (Lipped channel) and with edge stiffener or intermediate stiffener. Cold formed stiffened web steel section with edge stiffeners show higher value of load carrying capacity. Also the extension length of the specimen will reduce the ability of the specimen to hold the load capacity, due to the results obtained from finite element analysis and analytical considerations.

This shows that by increasing the length of the specimen modelling, it will produce a lower value of ultimate loading capacity. The comparison between these channel columns can be seen by the maximum load that it can carry when concentrated load is applied.

Table 2. Comparison of results for Cold Formed steel columns

Cold formed Steel Section Designation	Ultimate Load as per IS 801-1975 (kN)	Ultimate Load as per BS 5950-5:1998 (kN)	Ultimate Load as per ABAQUS Software for FEM analysis (kN)
P-500	31.253	43.348	41.993
P-600	30.810	42.627	41.352
P-700	30.290	41.851	41.066
L-500	39.142	59.052	77.502
L-600	38.940	58.541	76.638
L-700	38.700	58.018	75.205
S-500	57.850	114.020	116.942
S-600	56.504	112.870	111.436
S-700	56.020	105.200	106.499

5.2 Failure Modes

In this study, the channel sections generally deform with one or two half-wavelength in the web and flange as shown in Figure 4. The behaviour of the flange and the web are considered as local buckling which is particularly prevalent in cold formed sections and was characterized by the relatively short wavelength buckling of individual plate element. The deformed shape of the flanges at failure for section without stiffeners can be characterized by the inward and outward flange motions.

5.3 Comparison of Models

The study of various models can also be done by comparing the models by graphs as shown in Figure 5.

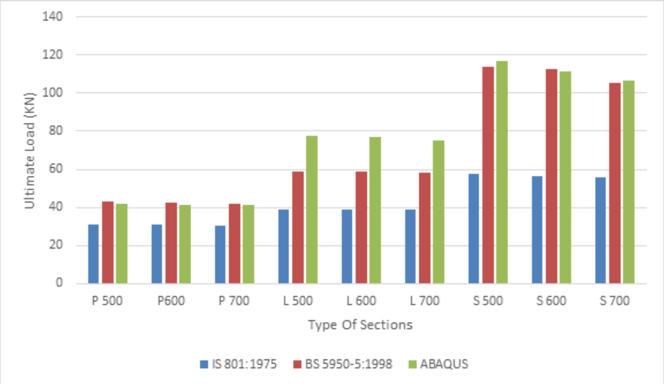


Figure 5. Comparison of ultimate loading capacity results.

The graph in Figure 5 shows that there is increase in Load Carrying Capacity of a column when the edge stiffeners and intermediate stiffeners are used. Hence adding stiffener gave higher value of ultimate load than the channel section without stiffeners. Also, load carried by column decreases when the length is increased for same section.

II. CONCLUSION

The findings of this study have lead to the following conclusions:

- The channel sections generally deform with one or two half-wavelength in the web and flange. The behavior of the flange and the web are considered as local buckling which is particularly prevalent in cold formed sections and is characterized by the relatively short wavelength buckling of individual plate element. The deformed shape of the flanges at failure for section without stiffeners can be characterized by the inward and outward flange motions.
- The ultimate loads of channel column with intermediate stiffeners are appreciably higher than Plain Channel Section and Lipped channel section of same column length.
- Generally for all the shapes of channel column, the load capacity is decreased gradually as the column length is increased. Thus, the shorter columns have the greater load carrying capacity as compared to the longer columns.
- All column sections failed in local buckling modes. The buckling and ultimate loads for the channel section without stiffeners are nearly 45% and 63% lower than the lipped channel section and lipped channel section with intermediate stiffener respectively. The channel sections with edge and intermediate stiffener has shown a less deformation in terms of buckling.
- The Load Carrying Capacity of IS 801-1975 is very less as compared to BS 5950-5:1998, ABAQUS Software results because Indian Standard uses working stress method to calculate Load Carrying Capacity and hence it predicts lesser value than the BS 5950-5:1998, ABAQUS Software.

III. REFERENCES

[1]. Indian Standard IS: 801-1975, "Code of practice for use of cold-formed light gauge steel structural members in general building construction", Bureau of Indian Standards, New Delhi (1976).

[2]. Jia-Hui Zhang, Ben Young (2011): "Compression tests of cold-formed steel I-shaped open sections with edge and web stiffeners". Thin Walled Structures73 (2013).

[3]. M. Macdonald, M.A. Heiyantuduwa, J. Rhodes, "Recent developments in the design of cold-formed steel members and structures", Thin-Walled Structures 46 (2008) 1047– 1053.

[4]. Shanmuganathan Gunalan, Mahen Mahendran, "Improved design rules for fixed ended cold-formed steel columns subject to flexural–torsional buckling", Thin Walled Structures73 (2013) Page No: 1–17.

[5]. S. Narayanan and M. Mahendran, "Ultimate Capacity of Innovative Cold-formed Steel Columns", Journal of Constructional Steel Research 59(4):pp. 489-508.

[6]. S.A.Kakade, B.A .Bhandarkar, S.K. Sonar, A. D. Samare, "Study of various design methods for cold – formed light gauge steel sections for compressive strength", International Journal of Research in Engineering and Technology, Volume 3, Page No 10-13.

[7]. Light – gauge steel engineers association http://www.Igsea.org/en/wiki/coldwork