Numerical Study on Cold Formed Steel Channel Section

Haritha M and Nithin Mohan

Abstract—One of the main reasons steel columns is used in so many construction projects is its durability. It has the highest strength to weight ratio of any other building material, making it ideal for buildings both large and small. Even thought, steel columns with thin walled open cross sections are highly susceptible to instability phenomena such as local buckling, global buckling, distortional buckling. These buckling modes can be critical depending with length and cross sectional properties of member. This work presents and discusses numerical study of behaviour of lipped steel channel columns experiencing distortional buckling. The objective of this research is to study the distortional buckling behavior of cold formed steel channel section strengthened by different shape stiffeners. Numerical analysis is carried out using ANSYS 18.1.

Keywords— Cold-formed steel column, Distortional buckling, FEA, Intermediate stiffeners, Buckling load capacity

1 INTRODUCTION

The typical steel column occupies 75% less floor space than an equivalent concrete column. Structures steel is tensile. It has a high strength to weight ratio which means it has high strength per unit mass. So no matter how large the overall stuctures, the *steel* sections will be small and lightweight, unlike other building materials. Some of the common advantages of using steel buildings are Design, Strength and Durability, Light in Weight, Easy Installation and Speed in Construction, Versatile, Flexibility, Ductility, Easy Fabrication in Different Sizes, Fire Resistance, Pest and Insect Resistant, Moisture and Weather Resistance …etc.

Buckling may occur even though the stresses that develop in the structure are well below those needed to cause failure in the material of which the structure is composed. Further loading may cause significant and somewhat unpredictable deformations, possibly leading to complete loss of the member's load-carrying capacity.

Different type of buckling that occur in cold formed steel section are local buckling, global buckling, distortional buckling. Local buckling is an extremely important facet of cold formed steel sections on account of the fact that the very thin elements used will invariably buckle before yielding. Global buckling is a buckling mode where the member deforms with no deformation in its cross-sectional shape, consistent with classical beam theory.

This paper investigates the behaviour of cold formed steel built-up open section columns with flange and web stiffeners. This paper study the distortional buckling behaviour of cold formed channel section. Distortional buckling, also known as "stiffener buckling" or "local-torsional buckling", is a mode characterized by rotation of the flange at the flange/web junction in members with edge stiffened elements.

In members with intermediately stiffened elements distortional buckling is characterized by displacement of the intermediate stiffener normal to the plane of the element. This study focuses on distortional buckling of members with stiffened elements. The cold formed channel section is strengthened by providing intermediate stiffeners on web and flange to overcome the distortional buckling. There by an increase in the distortional buckling load capacity of cold formed channel section. Also comparing the effects of V stiffener and C stiffener on cold formed channel section. The parametric study includes the effect of width of stiffeners on web and flange, effect of depth of stiffeners on web and flange, effect of S/N ratio and length of member and thickness of member. The finite element model for the parametric study is developed using ANSYS 18.1 software.

2 FINITE ELEMENT ANALYSIS

Finite element analysis (FEA) is an extremely useful tool in the field of civil engineering for numerically approximating physical structures that are too complex for regular analytical solutions. A geometrically and materially FE analysis was conducted using ANSYS 18.1.

2.1 Validation

Alexandre Landesmann *et al*. (2016) was choosen for validation. A thin walled open channel section column with intermediate stiffeners has been validated here. Steel element is defined with multilinear properties and mesh size of 50mm as shown in fig.1 is adopted. The loading direction shown in fig.2. The deformation of thin walled open channel column shown in fig.3.

- *Haritha M, M-Tech in Structural Engineering, Vidya Academy of Science and Technology, Thrissur, Kerala.*
  E-mail: harithamnambiarcv011@gmail.com
- *Nithin Mohan, Assistant Professor, CE Department, Vidya Academy of Sience and Technology, Thrissur, Kerala.*
  E-mail: nithin.m@vidyaacademy.ac.in

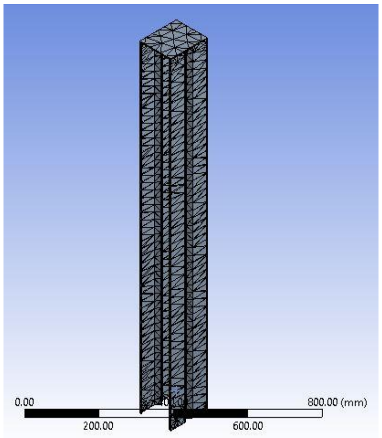


Fig.1. Mesh model

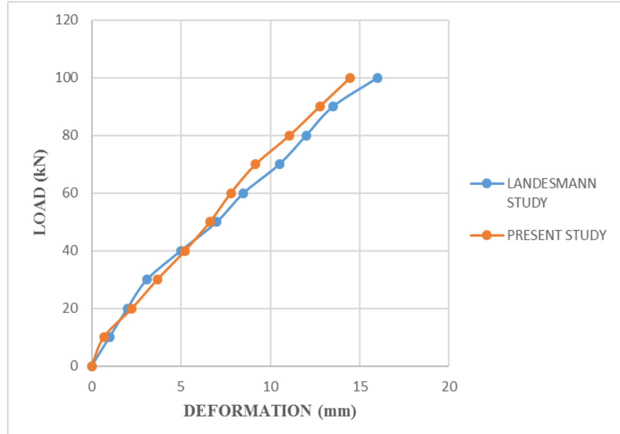


Fig.4. Comparison of result

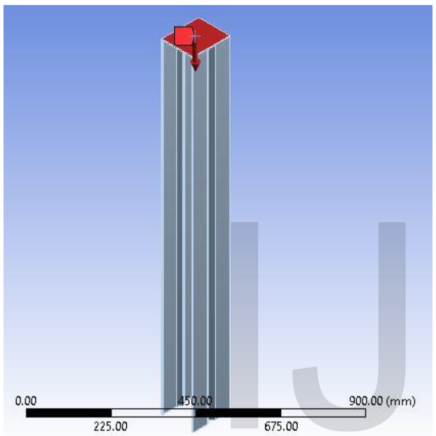


Fig.2. Loading

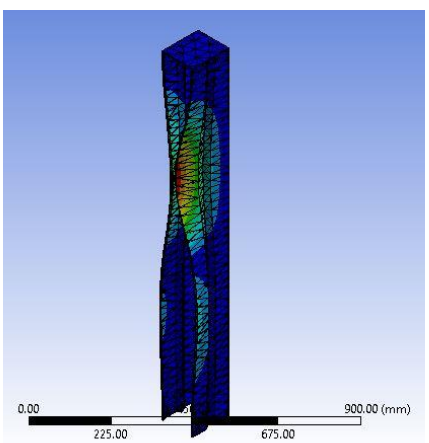


Fig.3. Deformation

3 NUMERICAL STUDIES

3.1 Steel Specifications

The finite element model for the parametric study is developed using ANSYS 18.1 software. Properties of the steel used for modeling the specimens are as specified in Table 1. The stress-strain curve of the steel is shown in Fig.5.

TABLE 1
MATERIAL PROPERTIES OF STEEL

Element used	SOLID 187
Young's Modulus (GPa)	202
Poisson's Ratio	0.3
Yield Stress of Steel (MPa)	283
Steel Density (kg/m^3)	7850

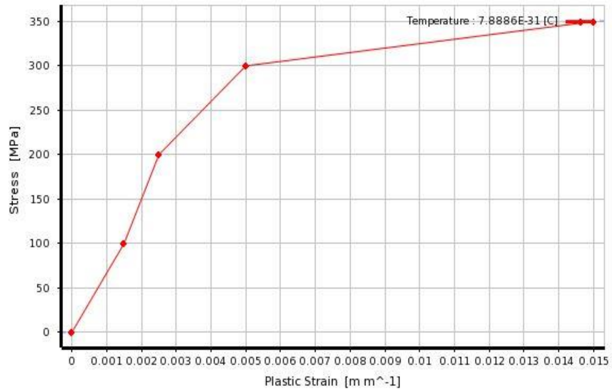


Fig.5. Stress-strain graph of steel

3.2 Loading Condition

The cold formed channel section is strengthened by providing intermediate stiffeners on web and flange to overcome the distortional buckling. Concerning the modelling of the end support conditions, the column end cross-sections were attached to rigid plates, thus precluding the occurrence of local and global displacements and rotations. Moreover, in order to enable the load application, the rigid-body axial translation is free at either one or both the cross sections. The axial compression is applied by means of a concentrated force applied on the rigid plate point(s) corresponding to end cross-section centroid.

3.2 Modelling

The cold formed channel section is strengthened by providing intermediate stiffeners on web and flange to overcome the distortional buckling. The first section is lipped channel column without intermediate stiffeners. Second section is lipped channel columns with intermediate C and V shape stiffener on web. The third section is lipped channel columns with intermediate C and V shape stiffeners on flange. The fourth section is lipped channel section with intermediate C and V shape stiffeners on web and flange. They are provided with hinged support at one end and fixed support at another end. axial loading is provided at one end of the column. Geometrical details with V stiffeners are shown in Fig.6. Geometrical details with C stiffeners are shown in Fig.7.

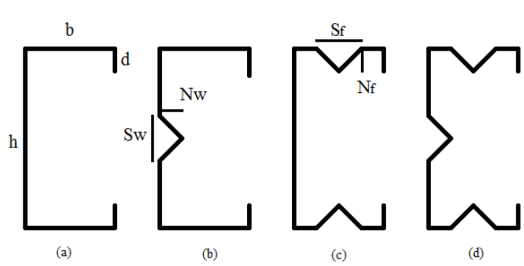


Fig.6. Channel cross section with V shape stiffener

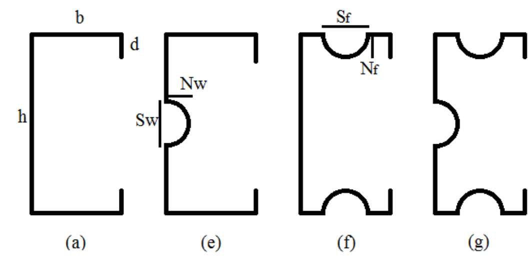


Fig.7. Channel cross section with C shape stiffener

Where h is the length of web, b is the length of flange, d is the length of lip section, S_w and S_f is the width of stiffeners on web and flange respectively and N_w and N_f is the depth of stiffeners on web and flange respectively. The thickness of section denoted as t and the length of member as L.

There is total of 48 Finite-element models were developed to simulate the distortional buckling behavior of cold formed steel channel column. For the study purpose 16 models of 130mmX110mm cross section (section I) and 16 models of 120mmX120mm cross section (section II) and 16 models of 125mmX90mm cross section (section III) were illustrated. The cross sectional details of section I and section II and section III are given below,

<u>**Section I**</u>

h=130mm	d=5.82mm
b=110mm	t=1.44mm

<u>**Section II**</u>

h=120mm	d=5.82mm
b=120mm	t=1.44mm

<u>**Section III**</u>

h=125mm	d=5.82mm
b=90mm	t=1.44mm

4 RESULT AND DISUSSION

4.1 Effect of Thickness of Member

Now to study the effect of thickness of member on distortional buckling capacity, consider both sections (I and II) with C and V stiffeners on web and flanges of member and compare the results of 2mm and 2.6mm thickness members with 1.44mm thickness members. Each steel channel columns has a length of 1500mm.

Comparison of buckling load capacity of section I with different thickness is shown in Fig.8. From the comparison it is clear that steel channel column having 2.6mm thickness giving higher resistance to distortional buckling load than steel channel column having thickness 2mm and 1.44mm. That means increase in the thickness of member increase the distortional buckling capacity of steel channel column.

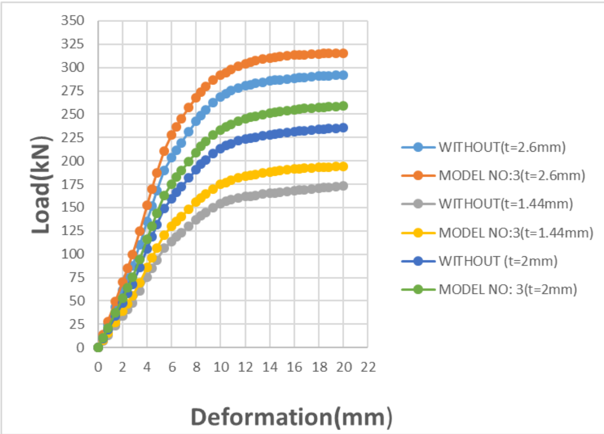


Fig.8. Comparison of buckling load capacity of section I with

4.2 Effect of Length of Member

Now to study the effect of member length, consider both sections (I and II) with C stiffeners on flanges of member and compare the results of 1500mm length members with 2000mm length members. Each steel channel columns has a thickness of 1.44mm.

The steel channel column with length of 1500mm ensure more buckling load capacity than that steel channel column with length of 2000mm. That means the buckling load capacity of steel channel column decrease with increase the length of section. Comparison of buckling load capacity of section I with different length shown in Fig.9.

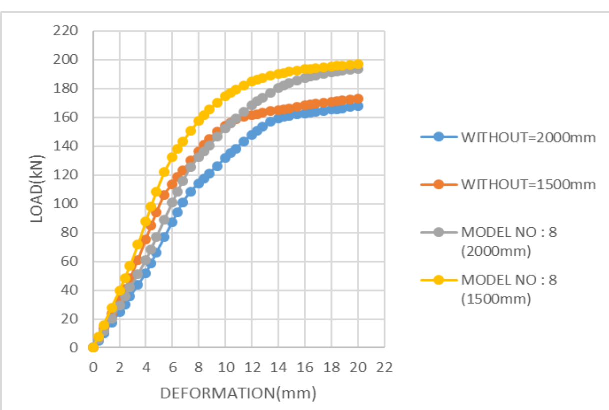


Fig.9. Comparison of buckling load capacity of section I with different length

4.2 Effect of Flange Stiffeners

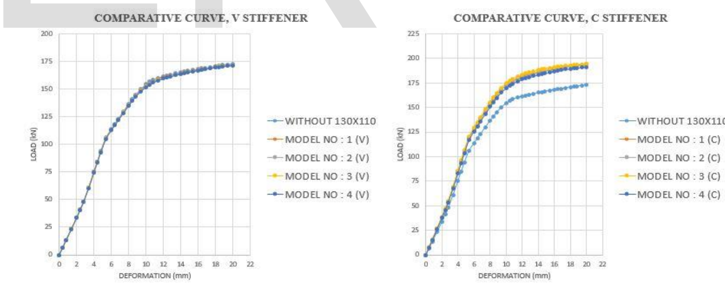
Here analyse the effect of stiffeners in buckling load capacity of steel channel column when the stiffeners provided only in the flanges of member. All sections are strengthened using flange stiffeners. V and C shape stiffeners are provided only in the flanges of section and buckling analysis is caried out. Each steel channel columns has a length of 1500mm and a thickness of 1.44mm.

4.2.1 Effect of Flange Stiffener Width

First the depth of flange stiffener (N_f) keep as constant and make changes in the width of flange stiffener (S_f). The buckling analysis results of section I (130X110) given in Table 2.

TABLE 2
BUCKLING CAPACITY OF SECTION I (N_F IS CONSTANT)

MODEL NUMBER	Nf (mm)	Sf (mm)	Sf/Nf	BUCKLING LOAD (kN) WITH V STIFFENER	BUCKLING LOAD (kN) WITH C STIFFENER
	WITHOUT STIFFENER			16.96 (0%)	
1	15	20	1.3	38.601 (127.5%)	87.149 (413.85%)
2	15	30	2	43.978 (159.25%)	98.841 (482.78%)
3	15	40	2.6	50.052 (195.10%)	107.29 (532.6%)
4	15	50	3.3	54.686 (222.4%)	105.35 (520.8%)



Comparison Of Buckling Load Capacity Of Section I With V Stiffener

Comparison Of Buckling Load Capacity Of Section I With C Stiffener

Fig.10. Comparison of buckling load capacity of section I with V and C stiffeners

4.2.2 Effect of Flange Stiffener Depth

Now the width of flange stiffener (S_f) keep as constant and make changes in the depth of flange stiffener (N_f). The buckling analysis results of section I (130X110) given in Table 3.

TABLE 3
BUCKLING CAPACITY OF SECTION I (S_F IS CONSTANT)

MODEL NUMBER	Nf (mm)	Sf (mm)	Sf/Nf	BUCKLING LOAD (kN) WITH V STIFFENER	BUCKLING LOAD (kN) WITH C STIFFENER
	WITHOUT STIFFENER			16.96 (0%)	
5	20	30	1.5	53.772 (217%)	128.14 (655.3%)
6	25	30	1.2	63.077 (271.8%)	151.08 (790.9%)
7	30	30	1	76.434 (350.64%)	197.24 (1062%)
8	35	30	0.8	79.237 (367.15%)	176.01 (938.3%)

4.3 Effect of Web and Flange Stiffeners

Here analyse the effect of stiffeners in buckling load capacity of steel channel column when the stiffeners provided on both web and flanges of member. All sections are strengthened using stiffeners. V and C shape stiffeners are provided on web and flanges of section and buckling analysis is caried out.

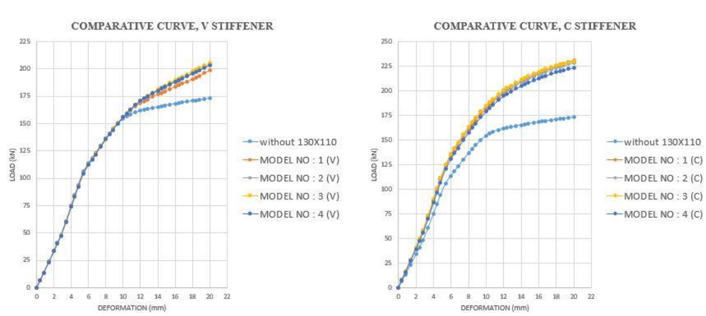
Each steel channel columns has a length of 1500mm and a thickness of 1.44mm.

4.3.1 Effect of Stiffener Width

First the depth of flange stiffener (N_f) keep as constant and make changes in the width of flange stiffener (S_f). The buckling analysis results of section I (130X110) given in Table 4.

TABLE 4
BUCKLING CAPACITY OF SECTION I (N_F IS CONSTANT)

MODEL NUMBER	Nf (mm)	Nw (mm)	Sf (mm)	Sw (mm)	S/N	BUCKLING LOAD (kN) WITH V STIFFENER	BUCKLING LOAD (kN) WITH C STIFFENER
	WITHOUT STIFFENER					16.96 (0%)	
1	15	15	20	20	1.3	38.94 (129.5%)	90.98 (436.4%)
2	15	15	30	30	2	43.99 (159.37%)	102.69 (505.4%)
3	15	15	40	40	2.6	51.04 (200.94%)	109.93 (548.2%)
4	15	15	50	50	3.3	55.03 (224.4%)	108.29 (538.5%)



Comparison Of Buckling Load Capacity Of Section I With V Stiffener

Comparison Of Buckling Load Capacity Of Section I With C Stiffener

Fig.11. Comparison of buckling load capacity of section I with V and C stiffeners

4.3.2 Effect of Stiffener Depth

Now the width of flange stiffener (S_f) keep as constant and make changes in the depth of flange stiffener (N_f). The buckling analysis results of section I (130X110) given in Table 5.

TABLE 5
BUCKLING CAPACITY OF SECTION I (S_F IS CONSTANT)

MODEL NUMBER	Nf (mm)	Nw (mm)	Sf (mm)	Sw (mm)	S/N	BUCKLING LOAD (kN) WITH V STIFFENER	BUCKLING LOAD (kN) WITH C STIFFENER
	WITHOUT STIFFENER					16.96 (0%)	
5	20	20	30	30	1.5	53.66 (219.8%)	130.94 (682.6%)
6	25	25	30	30	1.2	62.2 (271.06%)	158.32 (846.8%)
7	30	30	30	30	1	75.11 (348.4%)	211.13 (1163.2%)
8	35	35	30	30	0.8	78.28 (367.4%)	175.79 (951.7%)

This results are proving that when stiffeners are provided on both web and flange, the distortional buckling capacity of steel channel column increases than that stiffeners provide only on flanges. More over C shape stiffeners perform more effective than V shape stiffeners.

5 CONCLUSION

The cold formed channel section is strengthened by providing intermediate stiffeners on web and flange to overcome the distortional buckling. Numerical analysis is carried out using ANSYS 18.1. There is total of 48 Finite-element models were developed to simulate the distortional buckling behavior of cold formed steel channel column. For the study purpose 16 models of 130mmX110mm cross section (section I) and 16 models of 120mmX120mm cross section (section II) and 16 models of 125mmX90mm cross section (section III) were illustrated.

From this study we can understand that stiffener provided only on web has not much effect in the buckling capacity of steel channel column and when the C stiffener provided on both web and flange gives better increase in buckling load capacity. When stiffeners are provided only on the flanges of member,buckling load capacity inrease as inrease the width of stiffeners and shows maximum buckling load capacity when width and depth of stiffeners are same. The distortional buckling capaity of member increase with increase the depth of flange stiffener. When web stiffener and flange stiffeners are provide together, this shows higher distortional buckling load capacity than first two cases. The stiffeners having C shape shows greater distortional buckling capacity than V shape. In most cases the buckling load capacity is maximum when the ratio of stiffener width and stiffener depth (S/N) is 2.6. The steel channel column with web and flange C shape stiffeners provide highly increased distortional buckling load capacity.

To study the effect of thickness of member on distortional buckling capacity, consider both sections (I and II) with C and V stiffeners on web and flanges of member and compare the results of 2.6mm thickness members and 2mm thickness members and 1.44mm thickness members. From the comparison graphs it is clear that steel channel column having 2.6mm thickness giving higher resistance to distortional buckling load than steel channel column having thickness 2mm and 1.44mm. That means increase in the thickness of member increase the distortional buckling capacity of steel channel column. To study the effect of member length, consider both sections (I and II) with C stiffeners on flanges of member and compare the results of 1500mm length members with 2000mm length members. Each steel channel columns has a thickness of 1.44mm. The steel channel column with length of 1500mm ensure more buckling load capacity than that steel channel column with length of 2000mm. That means the buckling load capacity of steel channel column decrease with increase the length of section.

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