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BUCKLING BEHAVIOR OF COLD FORMED STEEL COLUMN UNDER AXIAL LOADING

Gokulpriya Malayandisamy[1], Nirmalraj. S[2]

[1]*Student, Department of Civil Engineering, Dr.Mahalingam College of Engineering and Technology, Pollachi-642003, Coimbatore, Tamil Nadu, India.*
[2]*Assistant Professor, Department of Civil Engineering, Dr.Mahalingam College of Engineering and Technology, Pollachi -642003, Coimbatore, Tamil Nadu, India.*

Abstract - *This Project work presents the buckling behavior of Cold-formed steel column under axial loading. The presence of imperfection and their effect on the buckling behavior is important to be considered in CFS sections while designing. These imperfections may be the outcome of the manufacturing process, shipping, and storage, or any other construction process. They require accurate examination in order to find the buckling behavior of cold-formed structures and calculate failure load. To study the buckling behavior of CFSC section with the factors like initial imperfection, the effect of stiffening, width to thickness ratio and to evaluate the load-bearing capacity of the member using the finite element software package, ANSYS. For the parametric study, four different geometric cross sections with uniform thickness were considered along with three different column length as 230, 950 and 1900mm stating that short, intermediate and long columns. Also, the influence of stiffening element and thickness of 1.0, 1.15, 1.2, 1.5, 1.6 and 2.0mm are studied. Also, a comparative study is made with the member with and without imperfection. The comparison shows that for a member with 10% of initial imperfection had a significant loss in its load carrying capacity and its efficiency is reduced to an average of 27%. Overall, the section S2 provides better buckling behavior, compared to the other three sections in this analysis by considering all the above parametric effects.*

Key Words: Cold formed steel, buckling behavior, initial imperfection, stiffening elements.

1. INTRODUCTION

Cold -formed steel (CFS) is a common term, whose product was made by rolling (or) pressing steel into semi-finished or finished goods at relatively low temperature i.e. at the room temperature. When compared to the hot rolled sections its yield strength was increased by 15% to 30% due to the pre-work. Now a day's CFS plays a major role in the construction field for panel constructions, roofing and wall system, formation of corrugated sheets, steel racks etc,. The strength of the elements used in the design was usually governed by buckling. One of the major difficulties with CFS design was to prevent the member from buckling, because of its low width to thickness ratio; the member can buckle first before yielding. The factors that cause a compression member to buckle are, slenderness ratio, eccentric loading, boundary conditions, imperfections etc,. Therefore cold-formed steel design should involve considerations for local, distortional, and global buckling.

Cold formed channel sections are fundamental parts for the structural elements of many engineering applications and have been studied extensively. A lot of research work has been done on different mechanical behavior of cold formed channel sections.[1] made a study on plain and lipped channel section under axial compression loading by considering imperfection in FEM and the results were compared with direct strength method. In the article [2] determination of initial geometric imperfection was done. The magnitudes for the local, distortional and global imperfections were taken as L.0 = 0.1t, D.0 = 0.1t and G.0 = L/1000.4. [3] carried a FEM to study the influence of type 1 imperfection by using ABAQUS. Accordingly, Type1 imperfection was defined as maximum local imperfection in a stiffened element, such as a web. They concluded that the local imperfection can have a significant effect on the buckling strength of the member, and this cannot be ignored in its design process. On average, the reduction can be up to 25.13% from the strength of the member without imperfection. at the suggested design level , this reduction can be as severe as 35.91%. [4] says that, beams with the short and the intermediate overall slenderness ratios were sensitive to the imperfect shape that comprise compression flange local buckling. However, for long beams, the overall buckling mode (lateral– torsional buckling) was the most sensitive mode. [5] analyzed a problem using the software ANSYS, in which for Pined- ended boundary condition, top section was identical to the bottom Section, except for the translational degree of freedom in the axial direction This was not restrained. [6] presented numerical linear and nonlinear buckling analysis of a conventional pallet racking system Nonlinear buckling analysis with material nonlinearity and the effect of plasticization is used to investigate post buckling behavior. [7] carried an elastic analysis using open source Constrained Finite Strip Analysis Software CUFSM 4.05 Then, the finite element analysis software ABAQUS 6.12 is employed to investigate the post buckling mechanics and use the magnitude of initial imperfection as 0.1times of thickness of the section for their numerical investigation. [8] undergone FEM based numerical study on influence of initial imperfection of thin walled cold formed lipped channel beams. The results of manual calculations are considerably lower than the results of simulation process by about 35-45% compared to the results obtained from finite element program ABAQUS. [9] carried out the experimental investigation and finite element analysis on buckling behavior of irregular section cold-formed steel columns under axially concentric loading and it says that due to the deviation of the shear center, the buckling behavior of such the section always shows buckling mode coupled with torsional response. [10] presented the study on thin walled beam, and gives the ideology that according to the theory of thin-walled beams does not take the effect of local buckling into account, and that the Resulting critical global forces do not correspond to the actual behavior of the beam. The FEM gives the value of the critical force by taking the effect of the local buckling into consideration and concluded that, for the C-section beam, the plane load does not go through the shear centre and here buckling and torsion appear simultaneously, so the rigidity of the plate, through which the load get transferred, had an influence on the value of the critical load. [11] contributed the guidance on the choice of most unfavorable geometric imperfection represented by the Eigen mode shapes, for FEM GMNIA. [12] investigated an non-linear buckling behavior by considering both the geometric and material non linearity's into account. PUT IN SAME BRAKET. [13] carried out non linear buckling analysis with initial imperfection whose magnitude was 10% to the thickness of the member. [14] and [15] provides an definition for the plastic Load, PP, was defined as the load corresponding to the intersection of the Collapse limit line and the load-deformation curve. They used twice elastic slope and tangent intersection methods to predict the inelastic buckling Load.

1.1 Torsional Buckling

In the flexural buckling, the members deform by bending in the plane of one of the principle axes. However columns as well as beams also buckle by twisting or by a combination of bending and twisting. These modes of failure occur when the torsional stiffness of the member is very small or if bending and twisting are coupled so that one necessarily produces the other. Thin walled open sections usually have very low torsional rigidity and are therefore especially prone to torsional buckling.

Combined bending and twisting occurs in axially loaded members, such as angles and channels, whose shear center axis and centroidal axis do not coincide. For single symmetric, the section usually has two buckling modes one for the pure flexural buckling and the other for the combined torsional-flexural buckling. And for channels and angles the torsional-flexural buckling load can be significantly below the Euler load, and torsional- flexural buckling must be considered for the design.

2. NUMERICAL INVESTIGATION

2.1 Euler Buckling for Solid Section

The finite element analysis (FEA) program ANSYS was used to predict the critical buckling loads for doubly symmetric section. It uses the solid square cross section of 100mm x 100mm with the length of 1m and it takes the young's modulus value as 2x 10^5 N/ mm^2

Table -1: Boundary condition details for FEA

S. no	Boundary condition	At Top	At Bottom
1	Both ends are pinned (K=1)	R_Z and U_Y are free	R_Z free
2	One end fixed other free (k=2)	free	fixed
3	One end fixed other end hinged (k=0.707)	U_Y free	fixed
4	Both ends are fixed (k=0.5)	U_Y is free in 6DOF	fixed

2.2 Singly Symmetric Channel Section

Euler buckling load is for the doubly symmetric section, where pure flexural buckling occurs. For the singly symmetric sections like channel sections , there are two possible modes of failure where the buckling can occur either by bending in lane of symmetry or by combination of twisting and bending which depends mainly on the dimension of the section. For channel sections, torsional flexural buckling load can be lower than the Euler flexural buckling load. Hence, Euler formula for finding out the critical load will not valid here. The theory of thin walled members does not consider the local buckling (imperfection) effects into account, where its critical load does not match with the experimental values. Hence the FEM was introduced here to know the buckling behavior of CFS channel column which includes all imperfection and material non linearity (GMNIA).

(A) Section Analyzed

At first 12 specimens were undergone for non-linear to Know the effect of initial imperfection, W/T ratio, and the stiffening effect. Later other 6 specimen of section S1 with length L1 are analyzed with the effect of knowing the thickness effect.

Table -2: Dimension of channel section

SECTION	DIMENSIONS(mm) WEB	FLANGE	LIB
S1	175	64	17
S2	125	81	25
S3	200	69	0
S4	175	70	25
LENGTH	**DIMENSIONS(mm)**	**DESCRIPTION**	
L1	230	Short column	
L2	950	Intermediate column	
L3	1900	Long column	

(B) Procedure for Numerical Analysis

- Initially, elastic buckling analysis called as Eigen value buckling analysis was carried out to obtain the linear critical load and corresponding mode shape. Later the non -linear analysis is carried out with the material and geometric non – linearity's.
- Using a nonlinear buckling analysis makes it possible to include such features as initial imperfections, plastic behavior, contact, large-deformation response, and other nonlinear behavior.
- Nonlinear buckling analysis with material nonlinearity and the effect of imperfection is used to investigate post buckling behavior
- Nonlinear buckling is more accurate than Eigen value buckling and is therefore recommended for the design or evaluation of structures.
- In addition, the buckled mode shapes can be used as an initial geometric imperfection for a nonlinear buckling analysis in order to provide more realistic results.
- Nonlinear buckling analysis employs a nonlinear static analysis with gradually increasing loads to seek the load level at which a structure becomes unstable and is a time consuming process.

(B) Code for Initial Imperfection

The following code is used for carrying the non -linear Eigen value buckling analysis along with initial imperfection where the buckled mode shape from linear Eigen value analysis can be used as an initial geometric imperfection for a nonlinear buckling analysis.

```
/prep7
UPGEOM, 1, 1, 1, file,rst
cdwrite,db,file,cdb
```

Where,

- first numerical in the second line of code represents the value of imperfection, here 1 resembles the magnitude of 100% of thickness (1t) for imperfection
- second numerical represents the load step which is time dependent
- third numerical represents the buckled mode shape number (i.e) at which mode the an initial geometric imperfection is considered.

3. RESULTS

3.1 Comparison of Euler load with Numerical Load

Table -3: Theoretical and analytical comparison of Buckling load for long column

Boundary conditions	Critical Buckling load (KN) Analytical (KN)	FEA (KN)	Error %
Both pinned	16449	16186	1.6
Fixed free	4112.4	4121.1	0.23
Fixed hinged	32908	32243	2.02
Both Fixed	65942.4	60746	7.88

3.2 Parametric Analysis for Channel Section

(A) Influence of Initial Imperfection:

The average ratio of zero imperfection with 10% of initial imperfection is 1.27862. The below chart shows, the linear and non -linear critical load with and without initial imperfection for 4 sections with 3 lengths of thickness1.5mm.

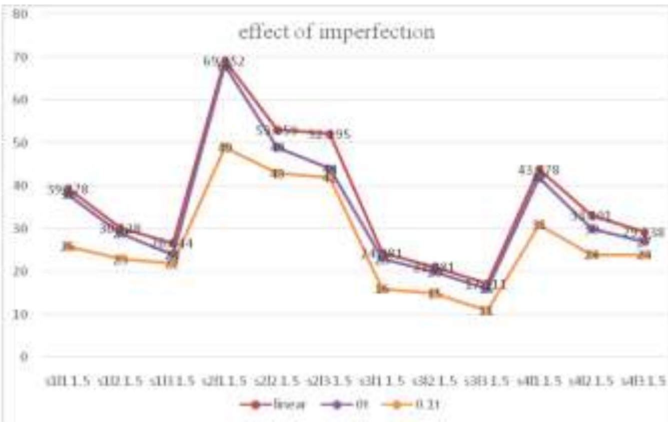

Chart -1: Comparison of Individual Limit Loads For Members Analysed For Imperfection Effect.

(B) Influence of W/T Ratio:

Load carrying capacity increases with decrease in w/t ratio were t is constant as 1.5mm and web length (w) varies. In average w/t 83.33(S2) is 1.748 times the capacity increased.

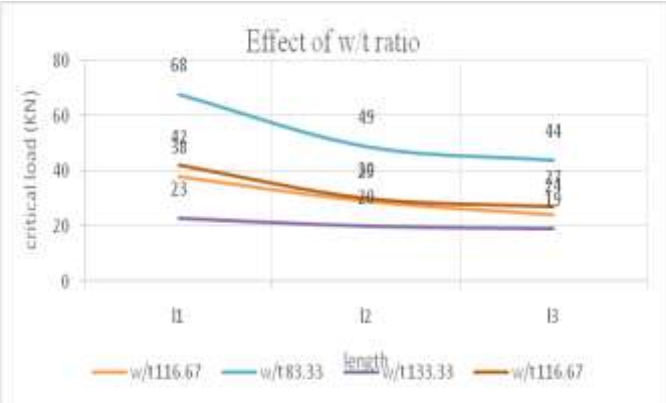

Chart -2: Comparison of Individual Limit Loads For Members Analysed For The Effect of W/T Ratio.

(C) Effect of Stiffening Element:

Section S2 shows the better carrying capacity of 2.12, 1.09, and 2.07 times the other sections of short, intermediate and long column. More Stiffer the element, capacity is more and reduction in occurrence of distortional mode where failure occurs quickly.

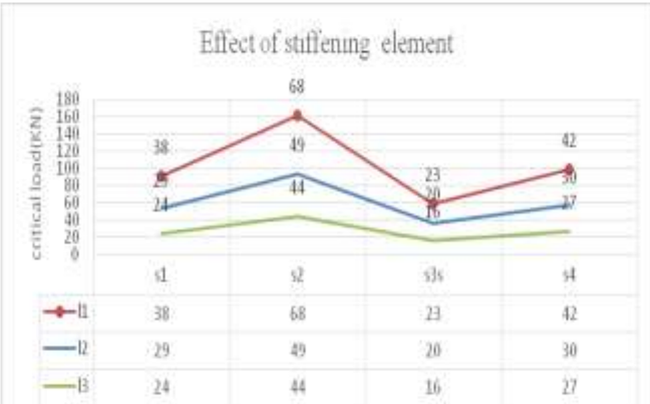

Chart -3: Comparison of Individual Limit Loads For Members Analysed For Stiffening Effect.

(D) Effect of Thickness:

It is clear that the capacity of section increases with increase in thickness this is due to increase in the stiffness.

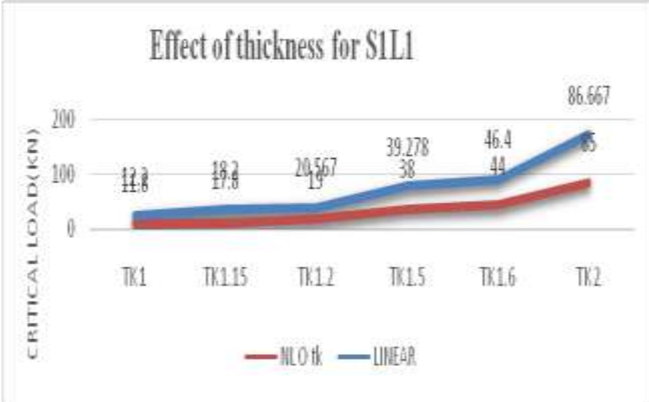

Chart -4: Comparison of Individual Limit Loads for Members Analysed For Thickness Effect

Table -4: Comparison of Axially Loaded Capacity Between with And Without Initial Imperfection For Varying Thickness.

SECTION S1 L1		FINITE ELEMENT ANALYSIS			
Thickness(mm)		**Linear**	**N.L (0t)**	**N.L(0.1t)**	**$P_{0t}/P_{0.1t}$**
SHORT COLUMN	1	12.2	11.8	8.4	1.40
	1.15	18.2	17.8	12.2	1.46
	1.2	20.57	19	14	1.36
	1.5	39.28	38	26	1.46
	1.6	46.4	44	31	1.42
	2	86.66	85	63	1.35
AVERAGE					1.16

3.3 Buckling Behavior

(A) Short Column

- It possess higher load carrying capacity than the intermediate and long column
- Buckling mode is local buckling, followed by distortional buckling.

(B) Intermediate Column

- Buckling mode is distortional.

(C) Long Column

- It possesses flexural buckling for un-lipped section distortional buckling is followed by flexural phenomenon.

4. CONCLUSIONS

This project work was conducted with a total17 specimens including four different cross sections with three different lengths of 230mm, 950mm, 1900mm stating of short, intermediate and long column respectively, with a constant thickness of 1.5mm and other five dealing with varying thickness of 1.0, 1.15, 1.2, 1.6 and 2.0mm which were analyzed for carrying the buckling behavior of cold formed steel column channel section. The above mentioned 17 specimens were undergone with non-linear analysis for both of perfect specimen and the specimen with 10% of imperfection. When there was an imperfection in the column it significantly reduce the carrying capacity of the column, hence imperfections have to be considered while designing. For a member with 10% of initial imperfection ,its efficiency is reduced to an average of 27%.It is for the section S2 the load carrying capacity is better compared to all the other three sections. The buckling behavior of sections was based on the length of the section, initially local buckling occurs first, later it is followed by the distortional buckling.

For slender columns combined flexural-torsional buckling phenomenon occurs first, in case of the short column local buckling is the critical mode and in case of intermediate column the failure mode is distortional also for the cross section without the stiffening element it contributes to the distortional buckling mode resulting in the reduced load carrying capacity of the specimen. When the thickness of the section increases, its stiffness also consequently increases resulting in the section with increased in its load carrying capacity.

5. SCOPE FOR FUTURE WORK

- For more detailed and accurate study, the result from analytical work has to be cross checked with the experimental works.
- Also a comparative study has to be made with an AISI specification.
- For the next stage of work study has to be conducted on the interaction of buckling behavior of cold formed steel sections.
- This work can become more effective if parameters like residual stresses, loading conditions and other are involved.

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