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Behaviour of Cold formed Steel Channel Column Sections with Web Stiffeners

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***Abstract* — In this study pin-ended cold formed steel channel axial columns with different types of web stiffeners is analyzed by finite element analysis. The yield strength of the material is taken as 270N/mm^2. The selected cross section profiles are met with all the possible failure modes of the compression members. The cross sectional dimensions are satisfied with pre-qualified section properties of cold formed steel structures. Length of the sections are varied and compared to analyse the load-deflection characteristics. Tests are then simulated by finite element analysis using ABAQUS software.**

Keywords— Cold formed channel column section, Intermediate web stiffener, Finite element Analysis.

I. INTRODUCTION

Cold-formed steel structures are steel structures that are prepared by bending flat steel sheets into desire shapes, while hot-rolled steel sections are formed at elevated temperatures. Cold-formed sections are usually bent by press braking operation. The primary advantages of the cold formed steel section are high strength to weight ratio, low self weight, easy lifting and fabrications. Open and closed sections are normally used in construction industry. The basic failure modes are local buckling, distortional buckling, flexural buckling, torsional buckling or interaction of local, distortional and flexural buckling. The buckling characteristics depend on the shape and the slenderness ratio of the cross section profile.

In this study, selected cross section profile cold-formed steel lipped channel section with various types of intermediate web stiffeners are analysed to minimize local buckling. The dimensions of the cross sections are arrived based on the North American Specifications (NAS) for the cold-formed steel structures. The cross section dimensions also satisfy the pre-qualified section profile Direct Strength Method (DSM) for the cold-formed steel structures. In this study totally 6 sections are analysed through finite element analysis and their failure mode and load carrying capacity are compared.

II. LITERATURE REVIEW

Literatures collected are related to experimental, numerical and theoretical investigations of cold-formed steel columns. Several researchers completed the behavior of simple lipped cold formed steel channel column with simple and complex web stiffeners. Hancock (1985) studied the distortional mode of buckling and described for cold-formed lipped channel columns very little post buckling strength available for distortional mode of buckling. Known and Hancock (1992) arrived the geometry of the section using a semi-analytical finite strip and a spline finite strip elastic buckling analysis. Schafer and Pekoz (1998) studied cold-formed steel channel sections with multiple longitudinal intermediate stiffeners. Yan and Young (2002) presented an experimental investigation of cold-formed steel channels with complex stiffeners subjected to pure axial compression under fixed-ended boundary conditions. Yang and Hancock (2004) described a series of compression tests on a range of lengths of lipped channels with intermediate stiffeners in the web and the flanges was tested between fixed ends to determine the strength of the sections. Zhang et al. (2007) presented an experimental and a finite element analysis on cold formed channels with inclined simple edge stiffeners compressed between pinned ends. Known et al. (2009) described a series of compression tests on cold-formed simple lipped channels and lipped channels with intermediate stiffeners in the flanges and web. The sections were specially capped at both ends as fixed end condition, to prevent the centroid position from changing. Nguyen and Kim (2009) studied the buckling of thin-walled composite columns in hat sections and lipped-channel sections reinforced with web stiffener under axial compression. The FEM was used to investigate the buckling behaviour of the column. Load-deflection analyses were performed to study the post-buckling behaviour of the column. Schafer (2011) presented a review of recent advances in applications, analysis and design cold-formed. Cold-formed steel applications continue to advance in three primary categories: framing, metal buildings, and racks. Many other areas of structural engineering, seismic engineering has made

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notable advances in applications, analysis, and design of cold-formed steel structures. Patton and Singh (2013) presented a finite element study on slender hollow columns with square and non-rectangular hollow columns under fixed end subjected to axial compression. Variations in buckling strength with changes in the cross-sectional shapes were studied. The FEA results were compared with the design strengths predicted by the Euro code and NAS specifications. A built-up I-section with longitudinal stiffeners have better performance to resist against local and distortional buckling compared to conventional built-up I-section by simply connecting two plain channels back-to-back. Hence Zhang and Young (2015) did non-linear finite element analysis of cold-formed steel built-up open section columns with edge and web stiffeners. A finite element model was developed and verified against the tests of cold-formed steel built-up compression members, in which the initial geometric imperfections and material properties of the test specimens were included. The finite element results and the test results were compared with the design predictions calculated from the current design rules in the NAS and ANZS. Aruna et al. (2015) described a series of experiments conducted in cold-formed built-up square sections with intermediate flange and web stiffeners under axial compression with hinged end conditions. The experiment results were compared with the design strength calculated using the DSM and NAS for cold-formed steel structures. Strength calculated by using the DSM is reliable and slightly unconservative. Wang et al. (2016) conducted pin-ended compression tests and numerical analysis of channels with complex edge stiffeners and different types of web stiffeners. Tests were then simulated by finite element analysis.

III. SPECIMEN LABELLING

The column specimen are labeled as, a Lipped Channel (LC), a lipped channel with inclined intermediate web stiffener (LC-V).

For example, a specimen labeled as "LC-500" is described as follows:

LC : Lipped Channel

500 : Length of the section is 500mm

A specimen labeled as "LC-V-1000" is described as follows:

LC : Lipped Channel

V : Inclined intermediate web stiffener

1000 : Length of the section is 1000mm

IV. SECTION DIMENSIONING

The flange (f), web (d), length (l) and thickness (t) of the section with uniform area are considered for the Finite Element analysis.

The geometric properties of the section are shown in the table

TABLE I.

S.No.	Section labelling	Section Dimensions (mm)					Length (mm)
		f	*d*		*l*	*t*	
			d1	*d2*			
1	LC-500	50	150		20	1.6	500
2	LC-700	50	150		20	1.6	700
3	LC-1000	50	150		20	1.6	1000
4	LC-V-500	50	55	20	20	1.6	500
5	LC-V-700	50	55	20	20	1.6	700
6	LC-V-1000	50	55	20	20	1.6	1000

V. SECTION PROPERTIES

The section properties are found for each section. The centre of gravity of each section is necessary to specify the point of load. The load applied for the FE model is through the centre of gravity of the section and are equally distributed.

The section properties are shown in the table below.

S.No.	Section Label	Yield Stress (N/mm^2)	Area (mm^2)	Centre of Gravity (X_{CG}) - (mm)	Moment of Inertia (I_{XX}) - ($x10^4$ mm^4)	Moment of Inertia (I_{ZZ}) - ($x10^4$ mm^4)
1	LC-500	270	432	14.82	147.24	15.77
2	LC-700	270	432	14.82	147.24	15.77
3	LC-1000	270	432	14.82	147.24	15.77
4	LC-V-500	270	432	1.432	122	14.91
5	LC-V-700	270	432	1.432	122	14.91
6	LC-V-1000	270	432	1.432	122	14.91

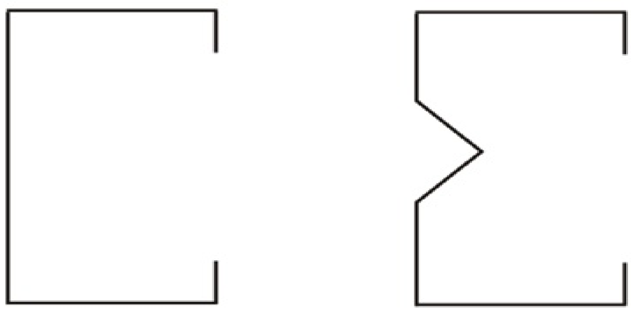

Fig. 1. Cross Section Profiles

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VI. FINITE ELEMENT MODELLING

To examine the strength and structural behaviour of cold formed steel channel column with different types of intermediate web stiffeners over different lengths, a finite element model is established with a commercial finite element package. The FE model is based on the centre line dimensions of the cross section. The shape of the FE model is taken as shell and type of the section as deformable. A uniform mesh size of 10 X 10 mm is used in the model. To ensure the axial loading condition all the support reaction and load are applied at the CG of the section. The CG of the section is formed as the Reference Points (RP1 and RP2).The section is loaded at RP1.To ensure the uniform distribution of load over the entire cross section entire nodes is connected to the reference points.

The preliminary geometrical imperfection shape plays a critical function in the non-linear analysis of the cold-formed steel column, as it may adjust the corresponding buckling behaviour and ultimate strength. The imperfections are 1t and L/1500 used in the study to initiate nonlinear analysis.

Initially, a linear perturbation analysis is performed to acquire feasible elastic buckling modes of the cold formed steel channel column with different types of intermediate web stiffeners. Finally, the non-linear analysis is performed to obtain the ultimate load and failure modes of the cold formed steel channel columns with different types of edge stiffeners subjected to axial compression.

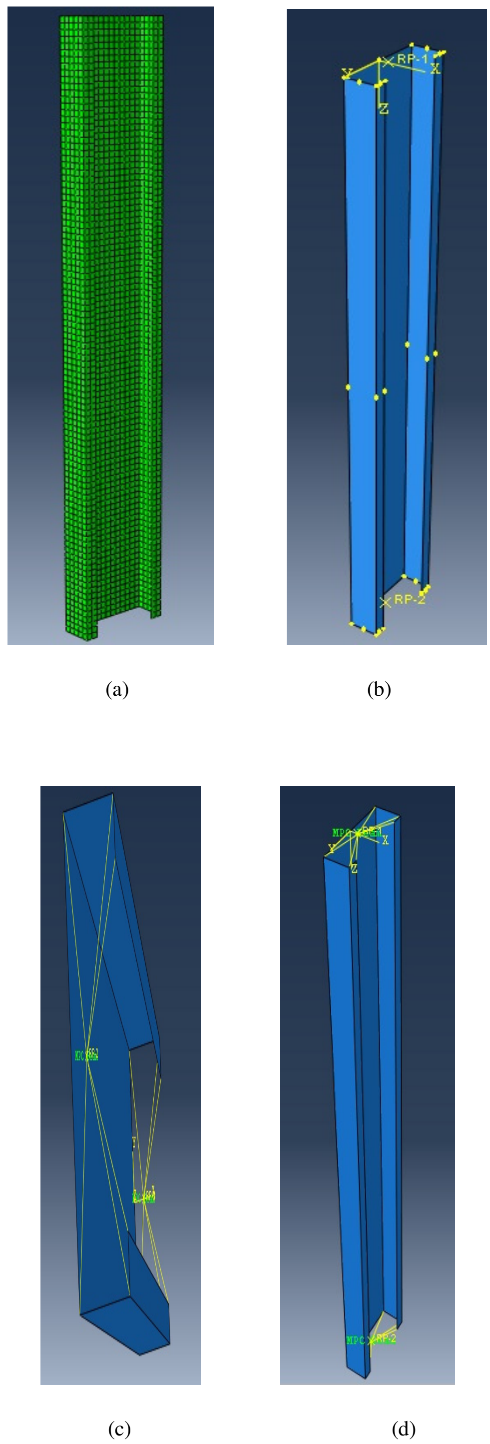

Fig. 2. Finite Element Modeling

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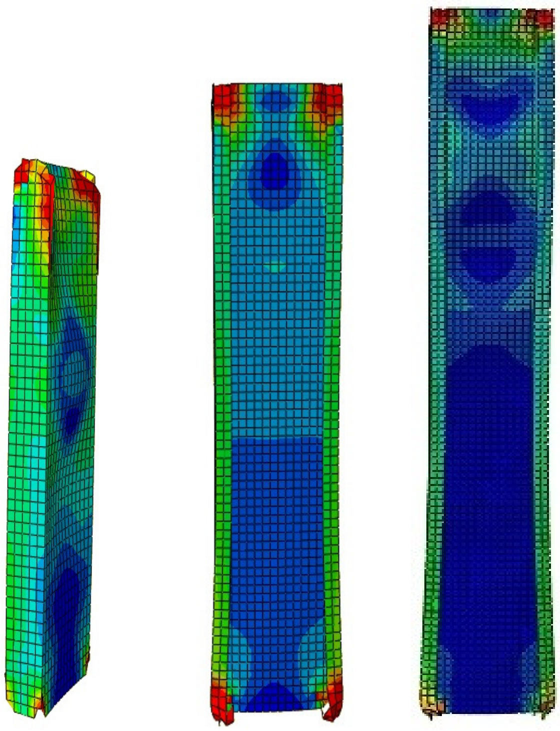
VII. DEFORMED SHAPES LOAD DEFLECTION CURVES

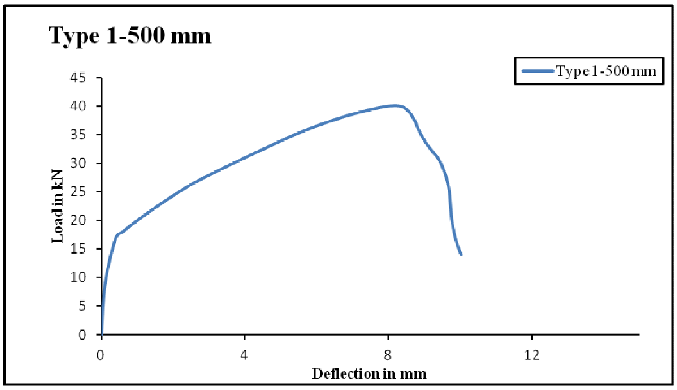
In Finite Element Analysis, the local and overall geometric imperfections can be included. This validates FEA and it can be used as an alternative for the prediction by experiments. In general, the ultimate load carrying capacity predicted by FEA overestimates the results from experiments. This is probably due to the small values of residual stresses and rounded corners of the section that are ignored in the FEA.



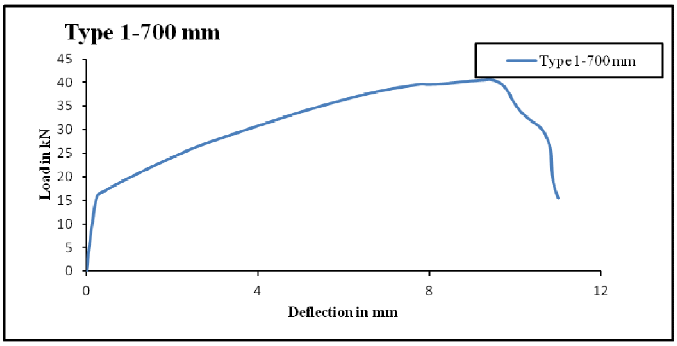
(a) (b) (c)

Fig. 3.Deformed shape of (a).LC-500, (b) LC-700, (c) LC-1000

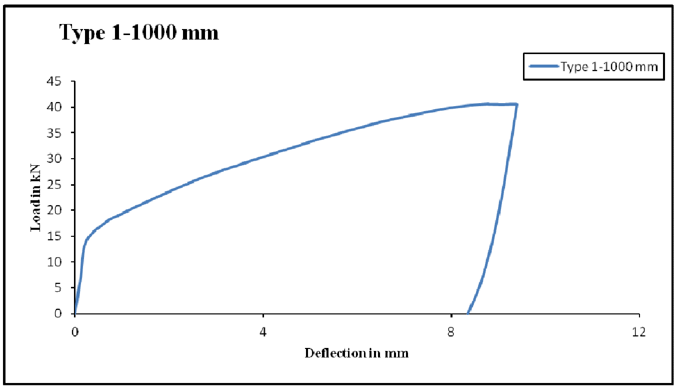
The behavior of cold-formed steel column sections with intermediate web stiffeners under axial loading, load vs deflection curve have been studied for the sections with length ranging from 500mm, 700mm and 1000mm are shown in figures .4 &6 (a), (b), (c).



(a)



(b)



(c)

Fig.4. Load deflection curves of (a).LC-500, (b) LC-700, (c) LC-1000

The deformed shapes of the section LC-V-500, LC-V-700, and LC-V-1000 are shown in Fig.5.

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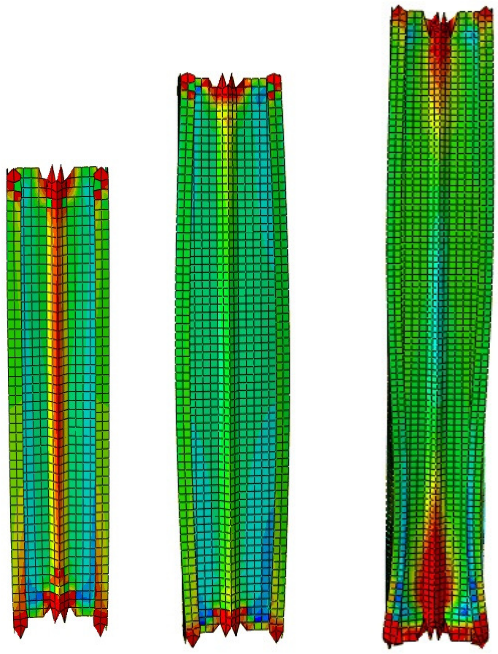
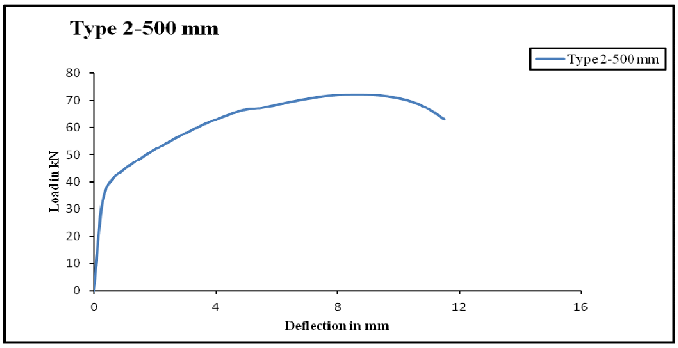
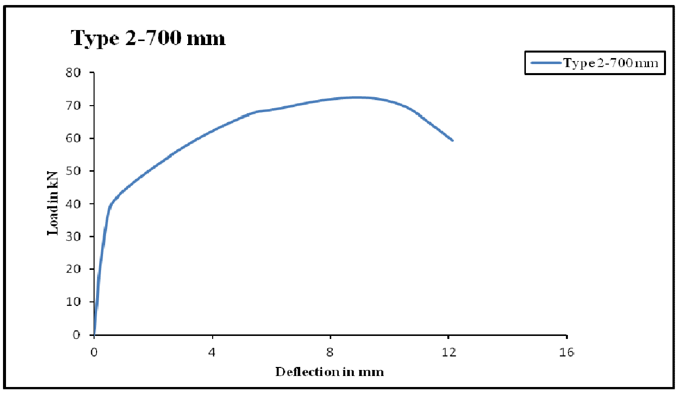


(a) (b) (c)

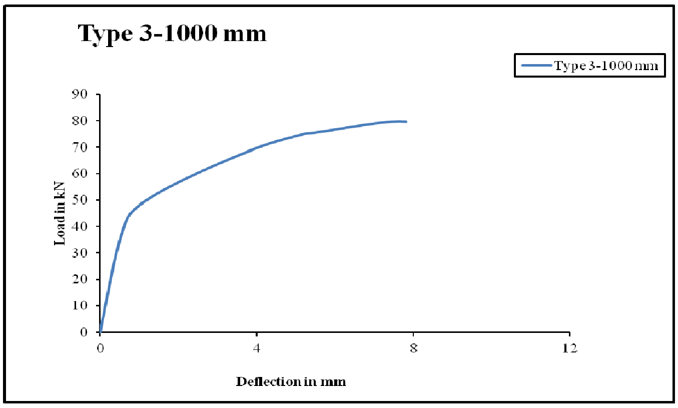
Fig.5. Deformed shape of (a).LC-V-500, (b) LC-V-700, (c) LC-V-1000



(a)



(b)



(c)

Fig.6. Load deflection curves of (a).LC-V-500, (b) LC-V-700, (c) LC-V-1000

VIII. CONCLUSION

The Section LC-500, LC-700, LC-1000 undergoes local buckling where as the section LC-V-500, LC-V-700, LC-V-1000 also undergoes local buckling. The load carrying capacity of the section LC-V-700 is found to be carrying maximum load when compared with the other section. The sections can be compared when experimentally tested and can be compared with DSM method and further parametric studies can be carried out. The intermediate web stiffeners shape can also be further developed and the parametric studies can be further carried out for further investigation.

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