Study on behaviour of Z-stiffened Columns with and without Lips Using Cold-formed Steel under Axial Compression

R. Renuka[1],
Assistant Professor, Department of Civil Engineering, Sona College of Technology, Salem, India.
Email: renukar@sonatech.ac.in

S. Kalaiselvi[2],
Assistant Professor, Department of Civil Engineering, Sona College of Technology, Salem, India.
Email: kalai_tptc@yahoo.co.in

M. Adhiyaman[3],
Assistant Professor, Department of Civil Engineering, Sona College of Technology, Salem, India.
Email: adhicivil@gmail.com

Dr.G. Arun Kumar[4],
Associate Professor, Department of Civil Engineering, Governement College of Engineering, Salem, India. Email: arun_8112005@yahoo.com

Abstract
Structural elements made by using cold formed steel sections are extensively used in India. By means of utilizing these sections the construction field, residential and commercial fields get benefitted. This research focuses the study on buckling performance of Z profiled trapezoidal stiffened section column with, without lips. This study involves the experimental and analytical examination of cold-formed Z trapezoidal stiffened section column. Four sections were tested with different dimensions of 600mm and 1200mm with and without lips. The section dimensions were formulated as per American standards for the design of steel structural members, 2007. Columns of Z profiled trapezoidal strengthened with stiffeners were later tested by using Universal testing machine subjected to axial compression. ANSYS software is been used to carry out the Finite element analysis. This study reveals that the cold-formed Z trapezoidal stiffened section column with lips performed well when compared to Z trapezoidal stiffened section column without lips. Load carrying capacity and less deflection were shown in Z stiffened trapezoidal stiffened section with lips than comparing with the section of without lips.

Keywords: Cold-Formed Steel, Z-section, Trapezoidal Stiffened, Lips, Without Lips.

Introduction

Cold-Formed Steel Sections also referred to as Light Gauge Steel Sections are thin sheets made by steel products utilized in various fields like building to industry, and are widely ranges from purlin, roof sheeting and floor decking in assembling as very vital structural elements at site. Cold-formed steel elements are made by thin steel sections subjected to low temperatures in order to enhance residual stress of the steel members. Cold-formed steel sections results to be more sensitive in local buckling than differentiating with the hot-rolled sections. These sections will be economical especially for the loads which are light in weight and also used to form roof covering and wall panels. Various types of sections can be shaped using cold-formed steel. They include angles, channels with and With-out lips, hat sections, lipped Z sections etc.

Cold-formed steel products like Z-sections has mainly used in the construction, transportation and manufacturing industries mainly due to their large range of applications considering the factors like economy, manufacturing of hot rolled sections subjects to higher elevated temperature, while increase of temperature will cause lower residual stress compared to cold-formed steel sections. Z-sections as purlins are majorly used in the lightweight and the span between the members is less such as roof systems. Column sections strengthened with edge stiffener will increase the strength and stiffness of the element. The edges of the Cold forms steel sections are press braked so that by the implementation of lips within the flanges of the section made will behave as a stiffeners of the angle section. Due to which cold-formed steel section having edge

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stiffener may results in good economic design and also results in higher buckling stress of the section. Intermediate stiffeners are also often preferred in many types of steel structures. Inclusion of stiffeners in the column elements will improve the local buckling capacity of the column members. The profile shape, dimension and place of the stiffeners provided at some intermediates will significantly affect the firmness of the cold-formed steel members.

Material Specification

The properties of the material specified for the specimens used were obtained by tension/coupon test as per IS 1608. Three coupon tests were conducted and the average values of stress at yield level, stress at ultimate level and Young's modulus are tabulated in 1

Table 1. *Element properties of the specimen*

DESCRIPTION	RESULTS
Yield stress	272 Mpa
Young's modulus	2.04 x 10^3 Mpa
Ultimate stress	349 Mpa

COLUMN - A: Z – Trapezoidal stiffened column without lips
COLUMN - B: Z – Trapezoidal stiffened column with lips

Specimen Dimension

The profile for the chosen Z-section with stiffeners is shown in Fig 1 & 2.

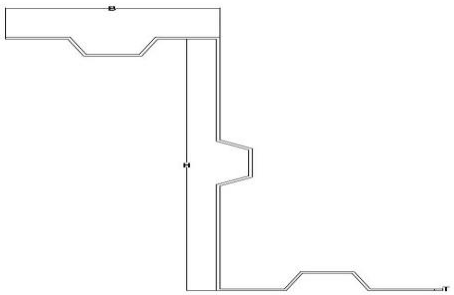

Fig. 1.*The individual Z-section without lip*

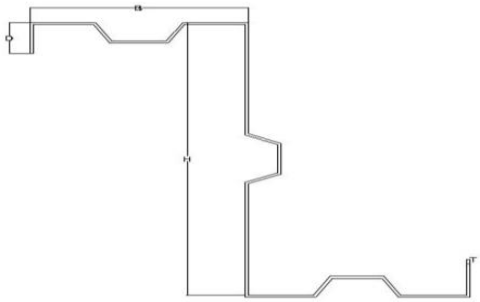

Fig. 2. *The individual Z-section with lip*

The Z profiled section dimensions are specified in table 2, using the arrangement as defined in fig 1 & 2.

Table 2. *Specimen Details (Z profiled section dimensions are in mille meters)*

Specimen	Length (L)	Web width (H)	Flange width (B)	Lip (D1)	Thickness (T)
COLUMN A1	1200	220	100	-	1.6
COLUMN A2	600	220	100	-	1.6
COLUMN B1	1200	220	100	25	1.6
COLUMN B2	600	220	100	25	1.6

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Test Setup for the z Profiled Section

The tests were conducted 2000kN capacity loading frame. The 200kN hydraulic jack has been positioned at the bottom of the Z section specimen. Hinged end conditions were used and it is shown in figure 3.1. The specimen was placed between the two support conditions. The verticality of the specimen checked. Dial gauges were to be placed exactly at the bottom and at the middle height of the specimens to measure the axial shortening and deflection at the mid portion of the specimen. The dial gauge readings were noted at uniform intervals. The ultimate load was observed by the rapid increase in the readings and the subsequent drop in the load. The load was increased until the specimen could not take any further axial compressive load. The experimental portion of the specimen is viewed in figure 3.

Fig. 3. *Experimental setup*

The chosen Z profiled section was not attaining the desired strength and the sections fails by distortional and local buckling mode of failure was observed. The failure mode of the Z profiled section was shown in figure.

Fig. 4. *Typical Z-section column with and without lip (600mm)*

Fig. 5. *Typical Z-section column with and without lip (1200mm)*

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The columns were loaded until the failure is reached. The following parameters were observed during the test, ultimate load and the maximum. The test results are shown in table.

Table 3. *Test results for the Z profiled column*

Specimen	Ultimate load (kN)	Deflection (mm)
COLUMN A(1)	72.28	2.96
COLUMN A(2)	91.65	3.4
COLUMNB(1)	78.345	2.81
COLUMN B(2)	109.20	4.5

The load vs Axail Compression graph for the Z trapezoidal stiffened section for 600mm and 1200mm column is shown in fig. 6 and fig. 7.

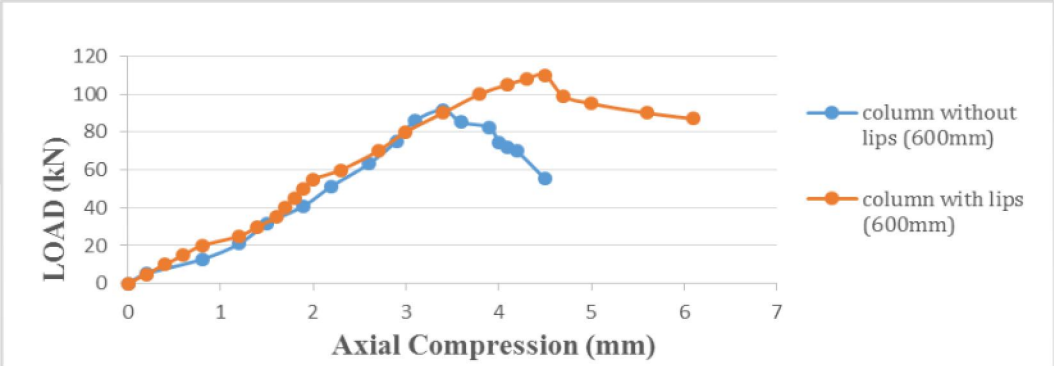

Fig. 6. *Load vs Axial Compression for 600mm Z section column*

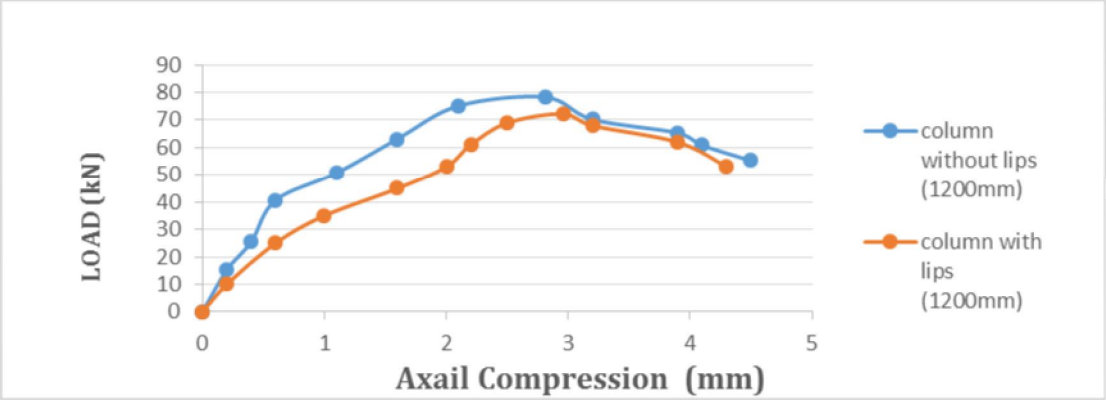

Fig. 7. *Load vs Axial Compression for 1200mm Z section column*

Finite Element Modelling

The elements subdivided into sub-elements are analyzed by means of a resourceful tool (ANSYS) which is used for analyzing the sections made up and also provide accurate behaviour for the prototype model which resembles with the tentative work done part. Hence, it is necessary to verify the numerical or analytical results with the investigational results. In general, finite element analysis is a most potent tool in determining the ultimate loads and modes of failure for the structural members. The Z Profiled section strengthened with trapezoidal stiffeners was analysed using ANSYS Software.

The finite Element modelling was done with the help of ANSYS software. The results obtained from the software were shown in fig. 8, 9 and fig.10

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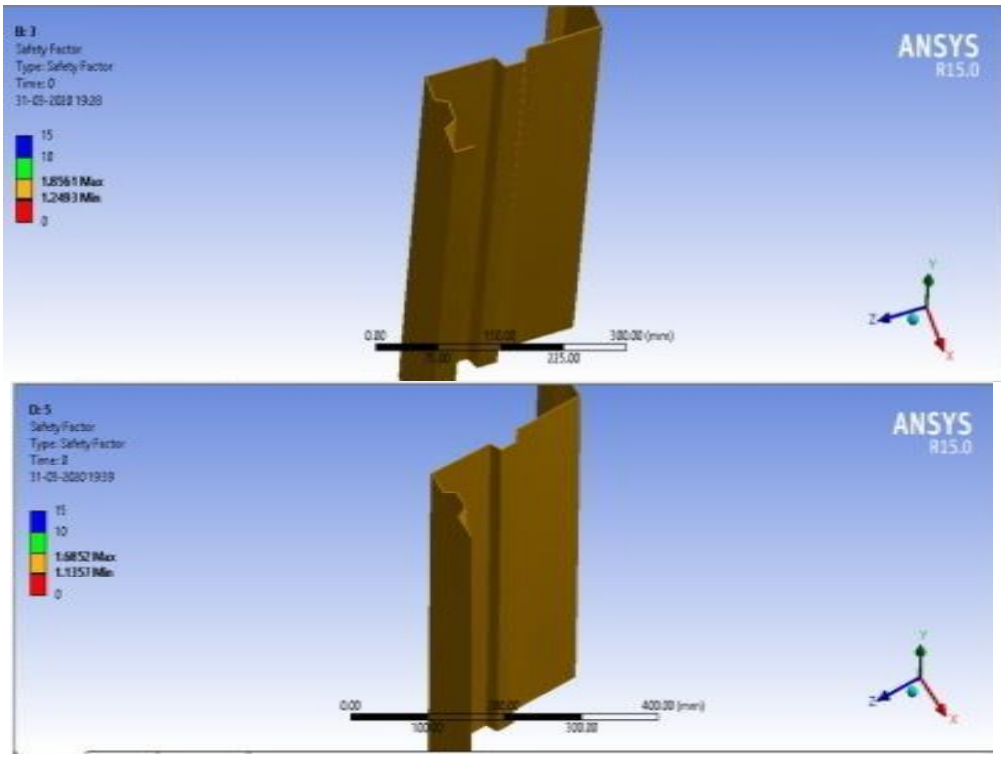


Fig. 8. *Stress profile of Z section with and without lips (600mm)*

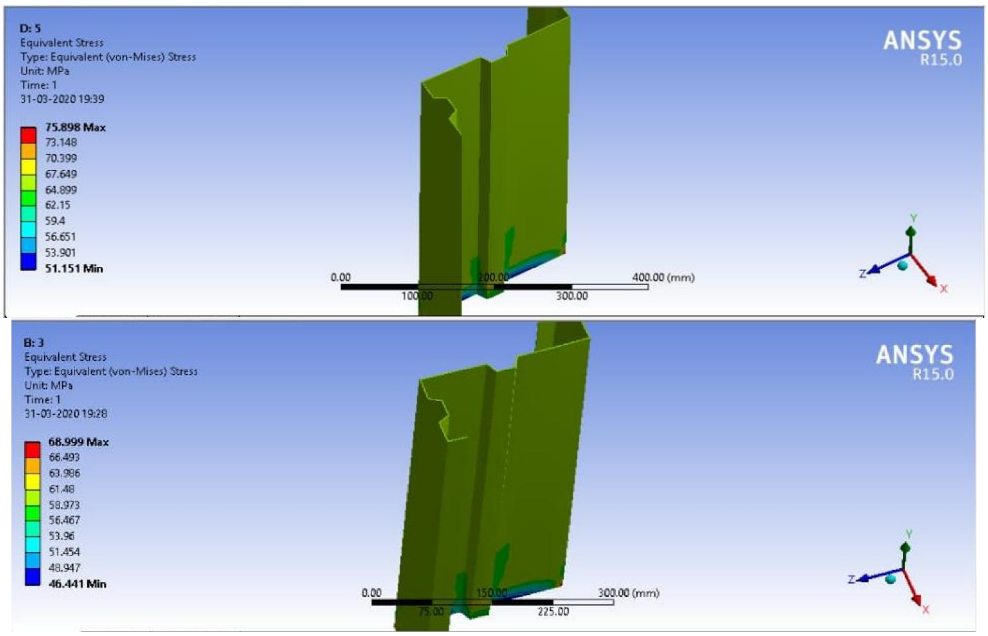
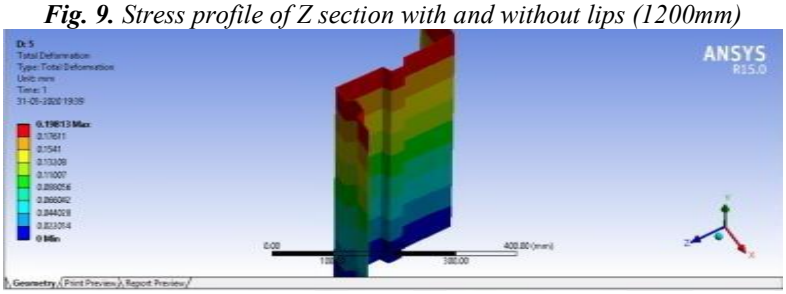


Fig. 9. *Stress profile of Z section with and without lips (1200mm)*



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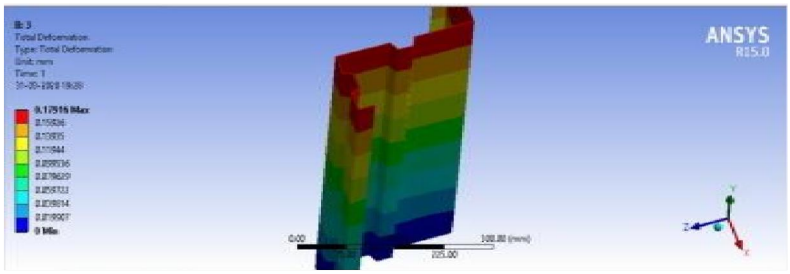

Fig. 10. *Deformation of Z section with and without lips*

The maximum deflection and the ultimate load values obtained from ANSYS is shown in Table 4

Table 4. *FEM results*

SPECIMEN	ULTIMATE LOAD (kN)	DEFLECTION (mm)
COLUMN A1	63.116	1.63
COLUMN A2	75.898	1.98
COLUMN B1	68.999	3.26
COLUMN B2	73.898	3.40

The Load Vs Axial Compression curves from numerical analysis was shown in figure 11 and 12.

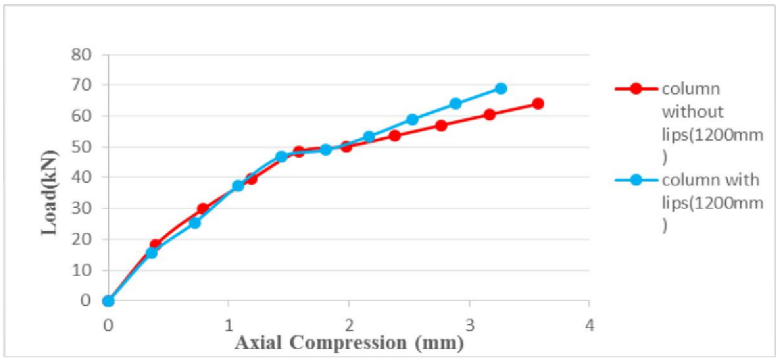

Fig. 11. *Load vs Axial compression for 1200mm Z section column*

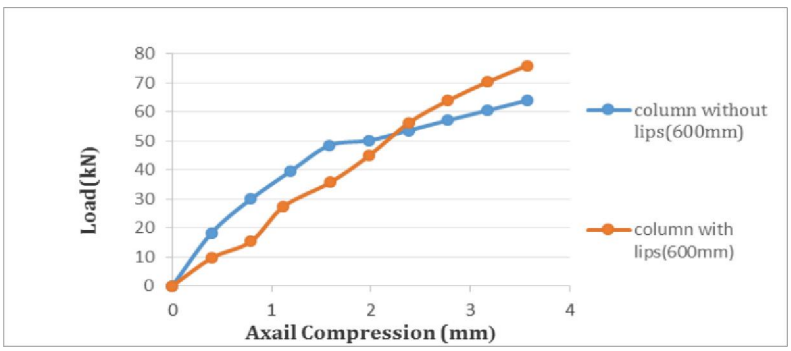

Fig. 12. *Load vs Axial Compression for 600mm Z section column*

Results and Analysis

The achieved outcomes both from the experimental, numerical part are tabulated in Table 5

Table 5. *Outcome values comparison*

SPECIMEN ID	ULTIMATE STRESS (kN)		P_{FEA}/ P_{EXP}
	Experimental P_{EXP}	Numerical P_{FEA}	
COLUMN A(1)	72.28	63.116	0.87
COLUMN A(2)	91.65	75.898	0.83
COLUMN B(1)	78.345	68.999	0.88

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COLUMN B(2)	109.20	73.898	0.52
Mean			0.775

It was shown that finite element analysis results were lower than the investigational grades. The mean of P_{FEA}/P_{EXP} is 0.775 respectively.

The Cold-formed steel Z-profiled Column with trapezoidal stiffening fails by distortional buckling. The obtained mode profile of Z-section with trapezoidal stiffened columns were over viewed in the following figures.

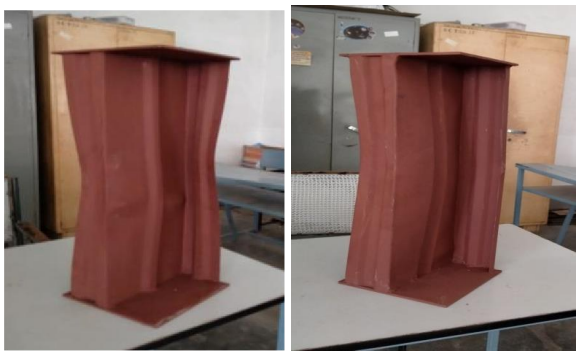

Fig. 13. *Typical Z-section column with and without lip*

This shows that the axial shortening of the Z- section with trapezoidal stiffened columns with lips gives the maximum load compared to without lips.

Conclusions

This research describes the behaviour of Z profiled Section strengthened by using trapezoidal stiffeners with and without lips. Four types of specimens were chosen and their corresponding section properties were predicted using GBTUL software. Numerical study was performed by ANSYS software. The columns strength for all the sections with and without lips were obtained by the investigational values were compared with the finite element analysis. The following conclusion are drawn from this investigation

- The result obtained from the experimental study lower than that of numerical analysis.
- The columns of Z profiled lip section with the provision of trapezoidal stiffening will enhances the maximum load carrying capacity compare to without lips.
- The strength and stiffness of the Z profiled lipped column section shows better performance than the section without lips.

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