ISSN 2229-5518

Lateral Torsional Buckling Behaviour Of Cold-Formed Light Gauge Steel Flexural Member With Triangular Shaped Web Corrugation

Harsha K P[1], Dr. C K Prasad Varma Thampan[2]

Abstract - The light gauge steel sections are formed by cold forming technique, it results in thinner section which may be more liable to buckle in different manner, which was basically a serious issuewhen it is used as a structural member. This paper is concerned with the study of lateral-torsional buckling behavior of cold formed light gauge steel beam with triangular shaped corrugations on the web by using Finite element software ANSYS. The strength of which under lateral torsional buckling are determined first by linear Eigen value buckling analysis by considering linear stress-strain behaviour. Then a non linear buckling analysis was performed for getting actual deformation and twisted profile by incorporating non-linear material properties. The analytical results obtained were compared with beam having Flat web.

Index Terms— Triangular web, Flat web, Cold formed steel,Lateral-torsional buckling, Eigenvalue buckling analysis, Non-linear buckling analysis, ANSYS.

1 Introduction

In steel construction, there are two main types of structural members one is hot rolled section and the other is cold-formed section. Usual practice is to use rolled steel section for structural applications. But for short span and light load, the use of it becomes un-economical. Hence it necessitates the requirement of cold-formed steel section. At present, the use of cold-formed high strength steel members has rapidly increased. In this current scenario it is being used as structural member because of certain major advantages such as lightweight, easiness for making unusual shape by cold forming, easiness for mass production, high strength and stiffness, and prefabrication. Thus its application covers wider area including car bodies, railway coaches, storage racks, transmission towers, transmission poles in addition to its application as purlin, girts, roof trusses, complete framing of one and two storey residential, commercial and industrial structures subjected to moderate loads etc.Since the light- gauge sections are formed by cold-forming techniques, it results in thinner sections which are more liable to buckle in different manner when it is subjected to compressive loads, bending, or twisting. One way to avoid such failure is by strengthening the section by introducing stiffeners. But this is found to be costly, increases weight and may cause difficulties for fabrication; the most suitable method is by introducing corrugations. Corrugation will impart both in plane and out of plane stiffness. Fatimah Denan and Mohd Hanim Osman [1] carried out a study on lateral-torsional buckling behavior of a beam with trapezoidal shaped web corrugation. They arrived at a conclusion that steel beam with trapezoidally corrugated web section have higher resistance to lateral-torsional buckling compared to that of section with flat web. The increased thickness of plate on web imparts increased strength were also included. Further, they presented study for understanding the shear buckling behavior of triangular shaped web profile cantilever beam under pure shear loading condition [3]. Eigen value buckling analysis result performed showed zonal distribution for triangular shaped web corrugation, whereas for flat web it becomes global. Mattias Larsson and John person [6] carried out a study on understanding the behaviour of trapezoidally corrugated web under torsional buckling. The critical buckling moments of steel girders with trapezoidally corrugated webs were calculated using different approaches available, and these values were compared to the critical moments obtained using FE analyses. They concluded that due to corrugated web profile, the increased stiffness is attributed to the warping constant I_w, and that the torsion constant I_t, which is more than that of flat web.

There are so many research activities undergone on studying the lateral torsional buckling behavior of trapezoidal shaped web beams. But it is very rare in the case of beams with triangular shaped web corrugation even though it is strong enough under flexure. The Research activities presented in this current study are focused on finding the critical buckling load and its linear as well as angular deformation when the beam with triangular shaped web corrugation subjected to lateral torsional buckling under static loading is a part of the ongoing research activity.

- *Harsha K P is currently pursuing master's degree program in structural engineering in Calicut University, NSS College of Engineering, Kerala, India, PH-7293787455. E-mail: harsharajeevan29@gmail.com*
- *C K Prasad Varma Thampan, HOD in civil engineering department, NSS College of Engineering, PH-9447442739. E-mail:ckpvarma@gmail.com*

2 Theory of Lateral Tosional Buckling

Cold formed light gauge steel sections consists of extremely thin web, this may results in instability of section, as it is subjected to bending which is resisted by a force couple in flange. At certain load this compressive flange will become unstable and buckle laterally. The web will prevent this from undergoing lateral buckling. The other flange subjected to tension and will anchor the lateral displacement of the cross section. This combined action will cause section to rotate about longitudinal axis. Along with this rotation, it is shifted laterally from its initial position. This is termed as lateral torsional buckling. The factors that influence lateral stability include torsion constant and warping constant and moment of inertia about minor axis. The figure 1 shows lateral-torsional buckling deformation of an I-girder subjected to bending about its strong axis.

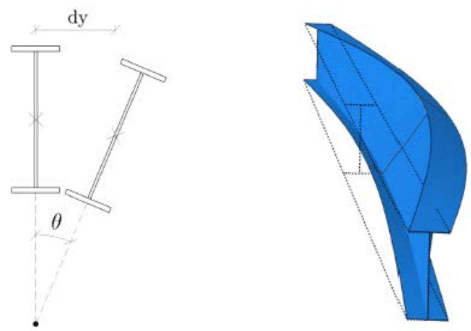

Fig.1 Principal lateral-torsional buckling deformation of an I-girder subjected to bending about its strong axis

3 Modeling of Cold-Formed Light Gauge Steel Beams with and without Corrugated Web

Two models were analyzed which includes beam having flat web (FW) and triangular shaped corrugated web (TWC). All material properties were kept same. Both linear Eigen value buckling analysis and non linear buckling analysis was performed. In the linear Eigen value buckling analysis, linear properties of the material was considered. Whereas in non-linear buckling analysis, it incorporates non-linear behaviour. The Young's modulus and yield strength of two models is 2x10^5 N/mm^2 and 210 N/mm^2. Poisson's ratio as 0.3.

TABLE 1: Geometric Details of TWC

Length of beam, L	2000 mm
Depth of beam,D	200 mm
Width of flange	100 mm
Thickness of flange, t_f	1.2 mm
Thickness of web, t_w	1.2 mm
Depth of lip	15 mm
Width of corrugated web,b	50 mm
Pitch of corrugation,p	100 mm

The details of the I-beam with triangular shaped corrugated web are given in the table 1. In beam having flat web all other parameters except corrugation is kept same. The geometry of triangular corrugated and flat web beam created in ANSYS is shown in figure 2 and 3 respectively

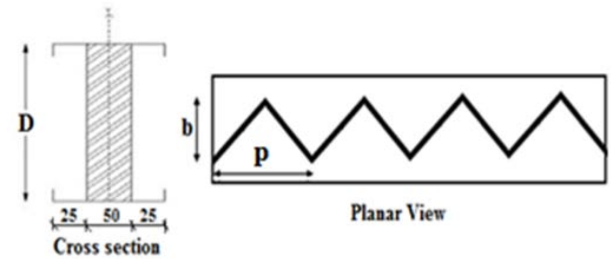

Fig.2 Geometry of I beam with triangular shaped web corrugation

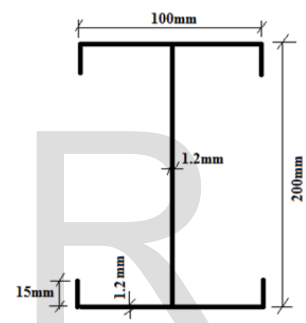

Fig.3 Cross sectional details of flat web

4 Numerical Analysis

The results presented in this paper are based on Finite Element analyses performed in ANSYS workbench version 16.2. The geometry created is meshed with SHELL181 element. It is a four noded element with six degrees of freedom at each node: translations in the x, y, and z directions, and rotations about the x, y, and z-axes. SHELL181 are suitable for thin to moderately thick shell also for linear, large rotation, and/or large strain nonlinear applications. Each model is first analyzed by linear Eigen value buckling analysis to obtain critical buckling load and buckled shape and these data are fed with non linear behavior and performed non-linear buckling analysis.

4.1 Eigen Value Buckling Analysis

It predicts the theoretical buckling strength(the bifurcation point) of an ideal linear elastic structure, which is shown in figure 4.Thismethodcorrespondstothetextbook approach to elastic buckling analysis: However, imperfections and nonlinearities prevent most real-world structures from achieving their theoretical elastic buckling strength. Thus, Eigen value buckling analysis often yields un conservative results, and should generally not be used in actual day-to-day engineering analyses

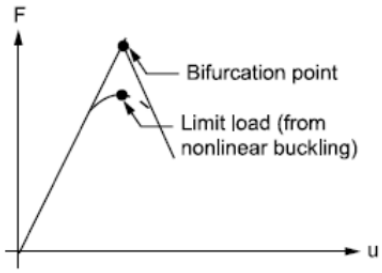

Fig.4 Linear (Eigen value) Buckling curve

4.2 Non linear buckling analysis

It is more accurate method of buckling analysis hence it is used effectively for evaluation of actual structures. In this method load is kept increased by steps until it become unstable. Using the non-linear technique, the model can include features such as initial imperfections, plastic behavior, gaps, and large-deflection response. In addition, by deflection-controlled loading, it is possible to track the post-buckled performance of the structure including snap-through.

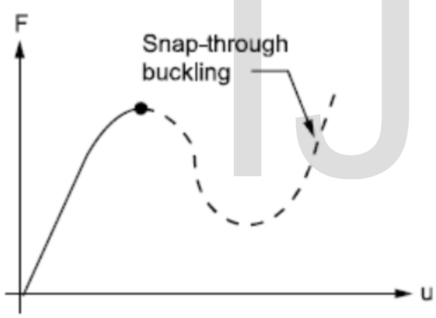

Fig.5 Fig.5 Non linear buckling curve

4.3 Loading and Boundary Condition

At one end of beam translation in X,Y,Z and rotation about X were constrained and on the other end, translation Y,Z and rotation about X were constrained. In-addition to this in order to prevent local buckling, translation in Y direction is prevented for all nodes at ends. For performing the analysis a force couple is induced at ends to have a small perturbation effect. Then a unit load is applied at top for linear Eigen value buckling analysis. The critical buckling load obtained for the desired mode by this analysis is used as vertical load for performing non linear buckling analysis. In non linear buckling analysis, since the load is kept in-plane a slight deformation is applied in Y direction to impart a slight out of plane deformation. Load is applied by steps and the location were the curve diverges is noted. This gives critical buckling load and actual deformation at time of initiation of buckling. The figure below shows the model created in ANSYS with load and boundary condition

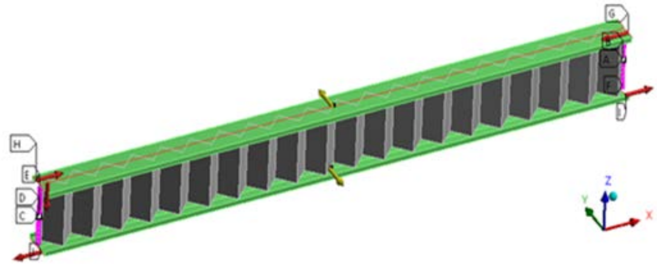

Fig.6 Model of TWC with load and boundary condition

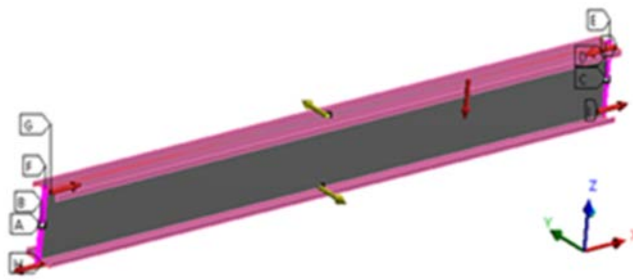

Fig.7 Model of FW with Load and boundary condition

5 RESULTS AND DISCUSSION

By performing liner Eigen value buckling analysis the load multiplier for the desired mode shape was taken. From this the critical buckling load is calculated. The critical buckling load obtained after performing non-linear buckling analysis by applying the load obtained from linear buckling analysis, as vertical in-plane load for both FW and TWC are shown graphically in figure 8.The table 2 shows deformation and angle of twist obtained after non linear buckling analysis

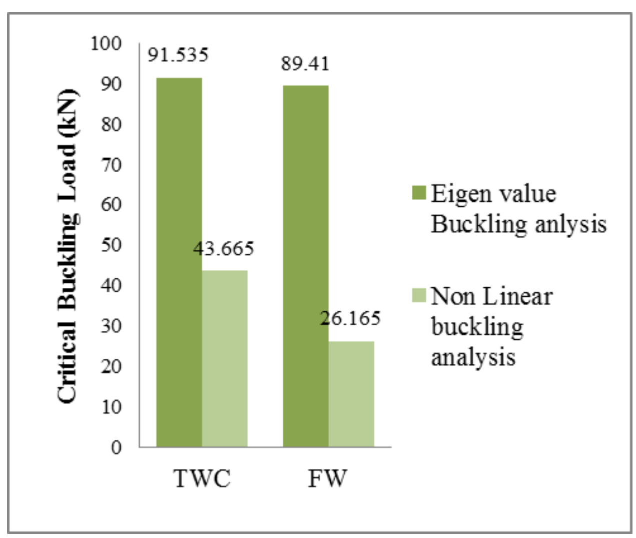

Fig.8 Graphical representation of FW and TWC

Table.2 Non-linear buckling analysis results

ISSN 2229-5518

	TWC	FW
Critical buckling Load (kN)	43.665	26.165
Deformation(mm)	11.546	26.152
Angle of Twist	1.8311°	6.317°

The result shows that the buckling strength of TWC is larger than that of FW. From linear Eigen buckling analysis, the strength of TWC is found to be 2.4 % more than FW. Whereas in non-linear buckling analysis, it is found to be 66.89% more than that of FW. The figure 9 represents Load-Displacement graph obtained for TWC and FW after non-linear buckling analysis

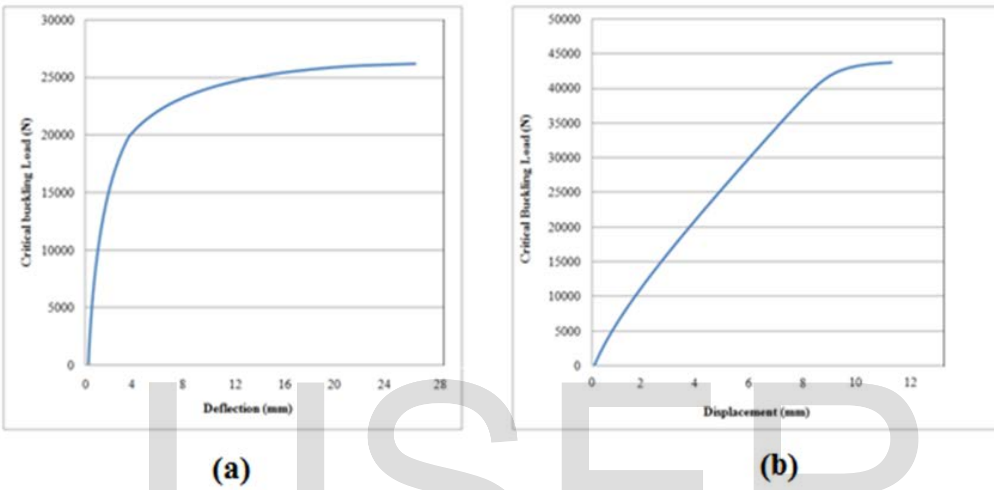

Fig.9 Load displacement graph for (a) FW, (b) TWC

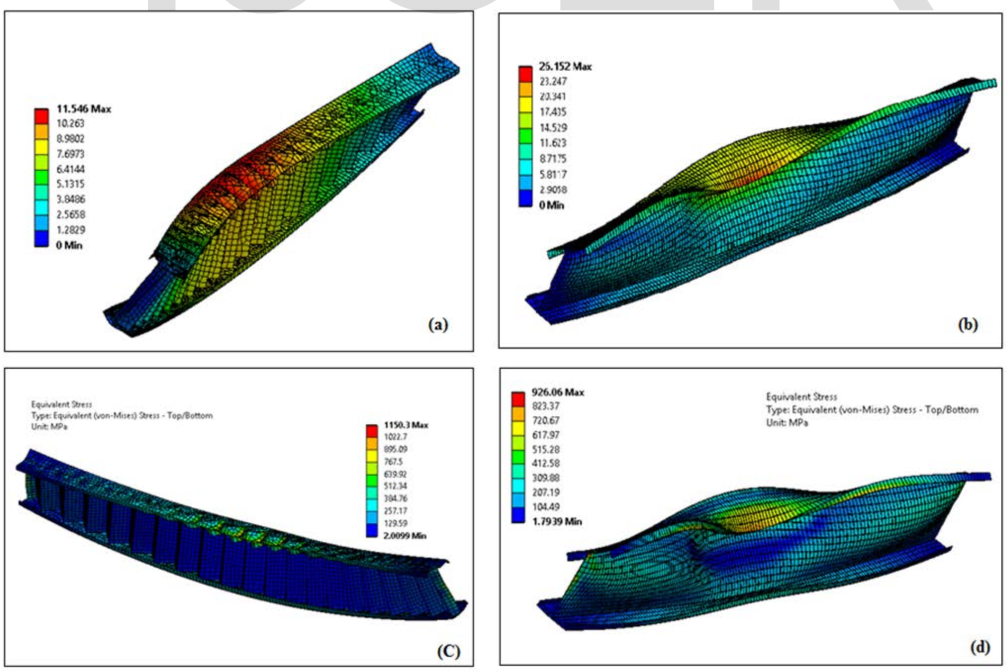

Fig.10 (a), (b) shos buckling mode of TWC nd FWC respectively, (c),(d) shows equivalent stress distribution

In figure 10, (a) and (b) shows the buckled shape of TWC and FW after non-linear buckling analysis. From this it is clear that maximum lateral displacement occurred in FW, it is 26.152mm. In TWC local buckling is found in top flange and lip. No severe warping deformation has occurred. Whereas for FW, global buckling is clearly visible in top flange and web. Also the beam has undergone warping deformation at middle. By carefully studying figure (c), yielding is initiated intop flange especially near the lip. But the web of which is not yet yielded except at top. Bearing failure is observed at ends of web. From fig (d), it is found that the web as well as flange undergone yielding. Web is mostly affected by warping deformation and also buckling. The FW offered less resistance to angle of twist compared to TWC. This higher resistance to buckling and less angle of twist for TWC is offered by higher out of plane stiffness imparted by the corrugations in the web

Table.3 Load and Weight comparison

	TWC	FW	% increment
Buckling Load (kN)	43.665	26.165	66.89%
Weight (kg)	10.232	8.6712	17.99%

From table.3, it is found that the percentage increase in load while providing corrugation in the web instead of flat web is 66.89%. But the corresponding increase in weight is only 17.99%. Thus for a slight increase in weight considerable increase in load is obtained by the introduction of corrugation.

6 CONCLUSION

- TWC offer higher resistance to lateral torsional buckling than FW
- Out of plane deformation TWC is small compared to FW
- The critical buckling load of TWC is 1.024 times that of TW in linear Eigen value buckling analysis.
- From non linear buckling, the critical buckling load of TWC is found to be 1.67 times that of FW.
- This increased load capacity of TWC is due to its increased out of plane stiffness.
- TWC offers higher resistance to angle of twist than FW.
- TWC subjected to local buckling at its top flange, but severe global buckling is observed in FW at comparatively lower load.
- Yielding was not initiated in web for TWC, whereas for FW the large areas of web get yielded.
- By introducing corrugation in the web the increase in weight is found to be 17.99 %, but the corresponding increase in load carrying capacity is much higher, that is around 66.89%

REFERENCES

[1]. Fatimah De'nan, Mohd Hanim Osman, Sariffuddin Saad(2010), "The study of lateral torsional buckling behavior of beam with trapezoid web steel section by experimental and finite element analysis", IJRRAS

[2]. Fatimah De'nan, Nor Salwani Hashim(2013), "Experimental study on bending behaviour of triangular web profile steel beam section", International Journal of Research in Engineering and Technology, vol.2

[3]. Fatimah De'nan, MusniraMustar, Adzhar Bin Hassan (2013), "Effect of Triangular Web Profile on the Shear Behaviour of Steel I-Beam", Iranica Journal of Energy & Environment

[4]. Jongwon Yi, Heungbae Gilb, Kwangsoo Youmc (2007), "Interactive shear buckling behavior of trapezoidally corrugated steel webs", Elsevier Science Ltd

[5]. Krishnan.L, Dineshraj.C.S, Prema.S, (2015), "Experimental Investigation of Cold-Formed Steel Section- Flexural Member with Triangular Web",Journal of Mechanical and Civil Engineering.

[6]. Mattias Larsson, John Persson, "Lateral Torsional buckling of steel girder with trapezoidally corrugated web", Master's Thesis published at Chalmers University of Technology, Sweden (2013)

[7]. Siva Prakash V, Prasad Babu.K(2015), "Flexural behaviour of cold-formed steel I-beam section with different corrugated profile sheet as web", Integrated Journal of Engineering Research and Technology