

## **EFFECT OF WEB OPENING ON THE BENDING BEHAVIOUR OF COLD FORMED STEEL BUILT-UP 'I' SECTION**

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**Abstract:** Thin walled cold-formed steel members have wide applications in building structures. In cases where beams carry less moment it is uneconomical to use traditional hot rolled steel. Cold formed steel is an apt solution for this case. For a latticed cold formed steel flexural member, the moment carrying capacity may be affected mainly by local, distortional or lateral torsional buckling. In this paper, the impact of web opening on the flexural behaviour of Cold formed built-up I section under two point loading is investigated for the simply supported end conditions. Experimental investigation has been carried out on 8 specimens by varying the thickness and depth of the built-up beam. Numerical investigations have also been carried out using finite element analysis software ANSYS13.0. Load vs. Deflection curve, failure modes and ultimate load carrying capacity of specimens are presented in this work.

**Index Terms:** cold formed steel, built-up, latticed, flexural member, two point loading etc.

### **I. INTRODUCTION**

One of the issues raised since the steel structure was introduced in the construction industry is how to reduce the weight and cost of the component parts such as girder and beams. Cold-formed steel members are widely employed in steel construction because they are lighter and more efficient than traditional hot-rolled ones. Nowadays the easy availability and accessible cost of high-strength low-alloy steels, weathering steels, and zinc-coated steels have led to members with height/thickness ratios, rendering them even more susceptible to local buckling and to another buckling mode called distortional, Z sections, hat, rack, etc.

The primary objective of this research is to study on the impact of web opening on the flexural behaviour of latticed built up I section. Eight specimens are experimentally tested by applying two point loading and the failure behaviour is studied. The possible modes of failure of the members under static loading by performing non –linear analysis are performed using ANSYS 13.0 software. The numerical method includes material and geometrical non-linearity. The geometric imperfections are also included in the model. The experimental test

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results are compared with the numerical analysis done using ANSYS package. The effect of web opening on the flexural behaviour is discussed here.

## II. EXPERIMENTAL ANALYSIS

Experimental study is carried out on the built-up I section in loading frame.

### *Section Preparation*

CFS: Cold Formed Sheets of thickness 1.2mm and 2mm of length 2400mm are cut and bent to angle 50×50×15mm using hydraulic machines.

Stiffener: 50×3mm plates are used.

Lacing Rod: Hot rolled reinforcement bar of 10mm diameter is used. Rod is inclined at 45° along length.

Process: Four angles are welded to the lacing rod so that built-up I section member is prepared.

### *Testing*

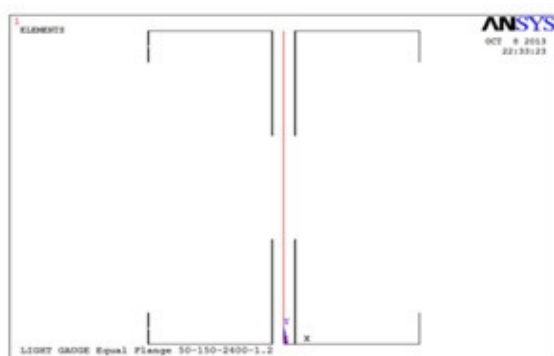
Testing is done on beam in loading frame.

Support condition: Simply supported at both ends.

Loading: Two point loading

The built-up section is modeled by connecting equal angles back-to-back latticed by 10mm diameter bars. 50×50mm angle with lip 15mm is used. Length of the specimen is taken 2400mm for all specimens. Lacing is inclined at an angle 45°. Eight specimens were casted by varying the web opening. 1.2mm and 2mm thick sheets were used to fabricate the angles. Web opening ranges from 50mm to 200mm. Intermediate stiffeners are used at end supports and points of application of load. 3mm thick plate is used as stiffener plate. Two point loading is preferred in order to obtain pure bending without shear.

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**Figure 1:** Cross section of Built up section



**Figure 2:** 3D model

Lacing is inclined at an angle  $45^\circ$ . Eight specimens were casted by varying the web opening. 1.2mm and 2mm thick sheets were used to fabricate the angles. Web opening ranges from 50mm to 200mm. Intermediate stiffeners are used at end supports and points of application of load. 3mm thick plate is used as stiffener plate. Two points loading is preferred in order to obtain pure bending without shear.



**Figure 3:** Experimental Setup

1: Proving Ring      2: Hydraulic Jack      3: Spreader Beam  
4: Specimen 5: LVDT at L/3 6: LVDT at L/2

**Table 1:** Specimen Details

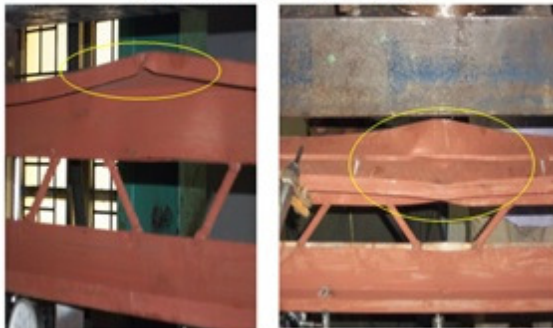
Specimen	Overall Depth (mm)	Web Opening (mm)	Thickness (mm)
50-50-150-1.2-2400	150	50	1.2
50-50-200-1.2-2400	200	100	1.2
50-50-250-1.2-2400	250	150	1.2
50-50-300-1.2-2400	300	200	1.2

50-50-150-2.0-2400	150	50	2.0
50-50-200-2.0-2400	200	100	2.0
50-50-250-2.0-2400	250	150	2.0
50-50-300-2.0-2400	300	200	2.0

Built-up beam is placed over the steel column with roller support so that the edge stiffener coincides with the mid portion of the roller support. The span of the beam is 2.4m. The lateral displacement is arrested at the supports. Loading is applied by hydraulic jack and the load value is observed in proving ring. Below hydraulic jack, spreader beam is placed. The load applied through hydraulic jack is thus carried by hollow beam and this load is divided into two at mid third portion of beam. Linear Variable Differential Transducer (LVDT) is used to measure vertical deflection at  $L/2$  and  $L/3$  points. Load vs. Deflection are determined.

#### Failure Modes

50-50-150-1.2-2400



50-50-200-1.2-2400



50-50-250-1.2-2400



50-50-300-1.2-2400



**Table 2:** Experimental Results

Specimen (mm)	Ultimate Load(kN)	Ultimate Moment (kN m)	Type of Buckling
50-50-150-1.2-2400	18.201	7.280	D
50-50-200-1.2-2400	20.216	8.086	L
50-50-250-1.2-2400	23.276	9.31	D SF
50-50-300-1.2-2400	20.291	8.116	D LF
50-50-150-2.0-2400	36.536	14.614	D L
50-50-200-2.0-2400	48.266	19.306	D LF
50-50-250-2.0-2400	36.026	14.41	C LT LF
50-50-300-2.0-2400	31.511	12.604	LT D LF

LF- Lacing failure    L- Local    SF- Stiffener failure

C- Crushing    LT- Lateral Torsion    D- Distortion

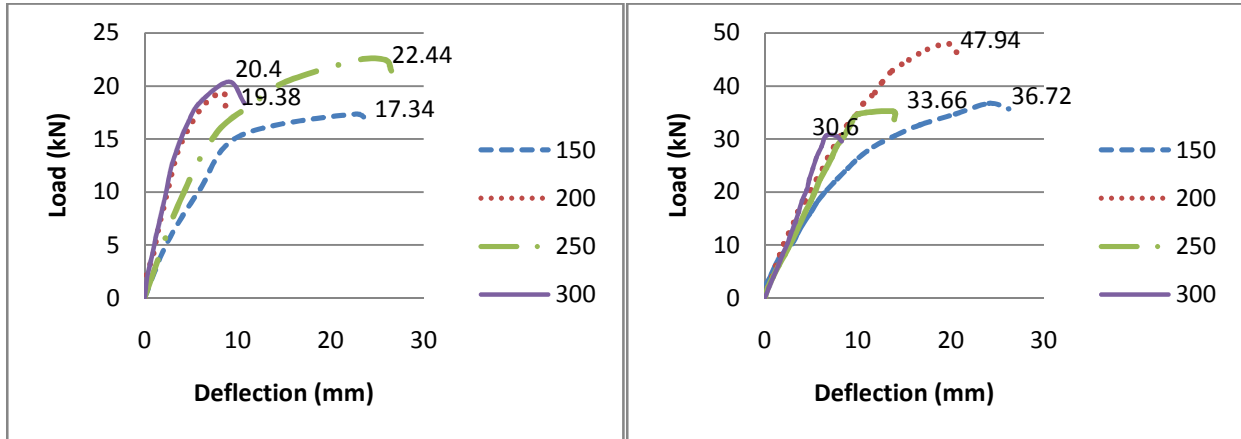


Figure 4(a): Load vs. deflection at L/2 for 1.2mm specimens.

Figure 4(b): Load vs. deflection at L/2 for 2mm specimens

### III. NUMERICAL ANALYSIS

The finite element method is a numerical analysis technique for obtaining approximate solutions to wide variety of Engineering problems. Most of the engineering problems today make it necessary to obtain approximate numerical solutions to problems rather than exact closed form solutions. The basic concept behind the finite element analysis is that structure is divided into a finite number of elements having finite dimensions and reducing the structure having infinite degrees of freedom to finite degrees of freedom. The original body of structure is then considered as an assemblage of these elements connected at a finite number of joints called Nodes or Nodal points.

Analytical study is carried out by using the Finite Element software ANSYS13.0

Linear and Non-linear analysis carried out. The properties of the material were determined by coupon test. The value of Young's modulus 'E' is given as  $2.01 \times 10^5 \text{ N/mm}^2$ . The Poisson's ratio is given as 0.3. The yield stress of the cold formed angle is taken as  $300 \text{ N/mm}^2$  and that of lacing bar is given as  $500 \text{ N/mm}^2$ . Density of steel material is given as  $7850 \times 10^{-9} \text{ N/mm}^3$ . Load Deflection curve, Load carrying capacity and failure pattern of the specimen is observed.



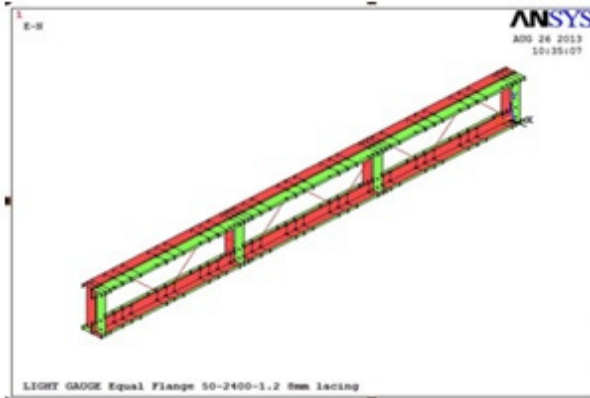


Figure 5: Model of Built-up I section Beam

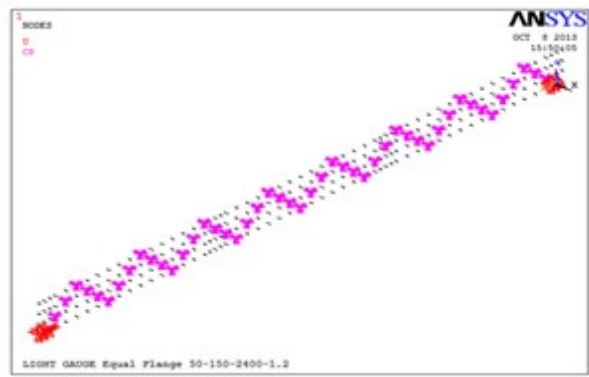


Figure 6: Coupling

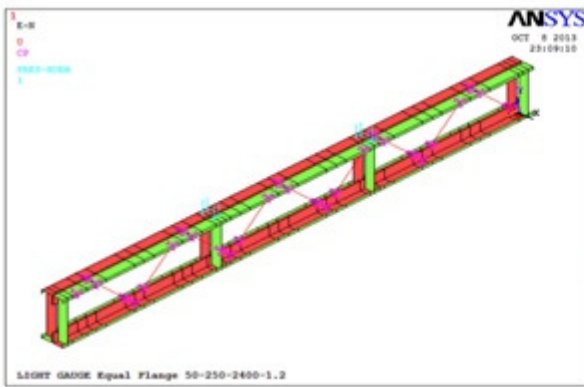


Figure 7: Two Point Loading

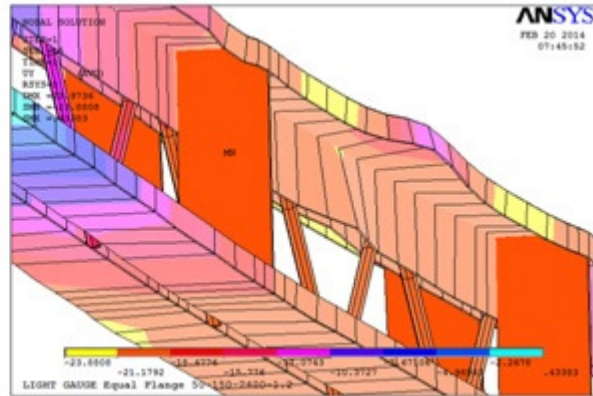


Figure 8: Deformed shape of specimen

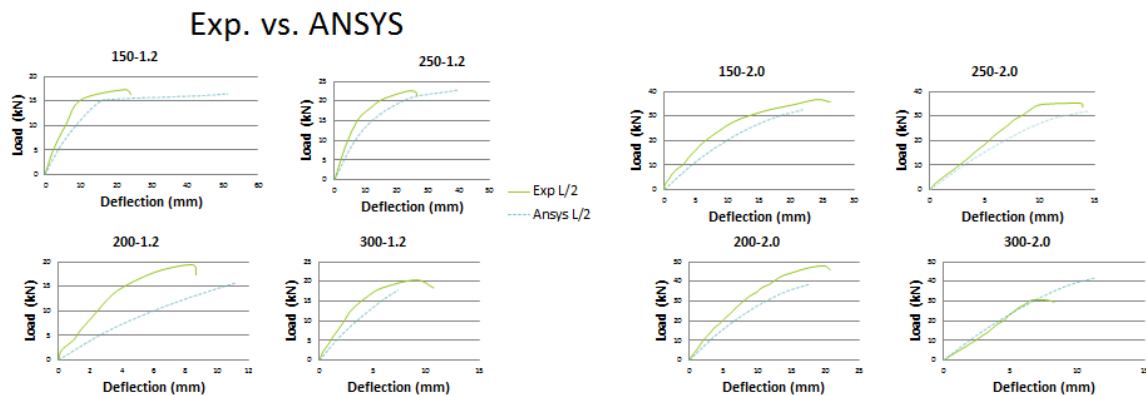


Figure 9: Load deflection graph

#### IV. CONCLUSION

From the numerical and experimental study, the behavior of built-up cold formed I steel sections with equal flanges was observed. The impact of web opening on performance of built-up section under static loading was compared. It is observed that the member 50-50-

250-1.2-2400 carries maximum moment while comparing 1.2mm thick specimens. This is because stiffer takes up load in this specimen. But while considering 2mm thick specimens, 50-50-200-2.0-2400 carries maximum moment. This shows that web opening to depth ratio of 0.5 would carry maximum moment. Also lacing failure is common in 2mm specimens and seen in 1.2mm specimen with maximum web opening.

Even though a lateral displacement is arrested at support, lateral torsion is unavoidable for 2mm thick specimens of web opening 150mm and 200mm.

### REFERENCES

- [1] Luís Laím, João Paulo C. Rodrigues, Luis Simões da Silva (2013) “Experimental and Numerical Analysis on the Structural Behavior of Cold-formed Steel Beams” *Thin-Walled Structures*, vol.72, pg.no.1–13.
- [2] Hassanein M.F., Kharoob O.F. (2013) “Flexural strength of Hollow Tubular Flange Plate Girders with slender stiffened webs under mid-span concentrated loads” *Thin-Walled Structures*, vol.69, pg.no.18–28.
- [3] Jung Kwan Seo, Mahen Mahendran, (2011) “Plastic bending behavior and section moment capacities of mono-symmetric Lite Steel beams with web openings” *Thin-Walled Structures*, vol.49, pg.no.513–522.
- [4] Haiming Wang, Yaochun Zhang (2009) “Experimental and Numerical Investigation on Cold-formed Steel C-section Flexural Members” *Journal of Constructional Steel Research*, vol.65 pg.no.1225–1235.
- [5] Cheng Yu and Benjamin W. Schafer (2007) “Simulation of cold-formed steel beams in local and distortional buckling with applications to the direct strength method” *Journal of Constructional Steel Research*, vol.63, pg.no.581–590.
- [6] Ever J. Barbero and Malek Turk, “Experimental Investigation of Beam-Column Behavior of Pultruded Structural Shapes”, *Journal of Reinforced Plastics and Composites*, 2000, vol. 19.
- [7] Ferdinando Laudiero, Fabio Minghini and Nerio Tullini, “Buckling and Postbuckling Finite-Element Analysis of FRP Profiles under Pure Compression”. *Journal of Composites for Construction*, 2013.
- [8] Pizhong Qiao, Julio F. Davalos, and Jialai Wang, “Local Buckling of Composite FRP shapes by Discrete Plate Analysis”, *Journal of Structural Engineering*, March, 2001, Vol. 127, No. 3,.



- [9] Sang Kyoon Jeong and Soon Jong Yoon, "Elastic Buckling of Orthotropic Open Section Compression Members with Edge Stiffeners". *KSCE Journal of Civil Engineering*, 1998, Vol.2, 377-386.
- [10] Shao-Yun Fu & Bernd, "Effects of Fiber Length and Fiber Orientation and Distributions on the tensile strength of short-fiber-reinforced polymers", *Composite science and Technology*, 1996, 1179-1190.
- [11] Zureick A, Scott D., "Short-term behavior and design of fiber-reinforced polymeric slender members under axial compression". *Journal of Composites for Construction*, 1997, 1(4): 140-149.