

Numerical and Theoretical Investigation on Cold Formed Steel Latticed Built Up I – Beams

P. Vijay, Dr. K. Sudha

P. G Student, Department of Civil Engineering, Government College of Engineering, Salem, India

Associate Professor, Department of Civil Engineering, Government College of Engineering, Salem, India

ABSTRACT: Cold formed steel section is widely used now a day for structural application due to its high weight to strength ratio. Light weight construction play's a vital role in industrial structure due to the economy in structural application. The ease and speed in fabrication and erection made it to find property. Uses of such light weight steel structure result in reduction in dead load and also meeting the necessary strength requirements. Hence a use of light weight structures is found steadily increasing. It has been reported that the performance of low rise building which were built with cold formed steel sections as major components increased the life of structures. Torsional buckling in cold formed steel beams can be avoided by providing lacing between the web portions. Theoretical calculation are done by procedures as per North American specification of cold formed steel (AISI S-100:2007) and the ultimate moments for various section were determinate. The numerical analysis was carried out by FEM software ABAQUS of version 6.13-1. It provides a cost effective way to explore the performance of products in a virtual environment. The ultimate capacity was obtained by performing both linear and non-linear analysis. Numerical finite element procedure was used to study the effect of various parameters on behaviour of beams. Seven specimens were taken for this investigation. The critical load and different modes of failure are studied by this numerical investigation. The numerical results were compared with the results of theoretical investigation. Comparison between deformed shape and Load Vs. Deflection curves of I-section by varying depth, span and thickness were carried out.

KEYWORDS: Cold formed built up section, Torsional buckling, Distortional buckling and Finite element analysis,.

I. INTRODUCTION

Steel are often preferred over wood because of the increased strength and durability. Steel is strong, resistant to moisture and last a long time, making it ideal for other structural components. There are two methods by which steel components are produced i) Hot Rolled and ii) Cold rolled sections however one of the most popular of which is cold formed steel (CFS). CFS are made using a special process in which steel material are rolled at (or) near to room temperature. Steel various shapes to create steel products such as CFS and other structural components. There are several benefits in using CFS, increased strength, and light weight. According to the American Iron and Steel Institute (AISI). CFS steel product have average yield strength of 33 to 50 kilo pounds per square inch (Kpsi). CFS member for decades have been used as secondary members in both steel and concrete structures. In recent years cold formed steel member are focussed towards local bearing for low and mid-rise structures. This increased use of cold formed steel member and connections. This article focus on the usage of four angles built up I section in cold formed steel structures along lacing in web portion in order to avoid the torsional buckling.

II. LITERATURE REVIEW

Cheng Yu Benjamin w. Schafer (2006)

Have determinate the ultimate bending capacity of cold formed steel C and Z members. They also studied the yielding capacity and the potential towards local distortional and lateral torsional buckling of the section. They also predicted the strength using American specification (NAS). Which result a poor prediction leading to distortional failure modes.

Cheng Yu Benjamin w. Schafer (2006)

Did simulation of cold formed steel beams in local and distortional buckling with application to the direct strength method. A nonlinear finite elements model was developed and verified against previously conducted flexural test on cold formed steel C and Z section beams. The finite elements analysis was made in beams. Which were not experimentally tested and the yield stress was formed between 228 to 506 Mpa. This result supports the direct strength methods.

MacDonald, M.A. Heiyantuduwandon, M .Kotekoban Rhodes (2010)

Has investigated the web crippling behaviour of cold formed thin-walled steel lipped channel beams. The result showed that the nonlinear finite elements models developed, based on closely representing web crippling failure. An average deviation in finite element strength was observed from experimental results.

Cao Hung Pham A, Gugory J. Hancock (2012)

Provide the solution to the elastic buckling of whole channel section including flange and lips. The section is loaded in pure shear parallel with the web in this investigation. The analysis plotted in the formed of interaction chart was given as design guidelines for designer to predict the elastic buckling shear coefficient (kiva) without using the spline finite strip methods (SFSM) software.

Vijayasimhan M, Marimuthu V, Palani G S, and Rama mohan rao P (2013)

Carried out the comparative study on distortional buckling strength of cold formed steel lipped channel section. The Indian code for cold formed steel design as per IS 801 was for revised during 1975, edition of AISI standard. Which use of As the direct strength method , which use the load factors corresponding to different buckling modes and their interaction, predicts the flexural strength of the lipped channel section closer to the experimental results, parametric study, had been conduct of direct buckling strength.

Luis Laim, Joao Paulo Rodringues and Luisimoesda Silva (2013)

Has investigated the behaviour of cold formed steel C –Lipped R and 2R section beams under bending condition at ambient temperature .Cold formed steel beams was very sensitive to local and distortional and global buckling and also their interaction. It was observed that the failure loads of the beams with C – and lipped I- shaped cross section. The corresponding to the lateral torsional buckling modes for the failure 1 of loads whereas the distortional buckling was the responsible buckling mode for the failure loads of the rand 2R beams.

Sudha K and Sukumar. S (2014)

Have investigated the behaviour of cold formed steel built up I section under bending an experimental and numerical investigation on the bending strength and behaviour of cold formed steel built up flexural member have been studied. The experimental results shows the modes of buckling and their influence on the bending strength and behaviour of cold formed built up I sections. The experimental results are also verified by simulating finite element models and analysed by using finite elements model software ANSYS.

Jun yu , iman hajiasouliha, jurgen becquekypros pilakoutas (2014)

Have investigated the development of more efficient of cold formed steel channel section in bending. Cold formed steel cross sections can be optimised to increase their load carrying capacity, loading to more efficient and economical structural system. The flextural strength of the optimized section is verified, using detailed nonlinear finite element analysis. The results indicated that the optimized folded flange section provides the bending capacity higher than standard optimized shapes with the same amount of materials.

III. SPECIMEN DETAILS

50-50-1.2-200-2400

50-50 – Size of angle

1.2 – thickness of specimen

200 – over all depth of specimen

2400 – Length of the specimen

I section has been created by four angle two are provided in the top flange and another two at the bottom flange, which act as the main chord of the member. These main chords are held in position by using secondary member in 10 mm and 12 mm diameter bar bend in the form of sinusoidal wave form of the 45°. The main chord and the secondary members are welded at the point of contact by spot welding. The angle shape of stiffener on either side is provided at the point of loading and at the point of supported.

IV. THEORETICAL INVESTIGATION

The theoretical calculation follows the procedures as per North American Specification of cold formed steel (AISI S-100:2007) and the ultimate moment for the various sections were calculated.

1. Nominal flexural section strength:

Nominal flexural section strength M_n , shall be minimum of lateral torsional buckling strength M_{ne} , Local buckling strength M_{nl} , distortional buckling strength M_{nd} .

$$M_y = S_e \times F_y$$

$$S_e = I_{xx}/d$$

Where

M_y (or) M_{ne} = Yield moment

S_e = Effective section modulus

F_y = Yield stress

I_{xx} = Moment of inertia at x-axis

d = Depth of the section in mm

2. Lateral Torsional buckling strength:

The nominal flexural strength M_{ne} , for lateral torsional buckling strength shall be calculated in accordance with for following

(a) For $M_{cre} > 2.78M_y = > M_{ne} = M_y$

(b) $2.78F_y > F_e > 0.56F_y$
 $F_e = (10/9) \times F_y (1 - 10F_y/36F_e)$

$$F_e < 2.78F_y = 615.19 < 695$$

$$F_e = C_b \times \pi^2 \times E \times d \times I_{yc} / S_f \times (L_y \times K_y)$$

$$I_{yc} = I_{yy}/2$$

Where

C_b = Bending coefficient

E = Young's modulus

D = depth of the section in mm

I_{yc} = Moment of inertia of compression portion of section

S_f = Section modulus of section



L_y = Unbraced length of compression member for the section

K_y = Effective length factor for buckling about y-axis

3. Local buckling strength:

The nominal flexural strength M_{nl} , for local buckling shall be calculated in accordance with the following

(a) For $\lambda < 0.776 \rightarrow M_{nl} = M_{ne}$

(b) For $\lambda > 0.776$

$$M_{nl} = (1 - 0.15 \left(\frac{M_{cr1}}{M_{ne}}\right)^{0.4}) \times \left(\frac{M_{crs}}{M_{ne}}\right)^{0.4} \times M_{ne}$$

$$F_{cr1} = K \cdot \pi^2 \cdot E / (12(1 - \mu^2))$$

$$K = 1, \mu = 0.3$$

$$M_{cr1} = F_{cr1} \times S_e$$

$$\lambda = \sqrt{\frac{M_{ne}}{M_{cr1}}}$$

Where

F_{cr1} = Critical buckling stress

M_{nl} = Nominal flexural strength for local buckling

M_{ne} = Nominal flexural strength for overall buckling

4. Distortional buckling strength:

The nominal flexural strength M_{nd} , or distortional buckling shall be calculated in accordance with the following

(a) For $\lambda_d < 0.673 \rightarrow$ belongs to condition 'b'

$$M_{nd} = M_y$$

For $\lambda_d > 0.673$

$$M_{nd} = (1 - 0.22 \left(\frac{M_{crd}}{M_y}\right)^{0.5}) \times \left(\frac{M_{crd}}{M_y}\right)^{0.5} \times M_y$$

$$\lambda = \sqrt{\frac{M_y}{M_{crd}}}$$

$$M_{crd} = S_f \times F_d$$

$$F_d = \beta \cdot K_d \cdot \frac{E}{12(1 - \mu^2)} \times (t/W)^2$$

$$\beta = 1, K_d = 4 \text{ (As per code ASIS 2007)}$$

Where

F_d = Elastic distortional buckling stress

K_d = Plate buckling coefficient for distortional buckling



M_{crd} = distortional buckling moment

M_{nd} = Nominal flexural strength for distortional buckling

β = A value accounting for moment gradient, which is permitted to be conservatively taken as 1.0

V. RESULTS AND DISCUSSION

The theoretical analysis was performed to determine the ultimate load carrying capacity of the various specimens. The ultimate moment carrying capacities of built-up I beams estimated done by AISI S-100-2007 are presented. The failure models are distortional and flexural. The theoretical failure modes are in good agreement with results as per code of American iron and steel institute (AISI S-100; 2007). Theoretically all specimen failed is distortional buckling of compression chords.

The ultimate moment carrying capacity is increasing while increasing in the depth of the specimen except depth. This reduction is due to insufficient stiffness.

VI. RESULTS FROM THE THEORETICAL ANALYSIS

S. NO .	Description of sections	M_{The} (KNm)	Modes of failure
1	50-50-150-2-1200	7.354	DB
2	50-50-200-2-1800	19.188	DB
3	50-50-200-1.2-2400	8.613	DB
4	50-50-250-2-2400	20.913	DB
5	50-50-250-1.2-2400	12.746	DB
6	50-50-300-2-2400	17.413	DB
7	60-60-200-1.2-1200	8.147	BF

Where

DB – Distortional buckling

BF – bearing failure

VII. MECHANICAL PROPERTIES OF COLD FOMED STEEL

The mechanical properties of cold formed steel is found out by conducting tension test on coupon cut from the CFS sheet used to fabricate the beam. The size of the test specimens are in accordance with IS 1608-2995 (PART -1).

Specification of coupon:

Thickens of the coupon = 1.2 mm, 1.6mm,
2mm, 3mm,
Height of the coupon = 240mm
Breadth of the web = 12mm



Figure 1.1 sample of coupon and dimension of the test specimen



Figure 1.2 Failure of the tested coupon

VIII. COUPON TEST RESULT

Thickness of the specimen in (mm)	Peak load (kN)	Area in (mm ²)	Strain in (%)	Peak stress in (N/mm ²)
1.2	2.3	14.4	7.033	160
1.6	2.9	19.2	11.253	151
2	4.1	24	12.5	171
3	14.1	36	13.4	392

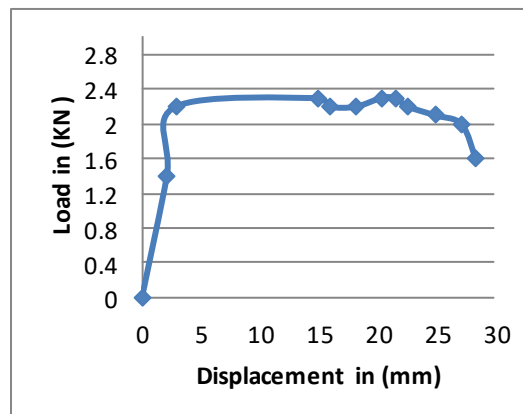


Figure 1.3 Load – Deflection curve obtained from coupon test for 1.2 mm thickness

IX. NUMERICAL VALIDATION

Numerical analysis provides a relatively inexpensive and time efficient alternative to physical experiments. Finite element model the moment carrying capacity of beams; the finite element model should include the effect of material and geometric non linearly. To carry over the numerical analysis ABAQUS standard version 6.13-1 is used as a finite element model.

The FE software ABAQUS 6.13-1 was used to simulate the numerical model of cold formed –steel built up I beams. The finite element method is a numerical analysis technique for obtaining approximate solution to wide variety of engineering problems. Most of the engineering problems today make it necessary to obtain approximate numerical solution to problems rather than exact closed form solution. ABAQUS 6.13-1 is a general purpose finite element modelling package for numerically solving a wide variety of mechanical problems.

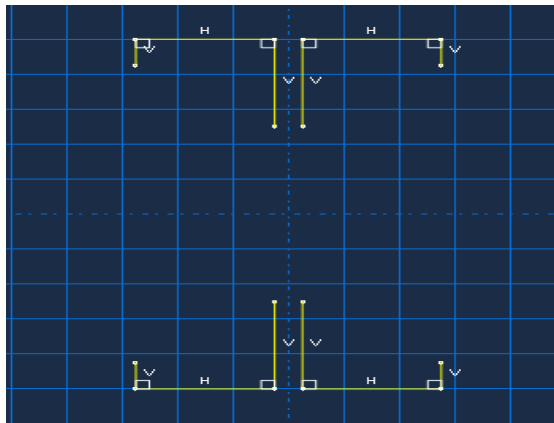


Figure 1.7 Front view of the angles (50-50-200-1.2-2400)

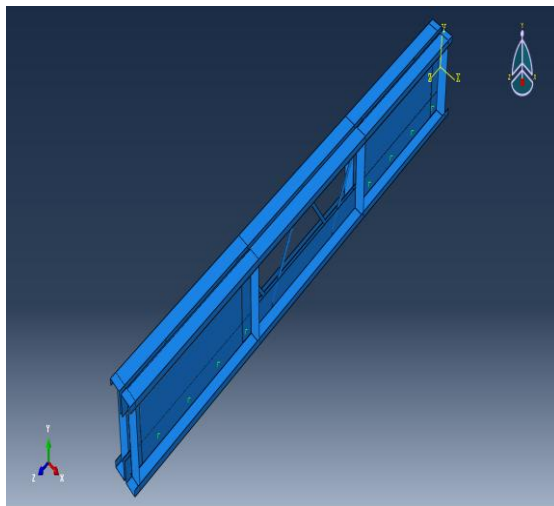


Figure 1.8 3D View of the built up I-section

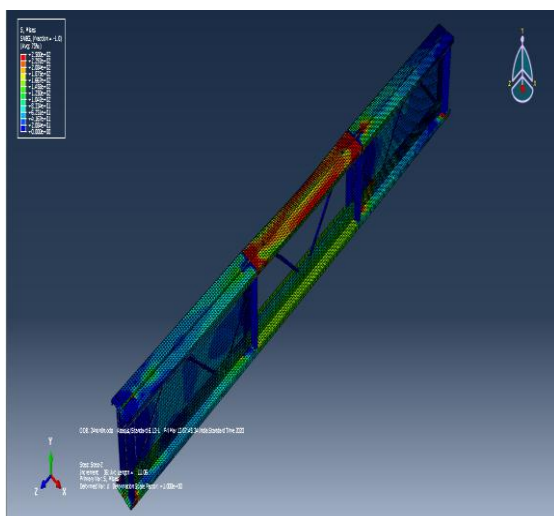


Figure 1.9 Deformed shape of the section(50-50-200-1.2-2400)

X.GRAPH FROM NUMERICAL ANALYSIS

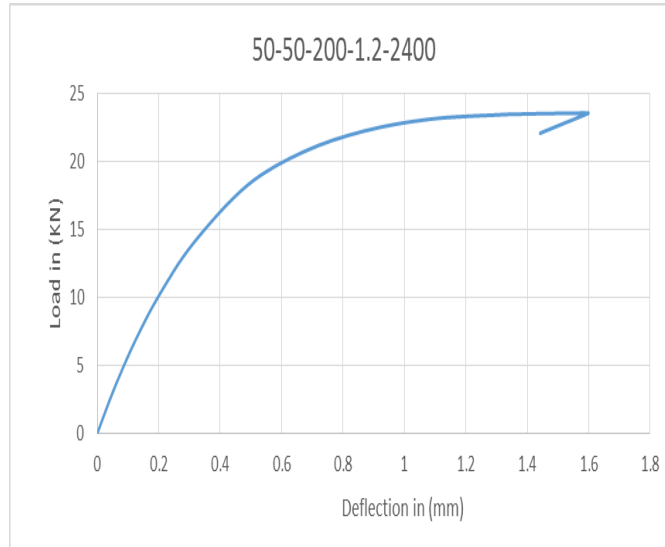


Figure 2 Load –deflection curve (50-50-200-1.2-24000)

XI. RESULTS FROM NUMERICAL ANALYSIS

S. NO.	Description of sections	M _{Num}
1	50-50-150-2-1200	6.654
2	50-50-200-2-1800	17.788
3	50-50-200-1.2-2400	9.210
4	50-50-250-2-2400	18.413
5	50-50-250-1.2-2400	10.714
6	50-50-300-2-2400	14.413
7	60-60-200-1.2-1200	7.989

XII. DISCUSSION

Built up I –section had been modelled and analysed by varying thickness, span and depth of the section. The procedure was adopted after the validation of analysis procedure. All beam where subjected to Distortional buckling except the specimen of thickness 1.2mm subjected to bearing failure .Beam failure occurs only in mid span and no failure was take places in shear zone.

XIII. COMPARISON OF RESULTS FROM THEORETICAL AND NUMERICAL

S. NO	Description of sections	M_{The}	M_{Num}	M_{The}/M_{Num}
1	50-50-150-2-1200	7.354	6.654	1.105
2	50-50-200-2-1800	19.188	17.788	1.0732
3	50-50-200-1.2-2400	8.613	9.210	0.935
4	50-50-250-2-2400	20.913	18.413	1.136
5	50-50-250-1.2-2400	12.746	10.714	1.189
6	50-50-300-2-2400	17.413	14.413	1.208
7	60-60-200-1.2-1200	8.147	7.989	1.098

XIV. GRAPH FROM COMPARISSION OF RESULT FROM M_{the} AND M_{num}

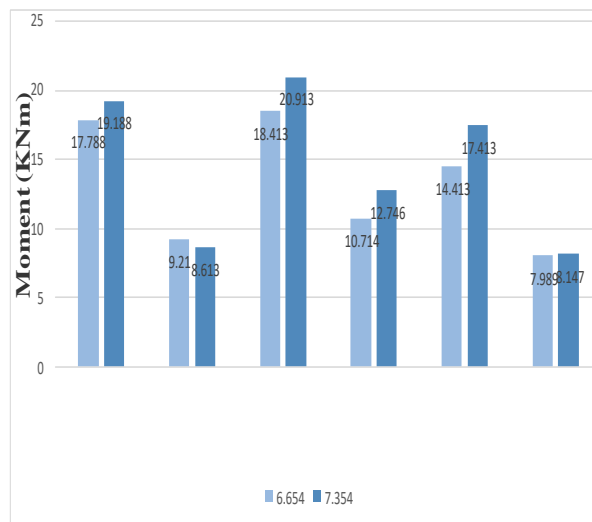


Figure 2.1 M_{the} and M_{num}

XV. CONCLUSION

Theoretical and Numerical investigation, the following observations are made. The ultimate moment carrying capacity obtained from numerical in good correlation with Theoretical results. The ratio between theoretical ultimate moment and numerical ultimate moment carrying capacity in latticed built up I-beams. The ultimate moment carrying capacity of Latticed beam depends on the depth of latticed I beams and thickness, spacing of opening, width of the flange. All the specimens are subjected to distortional buckling. Other than distortional buckling the latticed I beams may subjected to other modes of failure depends on the initial geometric imperfection and method of fabrication.

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