Flexural Investigation on Innovative Cold Formed Steel Built up Beam using Direct Strength Method

K. Mehar Sai, I. Siva Kishore

Abstract : Presently there's a growing tendency of using CFS in construction disclosed by great solidarity to cost proportion. The adoption of CFS has been increasing considerably in structural applications due to their light weight, high strength to weight ratio, ease of fabrication, erection, economy. The study of connections is essential for any type of structure because it is always desirable that structural member should fail first instead of connection. If the failure of connections happens before the member then it will cause of brittle failure. The focus of forming an innovative sections profiles is not only complex but also time consumes, sometimes the section fails before reaching its ultimate strength because the geometry plays a crucial role. This paper address the developing of built up open section cold formed steel beam based on American standard. In subsequent paper predicted to the DSM (Direct Strength Method) for an I section of mechanical model and also the parametric study is carried by experimental and finite element results. Rephrase AISI- S100-07 slenderness limits for section undergoes to bending are analyzed.

Index terms: Cold Formed Steel (CFS), light gauge steel, built-up beam, open section, finite element analysis, screw connections.

I. INTRODUCTION

In all the countries structural designers plays a vital role. But the designers are facing global competition of low cost and fast track structural systems to reach deficit of infrastructural systems. Due to this CFS sections are the technical choice not only for fast track construction but also a cost effective solution. Generally steel structures are produced by Hot rolled steel or Cold rolled steel. From the past decades structures with hot rolled sections are going on. Cold rolled sections are thinner than hot rolled sections. (LIGHT GAUGE STEEL). Because the thickness of sheet for CFS construction usually 0.8 to 3 mm.

Comparisons of CFS to convention structural methods was high quality control, time and cost, minimizing construction wastes and developing of sustainability. Cold rolled products are having with the high strength-to-weight ratio. They were with flexibility in fabricating different cross section shapes. Usually CFS sections are ease to transport and economy in handling and erect. All conventional jointing techniques such as riveting, bolting, welding, adhesives can be implemented. Anbarasu & Sukumar [2] suggested the CFS section profiles are not only for effective cost and also the best choice for fast tract construction. The intention of increasing the CFS by developing the several design standards and by codes from different countries. The CFS members are designed as per American Iron and Steel Institute with specifications AISI-S100, AISI- S210 and AISI-S211 and also AISI-S213 is for Lateral Force Resisting System. According to net section rupture the bolted connections are designed by NAS S-100 and AS/NZS 4600 [3].

CFS can be used in various aspects such as buildings, automobiles, railway coaches, utility poles, aircrafts and ships and so on. Using Cold Formed Steel profiles increasing day by day and that according to the survey CFS occupies 81% of non load cases, 39% of commercial applications and 23 % usage in structural applications. Due to support and bracing conditions, difficulties are perceive in both local and distortional failure, so that Schafer [4] perform the beam tests to clear the distortional and local failures, distortional values compressed between 0.68-1.53.

European countries, since 1920 the United States, Australia, Canada researchers were increasing the investigation on CFS. CFS member with slender cross sections, profile buckling phenomena depends on loading and geometry, i.e. L, D, G or coupled L-G, L-D, D-G and L-D-G where L - local buckling, D - distortional buckling and G - global buckling. Martin et al. [5], suppose the DSM based design Cold Formed Steel Beams that fails by L-D, D-G interaction and called as NDL i.e. nominal strength against local and distortional buckling. And also Martin founds the individual distortional cure of a beam is called nominal strength against global and distortional buckling i.e. NDG. Most of to overcome the issue CFS built up sections are to be utilized. Built-up sections are made by combining of two symmetric sections. Built-up sections are with open and closed type and connections of two symmetric sections are joined by self tapping screws. Most of the papers are includes the bolted connections, clinching, screwed connections, moment connections and fastener reliability. Yu & Panyanouvong [6], Yu & Xu [7], and Liu et al. [8] are referenced for bolted connections including bearing failure and section fracture. Jacques et al. [9] proposed the study of beams and columns of thin walled C section profiles connected by the screws.

CFS had the shapes of C, Z, Hat, Sigma, Rectangular, Circular profiles. These profiles are may be with stud or track sections. Address the connecting of back to back two symmetric C sections are preferred to form I section profile. The tests are carried by Obst et al. [10] on single and double

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box flanges of CFS profiles, and observed the double box flange beams are better than the single box ones. Zhou & Shi [11] proposed the strength reduction and effective width methods for CFS I-section beams.

Transverse loading is applied in the CFS built-up open section beam to investigate the flexural behavior by buckling, post buckling and design of (Direct Strength Method) DSM. Direct Strength Method can be deep investigated in detail for the flexural members, compression members, members in shear, combined bending and compression and the interaction between the modes, by this column design are referenced by De mirandal et al.[12], He & Zhou [13], Young et al. [14]. And the design of beam & purlins are referenced by Basaglia et al. [15], Gao & Moen [16], Keerthan & Mahendran [17], Pham & Hancock [18]. Maximum ultimate loads and shell finite element analysis factors are calculated by non-linear FEA performed by ANSYS, under flexure the developing of effective CFS channels and numerical study is carried by Ye et al. [19]. Using of corrugated webs as a beam that are mostly and widely used in many bridges and with a large span of buildings which are built by using of these I-beam profiles. The using of laser welded light gauge built-up beams the load carrying capacity is studied by conducting four point bending tests by Landolfo et al. [20]. Ductility and the higher energy dissipation of CFS beam sections, the study of optimization carried by Ye et al. [21]. Found that beams with inducing of intermediate flange and web stiffeners, the energy dissipating capacity is increases.

According to this type of beams with corrugated webs increases the stability against the buckling, the design criteria is done by reducing of web stiffeners and its most economical.

II. SPECIFICATIONS

The test specimen was the built up section i.e. the built up section was made by besides of two C-section profiles and that are connected with screws. The physical properties that are used in this project was in table 1.

Table I: Cold Formed Steel Specifications

ELASTIC MODOLUS	2.0 x 10^5 N/mm^2
POISSION RATIO	0.3
YIELD STRENGTH	210 N/mm^2
THERMAL COEFFICIENT	6 X 10^6 /^{0}F

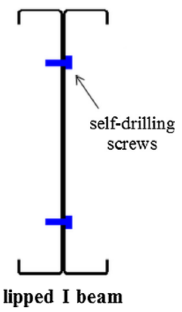

Fig. 1 : I- Section with screw arrangements

2.1. Specimen Dimensions:

The built-up section of Cold Formed Steel was having with thickness of 1.2 mm.

Table II : Dimension of CFS built-up open section beam

Specimen	Dimensions	Length
I-Section	200 x 120 x 14.7 x 1.8	550

The bolts are used to connect the two C – sections and used to form an I-section channel and half inch diameter bolts are used in this project.

III. EXPERIMENTAL INVESTIGATION

In this experimental program the main objective was to analyze the strengths of built up I section beam on screw spacing under bending. And the built-up open section I-channel beam of its screw arrangements is shown in Fig.2 i.e. web contains with two rows of screws.

3.1. Test Setup & Procedure

The acquire the moment capacities of built-up open I section beam the test arrangements are carried in Universal Testing Machine under the point bending shown in Fig 2.

Fig. 2: Point bending test arrangement

3.2. Test Results:

The Cold Formed steel built-up open section beam the experimental ultimate moment M_{EXP} and the modes of failure along the span are statement in Table 3 respectively. On the process of monitoring the experimental test on built-up open section CFS beam the moment capacities little bit influenced by the bolts, then there is a distortional buckling and its due to spacing of screws are been shorter than the half- wavelengths.

In this open I section beam with the reaching of ultimate load there is a cause of distortional buckling (D) and interaction of both Local and distortional buckling (L + D).

IV. FINITE ELEMENT MODELLING

4.1. Development of Finite Element Models

To do the further most performance of parametric studies, developing of numerical models are carried by finite element software ANSYS 18.0 and to replicate with the test results.

4.2. Verification of Finite Element Models :

Comparison of test results with numerical results i.e, FE model of built-up open section beam are provided in the

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Table 3 respectively. The CFS built-up open I section specimen having with the ultimate load that involved both local and distortional buckling (L + D).

And observed that there is a satisfactory agreement between the experimental and numerical results, indicating that the intelligible finite element model was capable of replicating the structural behavior of test specimen.

Table III : Comparison of moment capacities obtain from tests and FEA results for built-up open section specimen

Specimen	M_{EXP} (kN-mm)	M_{FEA} (kN-mm)	Comparison M_{EXP}/M_{FEA}
I – Section	2980	2611	1.14

V. PARAMETRIC STUDY:

As earlier description using the finite element model the parametric study was carried out on built-up open section beam. The parametric study is to investigate the effect of bolts arrangements on structural and strength of CFS built-up open I section beam in Table 4. The Cold Formed Steel built-up open section beam failed by both Local buckling (L) and distortional buckling (D) where within the moment span the FE beam model was failed.

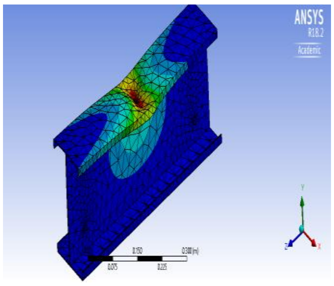

Fig. 3: Finite element model of built-up open section

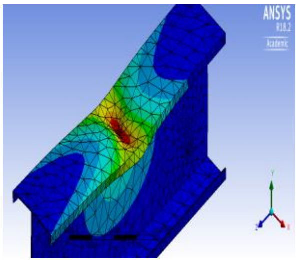

Fig. 4: Failure mode on flange of an I-section

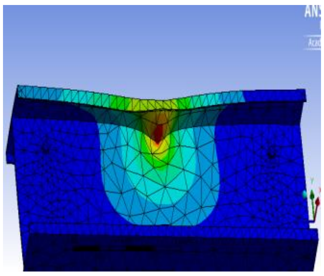

Fig. 5: Failure mode on web of an I - section.

VI. DESIGN APPROACHES

The design of Cold Formed Steel Channels was designed by two methods i.e. Direct Strength Method and Effective Width Method.

6.1. Direct Strength Method

In this study the design rules are implemented as the proxy design method for calculations of built up beams. This DSM can be widely used to study the beams and columns. Lateral-Torsional buckling (M_{ne}), Local buckling (M_{nl}) and Distortional buckling (M_{nd}), are summarized from the North American Specifications of AISI-S100.

$M_{DSM} = \min (M_{ne}, M_{nl}, M_{nd})$

M_{DSM} be the nominal flexural strength and it's the minimum of M_{ne}, M_{nl}, M_{nd}.

For $M_{cre} < 0.56\, M_y$

$M_{ne} = M_{cre}$

For $0.56\, M_y \le M_{cre} \le 2.78\, M_y$

$$M_{ne} = \frac{10}{9} M_y \left[1 - \frac{10 M_y}{36 M_{cre}}\right]$$

For $M_{cre} > 2.78\, M_y$

$$M_{ne} = M_p - \frac{[M_p - M_y]\left[\sqrt{\frac{M_y}{M_{cre}}} - 0.23\right]}{0.37} \text{ or} \le M_p$$

Where, $M_y = S_f F_y$, $M_P = Z_f F_y$

S_f = Gross section modulus

Z_f = Plastic section modulus and

F_y = Yield stress i.e. 0.2% of proof stress and Mcre is critical elastic of lateral torsional buckling moment.

For $\lambda_l \le 0.776$ and $M_{ne} \ge M_y$

$M_{nl} = M_y + (1 - 1/C^2_{yl}) (M_p - M_y)$

For $\lambda_l \le 0.776$ and $M_{ne} < M_y$

$M_{nl} = M_{ne}$

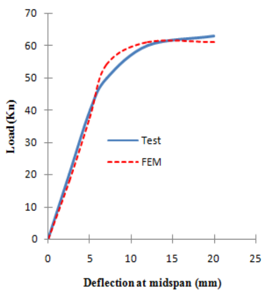

Fig 6. Load versus mid span deflection of a beam under point load bending for test and fem.

For $\lambda_l \le 0.776$ and $M_{ne} < M_y$

$M_{nl} = M_{ne}$

For $\lambda_l > 0.776$

$M_{nl} = [1 - 0.15 (M_{crl}/M_{ne})^{0.4}] (M_{crl}/M_{ne})^{0.4} M_{ne}$

Where, $\lambda_l = \sqrt{\frac{M_y}{M_{crl}}}$, $C_{yl} = \sqrt{0.776/\lambda_l} \le 3$

and M_{crl} is Critical elastic local buckling moment.

For $\lambda_d \le 0.673$

$M_{nd} = M_y + (1 - 1/C^2_{yd}) (M_p - M_y)$

For $\lambda_d > 0.673$

$M_{nd} = [1 - 0.22 (M_{crd}/M_y)^{0.5}] (M_{crd}/M_y)^{0.5} M_y$

Where, $\lambda_d = \sqrt{M_y/M_{crd}}$, $C_{yd} = \sqrt{0.673/\lambda_d} \le 3$

and M_{crd} is Critical elastic distortional buckling.

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Table 4. Comparison of design strengths of built up I-section, FEA and test results.

Specimen	M_{EXP} (kN-mm)	M_{FEA} (kN-mm)	M_{DSM} (kN-mm)	Failure mode	M_{EXP} / M_{DSM}	M_{FEA} / M_{DSM}
I – Section	2980	2611	3431	L + D	0.86	0.76

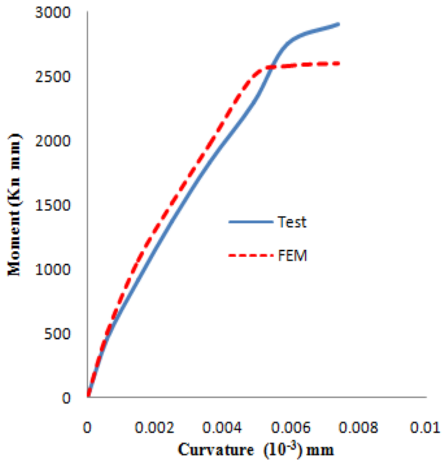

Fig 7. Moment versus curvature obtained from FEA and test.

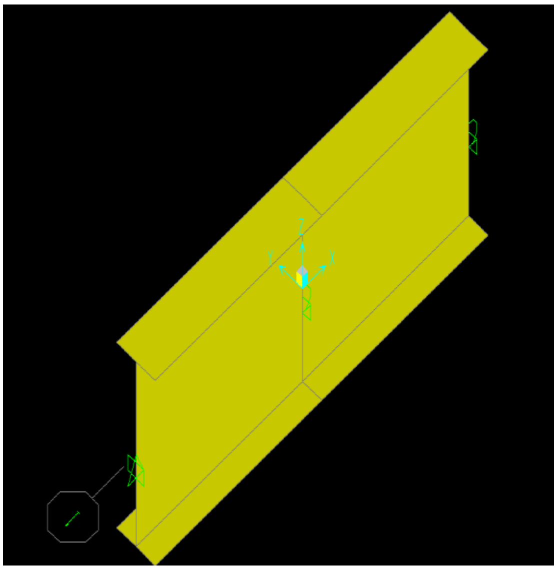

Fig 8. Design model of CFS built up I-section beam.

VII.CONCLUSION

For the CFS structures the numerical and test results are compared with the design strengths which was predicted by direct strength method. And with the two rows of screw arrangements of built-up open I-section beam the design strengths are stated by DSM equations. From the North American specifications for the CFS sections is to improving of the rightness of strengths by DSM. Finite element modeling of built-up I section beam was created and performing of non – linearity's due to geometry, contact and material are included for developing of numerical analysis. Also CFS I-section beam was developed in SAP-2000 design software which commend the good results in terms of moments with no lipped and screw arrangements and that was about 2890 kN-mm. Also specimen failed in web crippling under point of load application which is common type of failure in CFS beams under point loads. Web crippling failure load is not given by DSM moment design equations that's why results are not matching. FEA results are 14% more than experimental, also failure mode is web crippling due to point load effect under applied load. If pure moment is applied then its possible to may get the desired results. And finally the failure modes, load - deflection behavior, moment-curvature behavior and the experimental and numerical results are in precisely good in quality of forming a consistent ultimate moments.

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