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Experimental Study on Flexure Behavior of Cold Formed Steel Hat Section Subjected To Two Point Loading By Varying the Thickness by Finite Strip Method

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Abstract : - Cold formed steel members are thin walled have wide applications in building structures, industries, etc. Cold formed steel has been used as the primary structure for flexural and compression members due to variety of advantages such as high strength to weight ratio (h/w), non-shrinkage and non-creeping at ambient temperatures and ease of fabrication. The objective of this paper is to study the flexural behavior of cold formed hat section for various thicknesses such as 1 mm, 1.2 mm and 1.6 mm. The CFS material property has been tested by conducting tensile test for various thicknesses and the properties such as yield strength, ultimate strength and percentage of elongation are obtained. The flexural members are fabricated using press brake process and the parameters such as b/d is 2 for all specimens, b/t ratio varied from 62.50 to 100.00 and d/t ratio varied from 31.25 to 50.00. The specimens were subjected to two point loading with Simply Supported boundary condition. The experimental results shows the predominant buckling behavior of the flexural members are observed visually and the load–deformation behavior is also obtained. The experimental results are verified with finite strip method using CUFSM software. Experimental and Analytical results are compared. The behavior and the ultimate load carrying capacity of the members were compared for various parameters.

Key - Words : - Buckling, Cold formed steel, CUFSM, Flexural behavior, Hat section, Tensile Coupon, Two point loading

1 Introduction

Steel are of two types, Tensile steel and Mild steel, based on composition of carbon content. Mild steel are majorly divided into Hot rolled steel and Cold formed steel. Hot rolled steel are formed with high elevated temperatures where as cold formed steel are formed under room temperature and is also called as Light gauge sections. These sections are made from thin sheets of 0.5mm to 3.25mm thickness. CFS sections are formed by manual shearing, press breaking and mechanical shearing. These type of sections are used in the building industry as purlins, grits, light struts, roof sheeting and floor decking, bridges, car bodies, storage racks, railway coaches, door and window frames etc. These sections become economical for light loads and to form useful surfaces such as roof covering, wall panels. Load carrying capacity should decreases with increase in length and width to thickness (w/t) ratio. Due to minimum thickness of cold formed steel, considering the local, torsional and distortional buckling characteristics for its behavior study most of the failures occurs at 1/3 distance for 1mm and 1.2mm and at center for 1.6mm elements.

The primary objective of this paper is to study on impact of flexural behavior of hat section. Three specimens are experimentally tested by applying two point loading and the failure behavior is studied. The tensile coupon is done for the elongation property of the material. The load carrying capacity of the specimen and possible mode of failure in experimental and numerical is to be determined. The possible modes of failure of the specimens under static loading are performed using CUFSM (Cornell University Finite Strip Method) software. CUFSM employs the semi-analytical finite strip method to provide solutions for the cross-section stability of such members. The CUFSM is most commonly used for thin-walled cold formed steel members, it has also been used for a large variety of other materials and applications.

2 Literature Review

Sunil and Patil (2012) studied the difference between stiffened and un-stiffened lip formed of C section have been explained and concepts of effective width employed in analysis and design of cold rolled section also have been explained. Tensile test was done for Z-cold formed section according to ISI 1608-2005. The section properties for cold form member were calculated by CFS software. Manual calculation of purlin was done as per AISI-1996 code. The literature review detailed about the buckling occurred in CFS.

A.Jayaraman et al., (2014) studied the behavior and economical of cold formed steel (CFS) built up channel section and channel section by same cross sectional area. This study involved in examining the theoretical and numerical investigations of specimens in series. The theoretical data were calculated using Indian Standard code IS 801-1975 and the section properties of the specimens were obtained using IS 811-1975. The specimens were designed under uniformly distributed loading with simply supported condition. The theoretical results were verified using ANSYS V11 software. The studies revealed that the theoretical investigations channel section have high bending strength, high load caring capacity, minimum deflection and minimum local buckling& distortional buckling compared to the built up channel section by same cross sectional area.

Siva Prakash. V and K. Prasad Babu (2015) studied the behavior of cold formed built up I –section with different corrugation web. The effect of web corrugation on the bending strength or flexural strength of cold formed steel (CFS) I section was presented in this paper. Specimens were experimented under two point loading with simply supported condition. The experimental results were verified with finite element analysis using ANSY software. Experimental and Analytical results were compared with the predicted resistance by code provision of AISI S100-07 Specification. The experimental result showed that the bending capacity or flexural capacity of the corrugated web (trapezoidal, triangular) was larger than flat web. For the corrugated section beam, the deflection of the beam at mid span decreased in ANSYS analysis. Due to the corrugations, there was no failure in shear zone of web portion. The code results are conservative.

Martin Dara and Cheng Yu (2015) presented an attempt to develop a semi-analytical design approach for the web crippling strength using the Direct Strength Method concept. The focus was on the cold-formed steel C and Z sections subjected to on flange loading conditions. The research indicated that the Direct Strength Method is appropriate for predicting the web crippling strength. New design methods for calculating the nominal web crippling strength of the CFS C-sections and Z-sections subjected to End-One-Flange loading and Interior One-Flange loading conditions were developed and verified by the experimental results. ASD Safety and LRFD resistance factors were calculated according to the AISI standards. ABAQUS was used as the main tool for calculating the critical elastic buckling load of the C-sections and Z-sections.

L.Krishnan et al., (2015) investigated on the behavior of cold form steel built up I - section with triangular web corrugation at varying depth. The length of the specimen was kept constant for 2000 mm and hw/tw ratio was varied from 166 to 250 keeping all other parameters as constant. In total three specimen were experimentally tested under two point loading with triangular web corrugation by considering simply support condition. The experimental results were verified with finite element analysis using ANSYS software. The results obtained from test experiments and ANSYS software were compared with the predicted Indian Specifications (IS 801- 1975). The experimental result showed that the flexural capacity of the triangular web was larger than flat web. Due to the provision of triangular web corrugation, there was no failure in shear zone or in web portion.

Jayasheela et al., (2015) studied the behavior of built-up hat section with stiffened web and stiffened tension flange under flexure. The finite strip analysis program CUFSM was used to calculate the section and buckling properties of the hat section. Based on these results the cross section and dimensions of the built up section were arrived at and used in this investigation. The flexural tests were conducted on four specimens built-up hat section with stiffened web and stiffened tension flange. . The numerical simulation of the built up section were performed using Finite element Software ANSYS 12.0. In theoretical calculations, strength of beams was calculated using Indian Standard IS: 801-1975, BS 5950-1998. The experimental results were compared with theoretical and numerical analysis results. It was observed that this built up section could be used as a flexural member in structures subjected to light and moderate loads.

Srinath.T and Shanmugarajan.M.B. (2016) investigated the impact of web opening on the flexural behavior of Cold formed built-up I section under two point loading for the simply supported end conditions. Experimental investigations have 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. It was observed that the member 50-50-250-1.2-2400 carries maximum moment while comparing 1.2mm thick specimens. This was because stiffener takes up load in this specimen. But while considering 2mm thick specimens, 50-50-200-2.0-2400 carried maximum moment. This showed that web opening to depth ratio of 0.5 would carry maximum moment.

3 Material properties

Coupon Test

Coupon test is done for the elongation property of the material. The most common testing machine used in tensile testing is the universal testing machine (UTM). This type of machine has two crossheads, one is adjusted for the length of the specimen and the other is driven to apply tension to the test specimen. The strain measurements are most commonly measured with an extensometer, but strain gauges are also frequently used on small test specimen or when Poisson's ratio is being measured. Alignment of the test specimen in the testing machine is critical, because if the specimen is misaligned, either at an angle or offset to one side, the machine will exert a bending force on the specimen. So, provide punches on both sides it act as grips on the specimen.

4 Scope and Objectives

4.1 Scope

Light gauge steel, also called as cold formed steel (CFS) sections have several applications in the field of residential building and in factory structures that requires large spaces. In the construction industry and non-structural elements are created from the thin gauges of sheet steel. However as a structural member this type of light gauge steel have limited application, so the scope of the project is to focus on the application, potential for the light gauge steel members in industrial as well as conventional building.

4.2 Objectives

- To study the flexural behavior of CFS HAT section under two point loading.
- To study the ultimate load bearing capacity of the section.
- To analyze the section using CUFSM software.
- To compare the analytical and experimental test results.

5 Methodology

- Parametric study
- Two point loading arrangement
- Fabrication process
- Specimen testing
- Flexural strength behavior
- CUFSM results
- Results and discussions
- Comparison of Analytical and Experimental results
- Conclusion

6 Theoretical and Analytical investigation

6.1 Theoretical Investigation

To determine the load carrying capacity and moment carrying capacity of the specimens using IS: 801 – 1975, “Code of Practice for Use of Cold-Formed Light Gauge Steel Structures Member in General Building Construction”, and IS: 811 – 1987, “Cold Formed Light Gauge Structural Steel Sections”. The cold formed hat section is investigated by varying the thickness and all the other parameters are constant.

6.2 Designation

The cold formed hat section is designated of varying thicknesses and other parameters are kept constant.

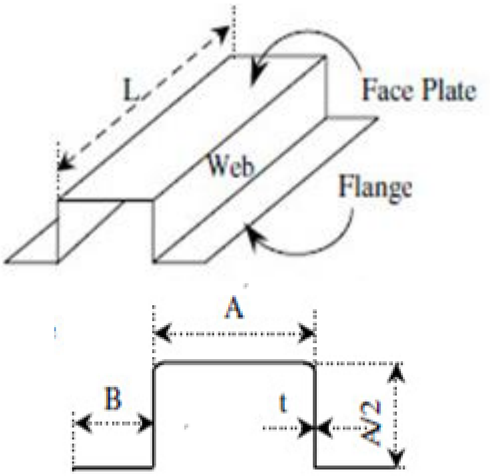


Figure1 Diagrammatic representation of specimen

A=100mm

B=25mm

t=1mm, 1.2mm, 1.6mm

A/2=50mm

The following are the designation and parameters of the specimens are presented in Table1

Table1 Designation of cold formed hat section

Parameter	Dimension (mm)
Thickness	1.0, 1.2 & 1.6
Length	750
Compression Flange	100
Web	50
Tension Flange	25
CFHATTK10	Cold formed hat section thickness 1.0mm
CFHATTK12	Cold formed hat section thickness 1.2mm
CFHATTK16	Cold formed hat section thickness 1.6mm

7 Analytical Investigation

CUFSM is the software for exploring the elastic buckling behavior, which calculates the buckling stress and buckling mode of arbitrarily shaped with simply supported boundary condition. CUFSM is originally written to support research on the behavior and design of cold-formed steel members with a variety of different types of longitudinal stiffeners. The hat section is analyzed by different thickness of 1mm, 1.2mm, 1.6mm and other parameters are constant.

The elastic behavior of hat section for various thickness are given in Table2,3 and 4 respectively.

Table2 Behavior of hat section of 1mm from CUFSM

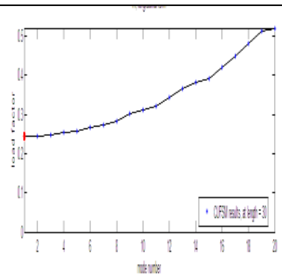
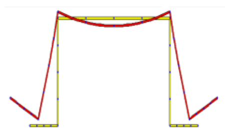
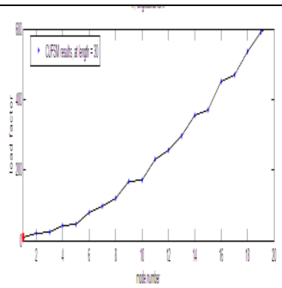
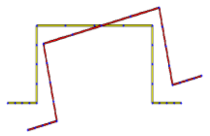
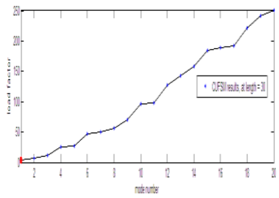
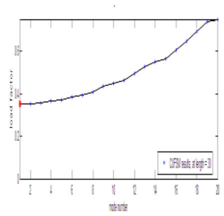
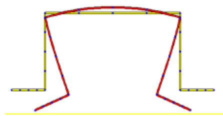
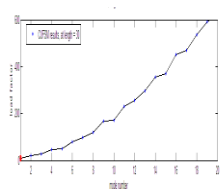
FM	CFHATTK10	LF vs MN
LB		
DB		
GB		

Table3 Behavior of hat section of 1.2mm from CUFSM

FM	CFHATTK12	LF vs MN
LB		
DB		

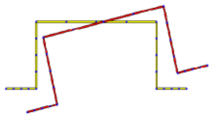
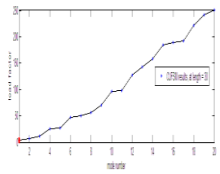
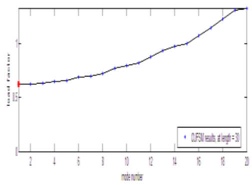
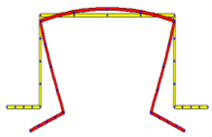
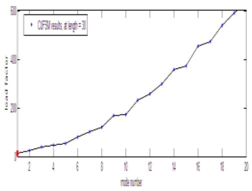
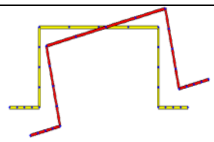
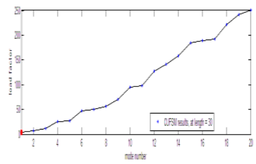
GB		

Table4 Behavior of hat section of 1.6mm from CUFSM

F	CFHATTK16	LF vs MN
LB		
DB		
GB		

F-Failure mode
LB-Local Buckling
DB-Distortional Buckling
GB-Global Buckling
LF vs MN-Load factor vs Mode Number

Table5 CUFSM Critical Moment Results

Critical Moment (Nmm)			
Specimen	**M_{crl} x10^6**	**M_{cre} x10^6**	**M_{crd} x10^6**
CFHAT TK10	14.30	176.15	15.67
CFHAT TK12	17.32	208.92	17.98
CFHAT TK16	22.14	278.68	19.29

7.1 Design Strength Method

The design strength method in which service loads are increase sufficiently by factors often referred to as load factors to obtain the ultimate design load. The structural element is then proportioned to provide the desired ultimate strength. Large margins are assumed on material strength to ensure such behavior it is equally if not more important to predict the ultimate strength of RC sections, so that they can be designed to resist the largest loads anticipated during the design lives.

Table6 Nominal Flexural Strength

Specimen	M_{nl} x10^3 Nmm	M_{ne} x10^3 Nmm	M_{nd} x10^3 Nmm
CFHATTK10	134.04	17.41	608.98
CFHATTK12	156.57	18.56	530.38
CFHATTK16	191.02	19.72	435.42

where,
M_{nl}-Nominal flexural strength for local buckling
M_{ne}-Nominal flexural strength for global buckling
M_{nd}-Nominal flexural strength for distortional buckling

8 Experimental investigation

Test setup

The specimens are tested under UTM (Universal Testing Machine) capacity of 100 tons. The specimen is placed to attain the simply supported boundary condition. The load is applied axially and it is distributed as two point loading to the specimen. Two deflecto meter is kept under the specimen at a distance of L/3 from both ends of the beam to records the deflections. The deflection in the X and Z direction and the axial deflection in Y direction are observed. The readings are noted from the UTM as rate of loading is 1kN at time. Finally the maximum deflection and maximum load is to be noted. The diagrammatic representation of test setup is shown in Figure1. The figure2 shows the experimental testing of cold formed steel beam with deflecto meter.

Figure2 Experimental setup

Figure3 Specimen before testing

Specimen after testing

Figure4 Deflection for 1mm

Figure5 Deflection for 1.2mm

Figure6 Deflection for 1.6mm

8.1 Deflection Behaviors of hat section

The following are the deflection behavior of the specimens in a graphical representation. The graph is plotted between the load vs deflection are represented in Figure7,8 and 9 respectively

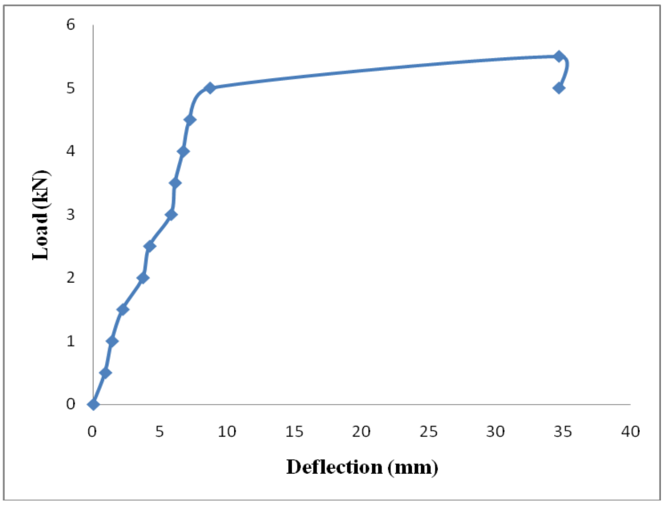


Figure7 Load vs Deflection curve of CFHATTK10

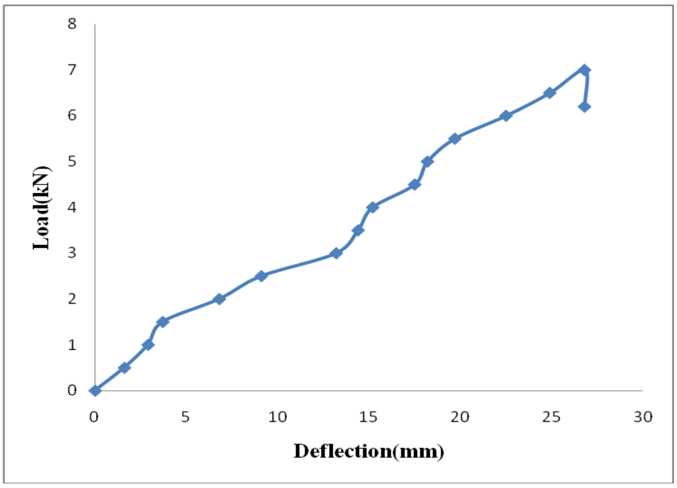


Figure8 Load vs Deflection curve of CFHATTK12

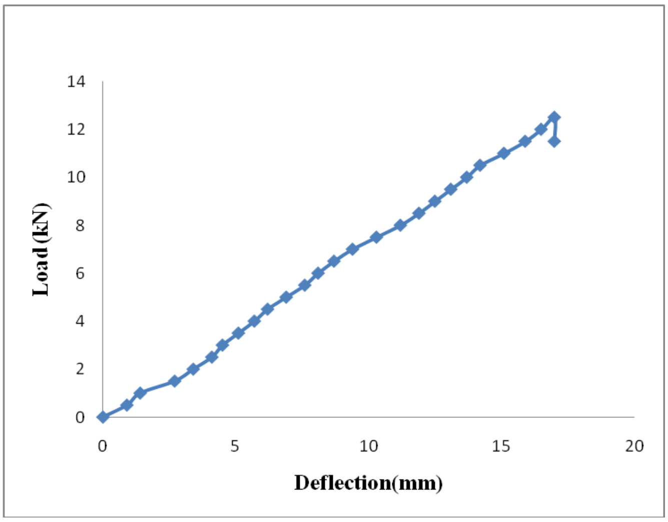


Figure9 Load vs. Deflection curve of CFHATTK16

9 Results and Discussions

From the results it is found that as based on the b/t ratio the load and moment values varied. The increase in thickness of the specimen increases the ultimate load and ultimate moment carrying capacity of the member which is represented in Table8

Table8 Results of Experimental load vs DSM load

Specimen	Experimental results Ultimate load kN	DSM results Ultimate load kN		
		LB	GB	DB
CFHAT TK10	5.65	5.00	6.53	10.03
CFHAT TK12	7.00	6.80	6.72	10.80
CFHAT TK16	12.50	11.89	7.30	13.0

10 Conclusion

From the investigation, the following conclusions are drawn.

- Failure modes of the specimen vary as the (b/t) ratio varies i.e. reduction in ratio causes reduction in deflection.
- Ultimate moment carrying capacity increases with increase in thickness of the specimen.
- Experimental results show that the failure of the section occurs mainly due to the buckling of flange plates and central lateral deflection.
- Decrease in (b/t) ratio increases the load carrying capacity of the specimen
  Compared to the experimental, the modes of failure in CUFSM are different.
- With increases in thickness, the flexural capacity of the member also increases.
- All the specimens are failed due to the crushing on top of the compression flange and local buckling.

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