Literature Survey on the Flexural Behaviour of Cold Formed Steel Beam Sections

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Abstract— Cold-formed steel structures are steel structural products that are made by bending flat sheets of steel at ambient temperature into shapes which will support more than the flat sheets themselves. Cold formed steel members are extensively used in the building construction industry, especially in residential, commercial and industrial buildings. Cold formed steel sections such as channel sections, angle sections are often used nowadays. Built-up I-sections have been extensively used whenever standard I-sections could not satisfy the moment carrying and shear capacities required. Built-up cold formed sections are expected to improve their flexural capacity and to increase their applications. They are also likely to mitigate the detrimental effects of lateral distortional buckling observed with single cold formed steel members of intermediate spans. Various experiments have been carried out to study the flexural behaviour of cold formed steel sections. However, the behaviour of built-up beams is not well understood. This paper aims to present a summary of the various experiments and analyses carried to study the flexural behaviour of cold formed steel sections.

Key words: Cold-formed steel sections, flexural behaviour, deflection, back-back section

I. INTRODUCTION

In steel construction, there are two main types of structural members one is hot rolled section and the other is cold-formed section. Cold-Formed Steel (CFS) is a type of steel fabricated by a cold forming process and Cold-formed steel goods are created by the working of sheet steel using stamping, rolling or presses to deform the sheet into a usable product. The thickness of the sheet used is generally between 1mm and 8mm Although cold-formed steel sections are used in car bodies, railway coaches, various types of equipment, storage racks, grain bins, transmission towers, transmission poles etc but in building construction it has limited advancement. The use of hot rolled steel sections becomes uneconomical for the steel structures subjected to light and moderate loads. The primary advantages of cold-formed steel are price stability, light weight, high strength and stiffness, uniform quality, ease of prefabrication and mass production, economy in transportation and handling, fast and easy erection and installation, non-combustibility, and the fact that it is termite-proof and rot-proof. The structural members like purlins, girts, roof trusses, complete framing of one and two storey residential, commercial and industrial structures subjected to moderate load, for which cold formed steel members may be sufficient. Cold formed sections like Channel, Zee sections, I-sections, angles, T-sections, hat sections, and tubular members are commonly used flexure members for purlins & girt in roof and wall system. These sections are extensively used in various engineering applications because of their high strength to weight ratio. Studies on the flexural behaviour of cold-formed steel beams are increasingly popular in the last decades. Understanding and dealing with these phenomena has been the central focus of recent research efforts.

II. LITERATURES

A. Pooja S. Ajay Et Al, "Flexural Behavior Of Cold Formed Steel Beams With Diagonal Stiffener", (IJETT) – Volume 17 Number 8- Nov 2014,:

This research investigated the flexural behavior of cold form steel I-beam with diagonal stiffeners. Here a total of six specimens were tested in which two specimens were without stiffeners, two specimens with stiffeners and two specimens with stiffeners and in-filled concrete. The span of the beam was 2000 mm and the cross sections of the I – beams were 150 mm x 100 mm x 2mm. The yield strength of steel used was 380 Mpa and the web was encased with M 30 grade. Intermittent welds of 4 mm were used and a pair of stiffeners was provided at both the load points to minimize the local effect due to concentrated loads. All the specimens were tested for flexural strength under two point loading. The results were compared and analyzed. The ultimate load of normal I section was 17 KN and the ultimate deflection was 6.5 mm. The ultimate load of diagonally stiffened beam was 30.8 KN and ultimate deflection was 9.5 mm. The ultimate load of encased diagonally stiffened beam was 92.6 KN and ultimate deflection of 24.9 mm. The majority of cracks were formed between the zone of two point loading and also some cracking was also observed near the supports end.The ultimate load carrying capacity of the beam with stiffeners was 40-45% higher than the beam without stiffeners. The ultimate load carrying capacity of the beam with stiffeners and in-filled concrete was 80-85% higher than the beam without stiffeners.

B. G. Arunkumar Et Al, "Investigation On Cold –Formed Steel Lipped I Beam With Trapezoidal Corrugation In Web By Varying Depth", Issn: 2278 – 0211 Vol 2 Issue 5 (2015):

The purpose of this paper was to investigate the effect of web corrugation and h w/tw ratio on the flexural strength of cold formed steel (CFS) lipped I section. Five specimens were selected in which one specimen was provided with flat web and the remaining were provided with trapezoidal corrugation. The CFS sheet of 2mm is used for flanges and 1.2mm for web. Flanges and web are connected by continuous thin weld. The length of the specimen was kept constant for 3600 mm and hw/tw was varied from 333.33 to 583.33 mm. At the loading point and support stiffening plates of 3mm are placed in order to avoid the bearing failure and distribute the load uniformly. All the specimens were tested under two point loading with simply supported condition and the results were verified with finite element analysis ANSYS.12. For all the sections theoretical analysis was performed using codal provision such as North American Specifications (AISI S100-2007) and Australian/New Zealand standards (AS/NZS:4600-2005).

The young's modulus of E=20000 N/mm2 and the yield stress of fy=210 N/mm2 were considered for the materials. The mode of failure is initiation of local buckling in compression flange leading to lateral torsional buckling. From the experimental and numerical investigation it is noticed that bearing failure at the loading and support point is avoided by provision of 3mm thick plate. From the experimental results it was found that as the depth increases the flexural capacity also increases within the parametric study. It was noted that the percentage increase in flexural capacity of the corrugated specimen when compared to flat web specimen is about 15%. Failure due to shear in web was eliminated due to corrugation in the web. The moment carrying capacity obtained from Australian/ New Zealand standards (As./Nzs 4600:2005) and North American specification(AISI S100-2007) codes are conservative while compared with experimental and finite element analysis results.

C. V. Jaya Sheela Et Al, "Experimental Study On Behaviour Of Stiffened Cold Formed Steel Built Up Hat Section Under Flexure By Varying The Depth By Finite Element Analysis", (Ijett) – Volume23 Number 1- May 2015:

This research investigated the behaviour of built-up hat section with stiffened web and stiffened tension flange under flexure. Four specimens of built-up hat section having thickness of 1.2mm and length 1500 mm and varying depth of 115, 135, 155, 175 mm was tested under simply supported end condition. The vertical stiffeners were connected to the web of specimen by welding. The numerical simulation of the built up section was performed using Finite element Software ANSYS 12.0. The strength of beams were calculated using Indian Standard IS: 801-1975, BS 5950-1998 (5) theoretically. The experimental results were compared with theoretical and numerical analysis results. Ultimate moment carrying capacity increases as the depth increases. The specimen with 175 mm depth had 32% higher capacity than other specimens. The joint failure between the top and bottom flange with the vertical web was prevented by the the spot welding at regular intervals between the flange and web plates. Experimental results showed that the failure of the section occurs mainly due to the buckling of flange plates. Finite element analysis also showed the same failure pattern. From the results observed it was concluded that this section could be used as a structural member and as beam supporting a composite slab.

D. L. Krishnan Et Al, "Experimental Investigation Of Cold-Formed Steel Section –Flexural Member With Triangular Web", Iosr Journal Of Mechanical And Civil Engineering (2015) Pp 36-39:

This research investigated the behavior of cold form steel built-up I-section with triangular web corrugation. The effect of web corrugation and hw/tw ratio on the flexural strength of cold formed steel (CFS) lipped I section was studied. 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. The Angle between the triangular webs is 900 for all the beams. Three specimens were experimentally tested under two point loading with simply supported condition. The experimental results were compared with the 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). They observed that the flexural capacity of the triangular web was larger than the flat web. Due to the corrugation provision, there is no failure in shear zone. Increase in depth increases the load carrying capacity. All the specimens were failed due to crushing on top compression flange and lateral buckling. Numerical Validation has been carried out to verify the appropriateness of the experimental results and found that they are quite closer to the corresponding test results. The code results were conservative.

E. Sudha. K Et Al (2014), "Behaviour Of Cold-Formed Steel Built-Up I Section Under Bending", ISSN : 0975-4024 Vol 5 No 6 Dec 2013-Jan 2014:

This paper presents an experimental and numerical investigation on the bending strength and behaviour of cold-formed (CF) steel built-up flexural members. Two types of built up Cold formed steel I Sections with equal and unequal flanges have been fabricated and experimented. The specimens were fabricated from 1.2mm thick steel sheets. The yield stress was 230 N/mm2 and young's modulus of 1.98 x 105 N/mm2. The specimens were built-up using four numbers of Cold Formed angles with lip in the flange alone. Out of four angles two were provided in the top flange and two at the bottom flange which act as the main chords of the member. Eight specimens in two groups, first group of four specimens with equal flanges and second group of four specimens with unequal flanges have been used. The Specimens were experimented under simply supported end condition with two points loading. All the sections fabricated for the experimental work were modelled and analysed. The experimental results were compared with the analytical results. The failure modes were mixed bearing, local, distortional and flexural. The experimental failure modes were in good agreement with ANSYS results. From the results it was concluded that in the compression zone, the individual top chord members were distorted. Equal Flange I-section carried approximately 40% more than that of unequal flange I – section. It was observed that each chord member bend individually. This showed that this type of members does not bend in a single wave as a whole as in the case of solid cross- section, but the constituent members bend individually. Local buckling, distortional buckling and interaction between local and distortional buckling were observed. The FEA predictions were generally in good agreement with the experimental buckling modes. The results showed that the buckling mode has greater influence on the strength of the specimens.

F. Parvati S Prakash Et Al (2014), "Flexural Behavior Of Cold Formed Steel Beams With End Stiffeners And Encased Web:

In this paper the results of the experimental study on the behavior of cold-formed steel section with plain web, with end stiffened web and with encased web were presented. The span of the beam was 2000 mm and the cross-sections of the I-beams were 150 mm x 100 mm x 2 mm. The yield strength of the steel used was 380 kN/mm2. 6 mm diameter mild steel rods were welded on either side of web at both ends of the stiffened beam. In the encased beam the web was encased with M30 grade fly ash concrete. The specimens were tested for flexural strength under two point loading in the vertical loading frame with a capacity of 400 kN. The specimens were arranged with simply supported conditions. Loads were applied at one-third distance from the supports at a uniform rate till the ultimate failure of the specimens occurred. The ultimate loads of normal I section, end stiffened beams, normal I section encased with concrete were compared. The ultimate load of normal I section was 15 kN and the ultimate deflection was 4.5 mm. The ultimate load of beam with bracing in the web was 38kN and ultimate deflection was7 mm. The ultimate load of normal I section encased with concrete was 70.6 kN and ultimate deflection of 12 mm. The failure was typically in the form of flexural cracks originating from the bottom of the specimen and extending towards the top of the specimen in the case of encased specimens. The majority of cracks were formed between the zone of two point loading and also some cracking was also observed near the supports end. The ultimate load carrying capacity of I section with stiffener was 60-65% higher than that of I-section. The ultimate load carrying capacity of I section with concrete was 75-80% higher than that of I section. The ultimate load carrying capacity of I section filled with concrete was 45-50% higher than that of cold-formed I section with stiffeners. The ultimate deflection of cold- formed light gauge steel I section with stiffeners was 35-40% higher than that of cold- formed light gauge steel I section. The ultimate deflection of cold-formed light gauge steel I section filled with concrete was 60-65% higher than that of cold- formed light gauge steel I section. The ultimate deflection of cold- formed light gauge steel I section filled with concrete was 40-45% higher than that of cold- formed light gauge steel I section with stiffeners.

G. Sakthivel M Et Al (2015), Experimental Study On The Flexural Behavior Of Cold Formed Steel Section, The International Journal Of Science & Technoledge (ISSN 2321 – 919X) (2015):

In this paper the flexural behavior of a cold-formed steel channel section connected back to back has been investigated. The span of the beam was 1.5 m. The section dimension was 200 x 80 mm. The thickness of the member was 2.5 mm and the channel was connected by bolts spaced at 150 mm. The two point loading test configuration was used for experimental investigation. The specimen was tested under the loading frame with the load applied manually. The theoretical ultimate load was 62.8 kN and the theoretical maximum deflection was 3.411 mm. The experimental ultimate load was 62.5 kN and the experimental maximum deflection was 3.2mm. From the results it was observed that the deflection increases gradually till the local buckling of specimen. Most of the failures were found at 1/3 distance of steel beam from the support. The experimental deflection of cold formed steel channel section was found to be within the permissible limit and calculated from theoretical calculation. From the research conducted it was concluded that the beams made up of cold formed channel section will give good flexural strength with less weight compared to hot rolled section.

H. Chi-Ling Pan Et Al, "Bending Strength Of Hybrid Cold-Formed Steel Beams", Thin-Walled Structures 40 (2002) 399-414:

This research investigated the strength of a cold formed hat section with a plate. Two steel sections of different yield strength are connected. The materials used in this study were 25 AK and 50 SK sheet steels. The nominal static yield strengths of these two sheet steels are 172 and 345 MPa. The thicknesses of 25AK and 50SK sheet steels are 2.0 mm and 1.9 mm, respectively. Four group of assembly were used for testing. Group W - hat-shaped beams which were assembled by using a hat section fabricated from 25AK sheet steel and a plate of 50SK sheet steel. Group Z - hat-shaped beams which were assembled by using a hat section fabricated from 25AK sheet steel and a plate of 50SK sheet steel. Group S - hat-shaped beams which were assembled by using a hat section fabricated from 50SK sheet steel and a plate of 25AK sheet steel. Group K - hat-shaped beams which were assembled by using a hat section fabricated from 50SK sheet steel and a plate of 25AK sheet steel. A total of 72 spot-welded closed-hat sections were tested under different strain rates. The beam was tested under simply supported condition and the midspan deflection was measured using LVDT. The results obtained were compared with the computed yield moments. The yield moments were calculated based on the effective design width formulas. From the results it was observed that the difference between the tested and the computed yield moments are within 10% for most specimens. For most cases, the yield moment and ultimate moment of hybrid beams increased with increasing strain rate for specimens having the similar w/t ratios. Also it was concluded that the dynamic stress–strain relationship can be used for calculating the ultimate moment of hybrid beams.

I. Ihong-Xia Wan Et Al, "Behaviour And Strength Of Hollow Flange Channel Sections Under Torsion And Bending", Thin-Walled Structures 94 (2015) 612-623:

This research investigated the strength of a cold formed hollow flange channel section subject to torsion and bending. Here the simply supported hollow flange channel section members subjected to a uniformly distributed torque along their spans were analysed. Nine hollow flange channel sections were selected with their spans varying from 2 m to 10m. The steel grade is G450, with a yield stress fy = 450 MPa and a shear yield stress τy = 270 MPa. The torsion capacity was calculated using the differential torsion equilibrium equation. It was concluded that for the same flange size greater section depth contributes little torsion capacity increases, especially for long span members. On the contrary, for the same section depth, greater flange size could improve the torsion capacity significantly. This proved that increasing thickness will contribute considerably to torsion strength. The accuracy of the results obtained by using the differential equations were verified by the FEA. FEA was done in ANSYS 13.0. It can be seen that the results obtained from the proposed equations are very close to those given by FEA. Also simply supported beams subject to a uniformly distributed transverse loads were analysed. The results obtained from the analytical methods were compared with the ANSYS results. It was concluded that greater section depth and thickness contribute to higher load carrying capacity, but the contribution decreases gradually with increasing span and it showed that for long span members, increasing the section depth and thickness does not help much in increasing the load carrying capacity. Meanwhile, sections with smaller depths or flange sizes were able to achieve their design moment capacities more easily. Torsion reduced the bending strength significantly.

J. Dan Dubina Et Al, "Experimental Investigations of Cold Formed Steel Beams Of Corrugated Web And Built-Up Section For Flanges", Thin-Walled Structures 90 (2015) 159-170:

This research investigated the behavior of Cold form steel corrugated web with built up flanges. Self-drilling screws has been used for the connections between flanges and web. The corrugated web is used to transfer the transverse loads while the bending moments and applied forces are resisted by the flanges only. Five beams with corrugated webs with a span of 5157 mm and a height of 600 mm have been tested. From the results it was found that the doubling of the web corrugation increases the capacity considerably. It was observed that the behavior was ductile and the maximum load carrying capacity was 218.9 KN. The collapse appeared for displacement of 58 mm.

III. CONCLUSION

Based on the literature survey, the following conclusions have been arrived.

1) The load carrying capacity of the cold formed steel beams can be improved by providing diagonal stiffeners.
2) The failure in the shear zone can be prevented by using corrugated webs than plain webs.
3) Concrete encasing is likely to improve the flexural capacity of the beams.
4) The flexural strength of built-up cold formed sections is more than the single cold formed steel sections.
5) For short span beams, greater section depth and thickness contribute to higher load carrying capacity.
6) Provision of trapezoidal corrugation gives higher flexural strength.
7) Bearing failure can be avoided by providing vertical stiffeners at the supports and at the loading points.

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