International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 2 Feb 2022, pp: 1515-1521 www.ijaem.net ISSN: 2395-5252

Local Buckling Behaviour of Cold Formed Steel Built-up Beams: Literature Review

Aathimoolam K[1], Asst.Prof.D.Amali[2]

[1]PG Student, Government college of Engineering, Tamil Nadu, India

[2]Assistant Professor, Department of Civil Engineering, Government college of Engineering, Tamil Nadu, India

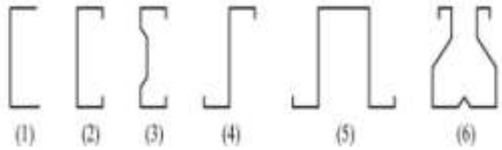
Submitted: 15-02-2022 Revised: 25-02-2022 Accepted: 28-02-2022

ABSTRACT: The objective of this paper is to provide a brief review of cold formed steel built-up beam over the last few years. Cold-formed steel flexural members are usually employed in civil construction for light loads. CFS sections such as C-sections with or without lips, Z-sections, I-sections and hat sections are normally used as flexural members. When standard sections are not sufficient for design loads, built-up sections made of back-to-back C-sections or nested C-sections forming a box section are ordinarily used as flexural members. Thin-walled built-up beams of open cross sections are liable to instability in a variety of modes, which might be listed as local buckling, distortional buckling, lateral-torsional buckling and interaction between the above buckling modes. Modern structural materials make its potential to scale back the weight of structures without decreasing their load capacity (the same cross-sectional area). This leads to the event of the theoretical and experimental investigations of such structures.

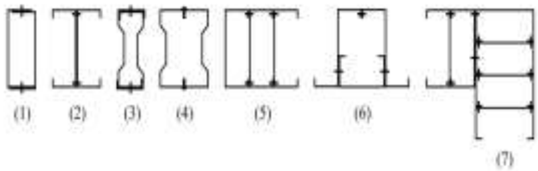
KEYWORDS: Cold formed steel, Built-up, Buckling, Beam, Literature review.

I. INTRODUCTION

Cold-formed steel structures are used extensively in the building industry, specifically in low to mid-rise construction as complete structures or in combinations with hot-rolled or fabricated steel framing. Examples of cold-formed steel applications are warehouses, factories, automobiles, equipment's, utility poles, and storage racks. Research over the past half-century has provided a thorough understanding of the behaviour of cold-formed steel members and resulted in comprehensive ground rule for their structural design [1, 2]. However, current construction methods and design guidelines almost exclusively beset the use of single section members (Fig. 1(a)), whereas there is a renewed focus in industry to enhance the applications of cold-formed steel to larger structures by connecting several single sections to form "built-up" cross-sections with higher axial and flexural capacities, as exemplified in Fig. 1(b). Typical connections are screws, bolts, clinches and spot welds. Now a days Built-up sections are extensively used in Australia, North America and Europe, e.g. as primary structural members of mid-rise residential buildings and large-span portal frames.



(a) Single Sections



(b) Built-up Sections

Fig.1.1 Single and Built-up CFS Section

Built-up members are fast becoming the leading edge of cold-formed steel structural elements and are producing innovative and efficient new solutions in mid-range and mid-span construction. But until now, current specifications offer very limited guidance for the design of built-up cold-formed steel members. The main problem in the design of built-up members is to account for the effect of partial composite action. As demonstrated in Fig. 2 for the case of two component sections, if the sections are welded along their full length, the abutting surfaces of the webs will undergo the same strain and fullcomposite action is achieved. Conversely, if the sections are not connected at all, they bend as individual sections and there is no composite

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 2 Feb 2022, pp: 1515-1521 www.ijaem.net ISSN: 2395-5252

action. Between these two limiting cases, for most types of fasteners, the component sections undergo relative longitudinal (shear) displacements at the fastener points and develop shear forces in the fasteners.In this case, the sections display partial composite action and the flexural rigidity, here referred to as the effective flexural rigidity (EI_{eff}) lies somewhere between the limiting cases of full (EI_c) and no composite action (2EI).

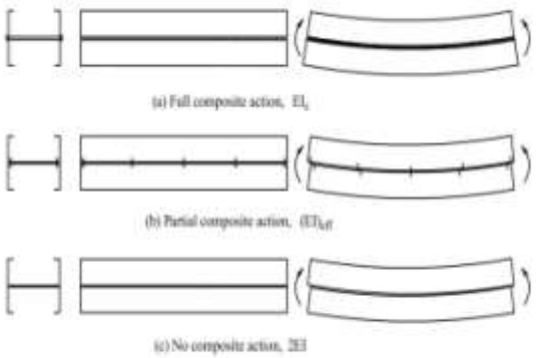


Fig.1.2 Full, Partial and no Composite action

The degree of composite action depends on the shear stiffness of the connectors, including the shear stiffness of the fastener and the in-plane stiffness of the connected ply, as well as the axial stiffness of the component sections.

Fig.1.3 Mid-rise CFS framing

II. BEHAVIOUR OF CFS BEAM

Normally, cold-formed steel such as Z section and C section are applied as purlin or beam. The built-up sections made of back-to-back C-sections, nested C- sections forming a box girder or face-to-face C-sections are introduced when single C sections are not enough for ultimate loads or allowable deflection. The strength of the beam might be limited by lateral torsional buckling, distortional buckling or local buckling of the beam depending on the geometry of the section. Because of very small thickness, the cold- formed flexural members are also failed by distortional buckling in contrast to hot- rolled sections.

III. PAST EXPERIMENTAL AND NUMERICAL STUDIES

Krishanu Roy et al.(2020) investigated flexural capacity of gapped built-up cold-formed steel channel sections including web stiffeners under four point bending. The gap between the back-to-back channels was formed through intermediate link-channels which were screwed to the webs of the back-to-back channels. Three different types of channels were considered to form the built-up channels: plain channels, channels with one web stiffener and channels with two web stiffeners. Two different beam spans as 1000 mm and 2000 mm were tested. An extensive parametric study was conducted by the authors to investigate the effects of web stiffeners and link-channel spacing on the flexural capacity of such gapped built-up beams. The flexural capacity of back-to-back gapped built-up sections with two web stiffeners was increased by 10% on average, when compared to the capacity of gapped built-up-beams with plain channel sections.

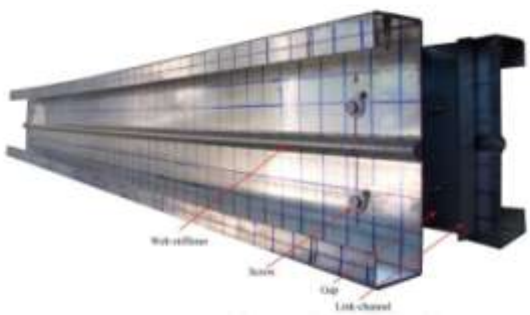


Fig.3.1built-up sections (Krishanu Roy 2020)

Experimental and numerical investigations of back-to-back gappedbuilt-up CFS channel sections under four-point bending have beeninvestigated by the authors. A total of 18 laboratory tests were reported,6 of which were for

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 2 Feb 2022, pp: 1515-1521 www.ijaem.net ISSN: 2395-5252

built-up gapped plain channel Sections, 6 werefor built-up gapped channels with one web stiffener and the remaining 6 tests were on built-up gapped channels with two webstiffeners. The failure modes, moment capacity-displacement behaviour, and deformed shapes at failure are discussed. It wasfound that there is little influence of link-channel spacing on themoment capacities of built-up gapped section beams. However,the influence of gap between the back-to-back channels on the moment capacities of built-up gapped section beams was moresignificant.The failure of the gapped built-up sections with plain channels isgoverned by the local buckling failure mode, while those with stiffenersare governed by distortional buckling failure mode. For specimens of2000 mm length, lateral-torsional buckling mode was the main failuremode that governed the flexural capacity. Whereas, for specimens of 1000 mm length, the main failure mode was distortional buckling. Itwas found from the comparison of flexural capacities that the flexuralcapacity of the built-up gapped sections with channels having twoweb stiffeners can increase the flexural capacity up to 10%, when compared to the flexural capacity of the gapped built-up sections withplain channels. However, for built-up channels with one web stiffener,the flexural capacity did not increase significantly.

Meza et al.,(2020)conducted a comprehensive experimental program on cold-formed steel built-up beams with two different crosssectional geometries. The work aimed to experimentally investigate the interaction between the individual components under increasing loading and to quantify the effect of the connector spacing on the cross-sectional moment capacity and the behaviour of the beams. In total,12 specimens were tested in a four-point bending configuration, with lateral restraints provided at the loading points in order to avoid globalinstabilities. The built-up specimens were composed of three or four plain channels with nominal thicknesses of 1.2 and 1.5 mm, which werejoined together using M6 bolts. Each built-up geometry was tested with three different connector spacing's. The specimens were designed to fail by local buckling of their components. Additionally, strut buckling of the channel comprising the top flange in between connector pointswas observed.The test results showed thatreducing the connector spacing in the constant moment span resulted in a modest increase in theultimate capacity of the specimens with Geometry 1. The beams with two rows of intermediate connectors experienced an averageincrease in ultimate capacity of 3% relative to the beam withoutconnectors, while the specimens with three rows of connectors exhibited an average increase of 11%.

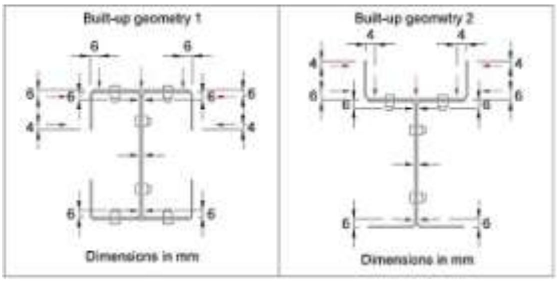


Fig.3.2built-up sections (Meza et al.,(2020))

The specimens with Geometry 2 showed a more substantial increase in ultimate capacity when the spacing between the connectors was reduced. The beams with two intermediate rows ofconnectors along the constant moment span experienced an average increase in ultimate capacity of 22% relative to the beams withoutintermediate connectors, while the beams with three rows of intermediate connectors displayed an average increase of 36%.

A study on the flexural rigidity of built-up beams assembled from lipped channels connected back-to-back was presented by **Dang and Rasmussen (2019).** The authors demonstrated experimentally, numerically, and analytically that the flexural rigidity of a built-up beam increases when more intermediate rows of connectors are provided and the connector stiffness increases, particularly when the connectors are located toward the end of the member.

Cheng Yu et al. (2016) investigated on distortional buckling experiment. When the compression flange of the beam is not laterally braced over a distance, 1.626 m in constant moment shows that distortional buckling is most failed. An average loss, 17% when laterally unrestrained C and Z section compared to the same beam which the section was restrained and failed in local buckling.

Jenitha G. et al. (2016)analysed of cold-formed steel C section beams and built-up beams. Two cold-formed C section beams, two cold-formed steel C back-to- back beams and one hot-rolled steel I beam were tested to obtain the maximum load and deflection at maximum load. The beams were also modelled in ANSYS 14 program in order to compare with experimental results. The maximum load of cold-formed steel C back-to-back beam was higher compared to the normal beam. Cold-formed steel beams are better than hot-rolled steel beam such as: thermal insulation, easy moulding, saving and light weight nature.

Wang and Young (2015) experimentally investigated the flexural behavior of built-up CFS members with open and closed cross-sectional geometries and with circular web holes, with the aim of extending the direct strength method (DSM) to cover these types of members. The open geometry consisted of two lipped channels screw connected in a back-to-back configuration, while the closed cross section was assembled from two plain channels screwed together through their flanges. The authors explored different ways ofcalculating the elastic buckling stresses required as input to the DSM, in order to account for the effects of the connectorsand the web openings. This research was further extended by the same researchers (Wang and Young 2016a, b) by carrying out an experimental and numerical investigation of flexural members with four different built-up cross-sectional geometries failing by cross sectional instabilities. Each built-up geometry was assembled from two identical sections, screw connected either in a back-to-back configuration to form an open section or through the flanges to form a closed section.

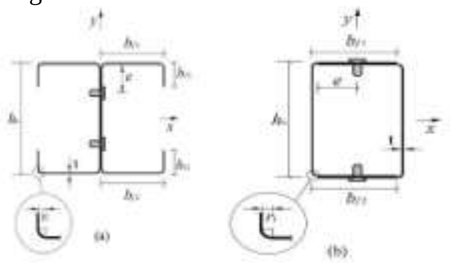


Fig.3.3 built-up sections (Wang and Young (2015))

The authors assumed in their elastic stability analysis that the built-up geometries behaved as one solid cross section and found that, while for some built-up geometries the DSM provided acceptable predictions, for others the predictions were either overly conservative or unsafe. They resolved to modify the DSM equations and proposed tailored equations for each built-up geometry based on their experimental and numerical data.

L. Laim et al. (2015) have studied about the flexural behavior of beams made of cold-formed steel sigma-shaped sections at ambient and fire condition. Two kinds of section such as single sigma and built-up I section by two sigma were tested by four-point bending test. Three repeated tests of one section were considered in their research. The span length of their specimens was 3 meters. Screws with self-drilling were used as the connection between two of the sigma sections.

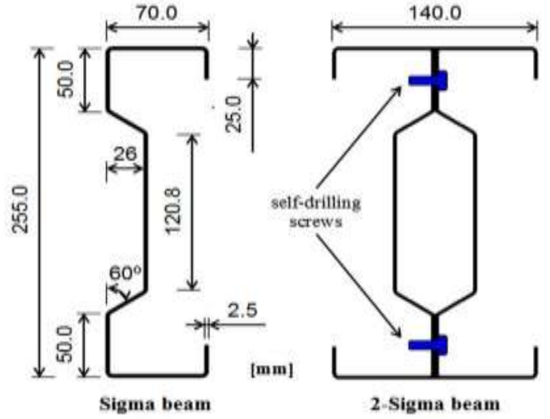


Fig. 3.4 Scheme of the cross-sections of the tested beams (Luis Laim et al. (2015)).

Restrain system of roller and pinned support of their study was shown in Figure 3.5Moreover, lateral deflection was restrained at the position of the support.

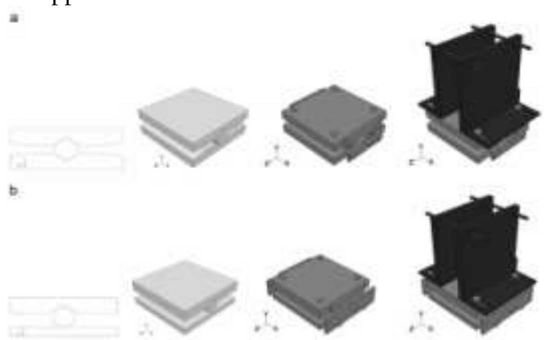


Fig. 3.5 Detail of the beam support system: (a) pinned and (b) roller supports. (L. Laim et al. (2015))

Their results show that the load capacity of the beam 1s affected by the shape of the section and the ultimate load of built-up I of two sigma sections was 2.9 times higher than the single sigma section. It means that symmetry section of 2 sigma was better than the asymmetry section of one sigma section. Local, distortional, and lateral torsional bucking were found for built-up I section with two sigma as shown in Figure 3.6

Fig 3.6 Failure mode of 2 sigma beam (L. Laim et al. (2015)).

Liping Wang and Ben Young (2015) investigated on flexural behavior of cold- formed steel C back-to-back and built-up box beams with holes at mid span. All forty- three beams with different ten section dimensions and holes were tested to obtain the maximum force and failure modes. The test set-up with four-point bending was shown in Fig 3.7

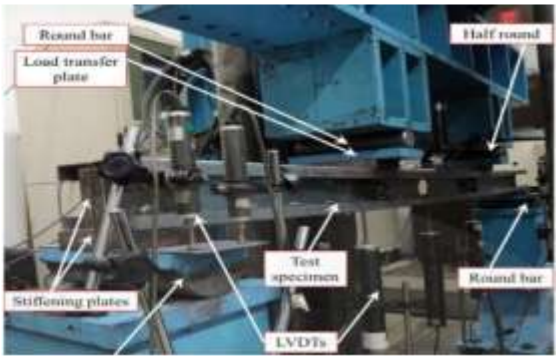


Fig 3.7 Test set-up with four-point bending (Liping W. et al. (2015))

Back-to-back section composed two C sections connected in the web while built-up box section was gotten from two U sections connected by screws at the top and bottom flanges. Bolts were installed when the beam was connected to the loading bearing plates and support bearing plates. The screw diameter was 4.8 mm. The proof stress at 0.2% used in the test was 450, 500, and 550 MPa. The different thickness with 0.42, 1.2, and 1.9 mmwas observed. The overall length of the beam was 1600 mm. The ranges of web depth were from 88 mm to 138 mm.

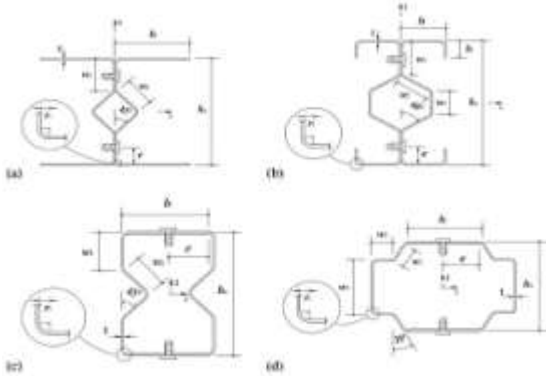


Fig 3.8 Types of cross sections (Liping W. et al. (2015))

The different ratio between hole diameter and web depth 0.25, 0.5, and 0.7. In the result, the reduction of maximum moment with a maximum value of 6% when d_b/h_w was increased from 0.25 to 0.5. The reduction of maximum moment with a maximum value of 16% when d/h, was increased from 0.25 to 0.7. It was observed from the test that some beams were failed by distortional buckling (D), local buckling (L), and flexural buckling (F). Some beams were failed by local buckling (L) and flexural buckling (F while some beams were failed by local buckling (L), and distortional buckling (D). Direct strength method (DSM) in North American Specification (NAS) was compared with the experimental test. In the result, DSM could be used to calculate the strength of C back-to-back and built-up box beams with holes.

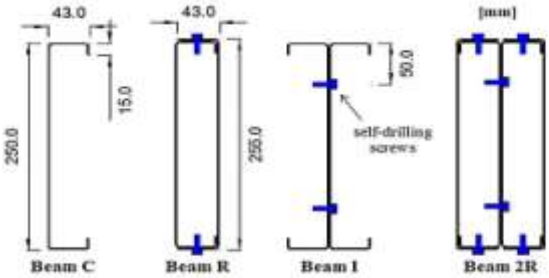


Fig 3.9Various built-up sections (Luis Laim et al. (2013))

In Australian and New Zealand code, the properties of cold-formed steel are determined as following step. First, the specimen will be taken longitudinally from a main flat part of the section (not include the corner) and the specimen will be taken from the flat part with the smallest yield stress increase from cold-roll forming machine. Then, yield stress (f,) and tensile strength (F,) were designed by using AS 1391.

Luis Laim et al. (2013) researched about the investigation on flexural behaviour of cold-formed steel beam with various sections such as: C section, R section, Isection and 2R section based on experiment tests and numerical. Twelve specimens were tested to obtain the maximum load,maximum deflection, and failure mode. Each section was tested the same three timesto better results.R section was got from C section and U section connected in the flanges while 2R section consisted of two R sections connected to the web. For the section geometry, the height of C section and U section was 250 mm, and 255 mm, respectively. The thickness of C and U section was 2.5 mm. Self-drilling screw was used to connect the sections . The test set-up schema was illustrated in Figure 3.10 Lateral supports were also needed to prevent torsion. Figure 3.11 showed load- displacement curves of C, I, R and 2R beams.

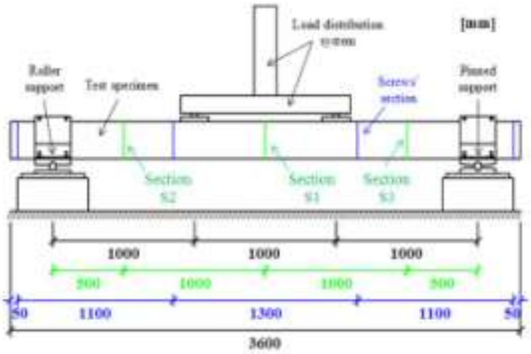


Figure 3.10 Schematic view of the experimental set-up (Luis Laim et al. (2013))

Haiming W. et al. (2009) investigated on cold-formed steel section beams with inclined, upright and complicated lips in experiment and finite element method. It was observed that some beams were failed by distortional buckling. Some beams were failed by local buckling, and some beams were failed by interaction between local buckling and distortional buckling. The section lip has much influence on the strength of the beam. The flexural strength of upright lip beams is more than that of inclined lip beam in both four-point loading and non-four point loading tests. It is a good agreement between experimental and numerical results. Self-piercing rivet connections, pop rivet connections, and screw connection of similar thickness of two layers of steel 1.0, 1.2, 1.6, and 2.0 mm thick have been tested by **Sinha et al. (1999).** Their conclusion is that the corresponding load displacement curves are in the large of variation between those different types of connections. Press joins gave a nonlinear behaviour in smaller range of load. Self- piercing shows high initial stiffness behaviour than the other type of connection. Whereas, self-tapping screws shows low initial stiffness behaviour. Self-piercing rivets show a high peak load and high ductility.

It was observed that during unloading stage, some curves had discontinuities due to failure of the screws. The test result proven the good agreement between the numerical and experimental. The failure buckling modes shown in the numerical analysis are also consistent with that of the tests. Furthermore, so as to evaluate the effect of height, thickness, and length of the beam to the moment capacity of the beam, fifty two finite element models were undertaken.

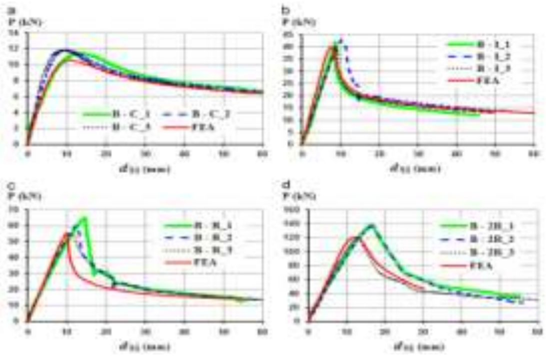


Fig 3.11 Load-displacement curves of C, I, R and 2R (beams Luis Laim et al.(2013))

Cheng Yu et al. (2003) studied about local buckling experiment. The test was shown to fully restrain with distortional buckling and gave the beam to fail with local buckling for C section and Z section. The experimental result showed the AISI, NAS and S136 design methods gave the suitable strength predictions. The direct strength method gave the best predicted strength for slender and un-slender beam among three methods.

C and Z sections **(Hancock et al.)** are usually applied for the beams. C section is singly symmetric and Z section is point symmetric. In the case of full lateral constraint, C section, and Z section will have flexure in a plane parallel with the web and bending theory can be used to calculate the normal stress and shear stress in the section. In case of C and Z sections have the same dimensions so that the shear stress distributions are similar the same.

The bolt connection behaviour in cold-formed (CFS) steel structure **(Wei-Wen Yu et al.)** is unlike from that in hot-rolled steel heavy structure. There are four failure modes of bolted connection: longitudinal plate shearing, bearing of sheet in front of the bolt, tearing of the plate in the net section, and shear of the bolt. For the limitation of the thickness, AISI specification shall be applied when the thickness 1s less than 4.8 mm. In contrast, when the thickness is not less than 4.8 mm, AISC specification shall be used.

Other research on CFS built-up flexural members has spurred some noteworthy innovations. The built-up LiteSteel beam (LSB), consisting of two channels with hollow rectangular flanges connected back-to-back, was investigated numerically and experimentally by Jeyaragan and Mahendran (2008a, b). The authors found that the detrimental effect of lateral-distortional buckling, to which a single LSB is susceptible, can be mitigated by connecting two LSBs back-to-back, resulting in a moment capacity which is more than twice the capacity of the individual LSB section. The modular light-weight cold-formed beam (MLC beam) is another innovative built-up beam, consisting of two lipped channels with hollow flanges and a web containing stiffened openings. The channels are laser welded together in a back-to-back configuration with reinforcing plates placed inside the flanges. The MLC beam was designed to provide high resistance to lateral-torsional buckling and has been extensively investigated both numerically and experimentally(Di Lorenzo et al. 2004, 2006; Landolfo et al. 2009, 2008; Portioli et al. 2012).

IV. CONCLUSION

From the above literatures, the behaviour of CFS build up sections based on fasteners spacing, stiffeners, aspect ratio, various loading conditions have been investigated. The Americanstandard (AISI)and AZ/NZ codalprovisions have been used for arriving cross sectional dimensions. The Numerical modelling of the various CFS section is being carried out by using the FEA software's, ANSYS and ABAQUS. For validation the results obtained from Numerical and theoretical methods has been evaluated and compared. The behaviour of the sections and the Failure patterns obtained under various types of loading conditions has been investigated.

REFERENCES

[1]. Dang K. Phan, Kim J R. Rasmussen (2019)., " Flexural rigidity of cold formed steel built-up members". Thin walled Structures.

[2]. Dileep Kumar PG, Merin Mathews(2017), "Web buckling analysis of cold formed built-up I section"

[3]. Francisco J. Mez (2020), "Experimental Study of Cold-Formed Steel Built-Up Beams". J.Struct.Eng

[4]. G.Jenitha , V. GokulNath and N. Ganesh Kumar "Analysis of Cold-Formed C-Beam andBuilt Up Beam". Indian Journal of Science and Technology, Vol 9(2), DOI: 10.17485/ijst/2016/v9i2/86350

[5]. Kim J.R., Rasmussen, Mani Khezri A, Benjamin W. Schafer ,Hao Zhang., (2020)., "The mechanics of built-up cold-formed steel members".

[6]. K.Roy, H.H.Lau, T.C.H.Ting, J.B.P.Lim., (2020) "Flexural capacity of gapped built-up cold-formed steel channel sections including web stiffeners."

[7]. Liping Wang, Ben Young (2015)., "Beam tests of cold-formed steel built-up sections with web perforations". J.Struct.Eng

[8]. Liping Wang and Ben young (2015), "Behavior of Cold-Formed Steel Built-Up Sectionswith Intermediate Stiffeners under Bending. I:Tests and Numerical Validation". J.Struct.Eng

[9]. Luis laim (2013)., "Experimental and Numerical analysis on the structural behaviour of cold-formed steel beams". Thin-walled structures 72 (2013) 1-13.

[10]. Luis laim (2015) "Flexural behaviour of beams made of cold-formed steel sigma-shaped sections at ambient and fire conditions". Thin-Walled Structures 87(2015)-53-65.

[11]. M. Adil, N.Subramanian, M.anbarasu, James B. P.Lim (2020), "Flexural strength of cold-formed steel built-up composite beams with rectangular compression flanges.

[12]. P. Manikandan, M. Thulasi (2019)"Investigation on cold-formed steel lipped channel built-up I beamwith intermediate web stiffener".International Journal of Advanced Structural Engineering.

[13]. P.Manikandan, A.Ezhilan (2019), "Investigation on cold-formed steel built-up new innovativehat-shaped closed section under bending". International Journal of Advanced Structural Engineering

[14]. P. Manikandan (2014), "Efective shaping of cold-formed thin walled Built-up beams in pure bending". Arab J Sci Eng.