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A Comparative Study on Light Gauge Member and Castellated Beam

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Abstract: This research paper examines the comparative study on strength characteristics of a Cold rolled steel with castellated beam under the lateral distortional and torsional buckling modes. For studying a beam element, a STADD model is built. In the examination of cold formed steel sections, material non-linearity and geometric imperfection were taken into account. Variations in length and cross section of a finite element model were investigated. For cold formed steel sections and castellated beams, the load deflection curve is plotted and examined. To investigate the strength and behaviour of castellated steel beams, finite element modelling was used to modify the cross section. The study shows that the web distortional buckling has greatly influenced by the failure load in castellated steel beam. The failure load of the beam is influenced by the steel strength; the higher the steel strength, the higher the failure load. The high strength castellated steel beam fails due to local flange buckling, whereas the regular castellated steel beam fails due to lateral torsional buckling in the web.

Keywords: Steel beam, four point flexural test, structural design, finite element modelling, cold formed steel

1. Introduction

Kaustabh V.Raut [2] proposed the cold-form steel [CFS] which was used in the steel construction and also verified as highly essential when correlated to the hot steel. A steel beam are also known as flexure or bending members. They are susceptible to distortion and torsional buckling that leads to decrease the level of resistance. Amor Hossein Gandomi [1] examines about the development of welding technology in the construction of steel and the CSB became available to engineers. IMC profile was used as the structural components in constructing the building. A consumption of material texture increases cross section slenderness which cause a high deformation because of high stress. Mario D'Aniello [13] proposes steel was nowadays used as an important material for structural process. Steel beam was made up of CFS sections which are torsional constraint than flange segment.

Ehab Ellobody 2011[14] examines the CSB was fabricated form hot rolled steel I section which have many benefits such as architect structure, proportion of optimum weight and depth, large section modulus, greater bending rigidity, easy of service through the web opening and economic construction. Fatmir Menkulasi Castellated beams have been used since the 1940's (Zaarour and Redwood 1996) [6] because of their ability to offer wide and open spaces,

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reduce floor to floor heights, increase illumination and improve aesthetic appeal. Engineering advantages of castellated beams include superior load deflection characteristics, higher strength and stiffness, lower weight and the ability to span up to 90 ft. without field splicing. M.R. Soltani [3] CSB are having different girders along with the hexagonal and circular web openings are provided at equal interval. The manufacturing process of CSB, breaking the web in zigzag method and combining the 2 halves using welding guides to increase the bending capacity and decreases the beam weight which can be used for long span construction. Delphine Sonck [4] an important benefit of castellated beam or cellular member correlated to ordinary I section to increase the flexible axis through the resistance of bending. Arizu Sulaiman CFS structural member can become even more effective when used in conjunctions with other materials but the main problem in implementation of the designs is ensuring adequate shear transfer between the slab and the cold formed section. Jin Ying Ling [11] six various opening shapes were conducted to examine the shape which gives the low decreases in the moment of buckling. The C hexagon shape was established to create designs with various number of openings, spacing, edge distance and size. Rujuta A. Bhat [7] In this research, the characteristics of steel beam in the web was studied analytically. A hybrid steel beam was used in this model which was not satisfied by homogenous or hot steel section. Ehab Ellobody 2013[5] an approach of finite element approach can be extended easily to learn the construction of columns from built up or other material by using different form of sections. Structural performance of column in cold condition is very important to analyse the behaviour of column in fire condition. Nadjai [10] four specimens comprise the 2 various geometries in steel and the load capacity. These were examined under the monotonic loading and high temperature. Shear connections were provided between the beam-steel and concrete flange. S.Santosa [12] the bending resistance of an empty thin-walled beam typically drops very significantly after reaching the ultimate value at a small rotation. The decrease of load carrying capacity is due to inward fold formation at the compression flange, significantly reducing the cross-sectional area at the crush zone. Ehab Ellobody 2015[7, 15] by using nonlinear FEA the structural behaviour was studied.

2. Experimental Work

In this research, two quantity of C shaped cold formed steel section were bought from the nearby market where the material length ranges from 200 and 250 mm. The different calculation parameters were shown in table.1.

Table 1 - Specimen details

Specimen	200 – C – Section	250 – C – Section
Section description (mm)	C-200 x 80 x 30 x 3 mm	C-250 x 80 x 30 x 3 mm
Area (mm^2)	1224	1524
Perimeter (mm)	822	928
I_{xx} (mm^4)	7622735	12901332
I_{yy} (mm^4)	1146024	1303482
R_{xx}	78.91	92.00
R_{yy}	30.59	29.24

Plasma torch cutting processes were adopted to produce the hexagonal on the Cold-form of steel. Initially, two same types of hexagonal pattern were drawn on the steel using the plasma torch. A hexagonal portion is cut away from the c shape CFS steel through the plasma arc cutting process. After this process, the hexagonal portion was completely taken away from the cold-form steel. An edge of the steel was cleaned using the finishing tool. Hexagonal dimension pattern verification also carried out on the C shaped cold formed steel section. After hexagonal dimension pattern verification process, the two portions of the C shaped cold formed steel section were welded together with the help of metal inert gas welding process. Overall dimension verification of the welded cold formed steel section also executed with the help of measuring tape. In order to avoid the surface rust formation on the cold formed steel section, primer coating was applied on its surface. Finally, the assembled castellated beam section were produced as per the testing requirements. The step-by-step specimen preparation processes were illustrated as images in figure.1 (a) to figure.1 (h) correspondingly.

Fig. 1 - (a) C shaped - Cold formed steel section; (b) cross sectional view- C shaped - Cold formed steel section; (c) plasma torch cutting pattern -1; (d) plasma torch cutting pattern -2; (e) hexagonal dimension pattern verification; (f) overall dimension verification; (g) castellated beam - assembled section; (h) primer coated with finished cold formed metal surface

Four point flexural test was performed on the well-produced C shaped steel which is CFS by the universal testing machine. An experimental setup for four point flexural test was depicted in figure.2 (a) to 2 (d) respectively.

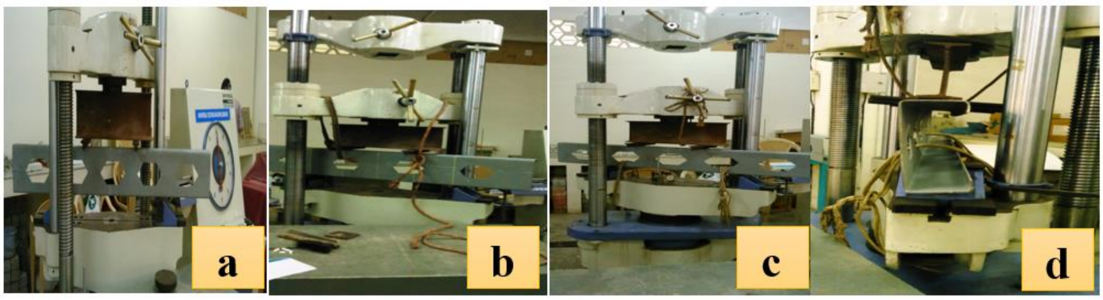

Fig. 2 - (a) Specimen setting up on instrument; (b) setting up deflection meter; (c) setting out specimen 2 – 250 mm depth; (d) local buckling case under worst loading stage

The method for organising the investigation involves in a particular test on a universal machine. The sample is simply supported and two-point loading was applied. A constant loading was applied till failure. The experimental results were discussed in the result and discussion section.

3. Finite Element Analysis

Many ways to model the stiffened plate structure using FEM.A simple cantilever beam structure was modelled. The performance based on different web depth was examined.

Design the plate frameworks with the method of finite element were involved inside every finite element. The capabilities of finite element were examined thoroughly by solving and constructing the design of finite element of beam framework. An influence of the web depth on the process of the various designing was investigated. The usage of beam steel with the web structures like high and industrial buildings. It was converted out to be enlarged in current times. Many reason for openings are initiated. An experimental examination was organized and planned on different designs. The beginning was to found the deflection of steel and high load with the web openings. Every beam is observed by the method of finite element with the help of Analysis System Software. The outcome obtained where compared with those of the experimental process.

4. Typical Pre- Engineered Building System STAAD Model

4.1 Element Design

The aim of this research was to determine the FEA [Finite Element Analysis] of the castellated beam which was examined in the experiment to investigate the load capacity. An element method was used to judge the whole response to high values of outside loading till it loses its load capacity. These element designs were used to examine the research to prove the result and to propose the non-linear characteristics of modes like buckling in shear and web post. A three-dimensional element design was created to examine the characteristics of beam along with the web site while having a c shaped section using the package of Analysis System 13.0 software. It incorporates components and non-linearity in beam design. A stress of bi linear was used in designing the component of steel with the help of Von Misses criterion and hard rule which is perfectly combined for steel. An impact of deformation was examined in this paper.

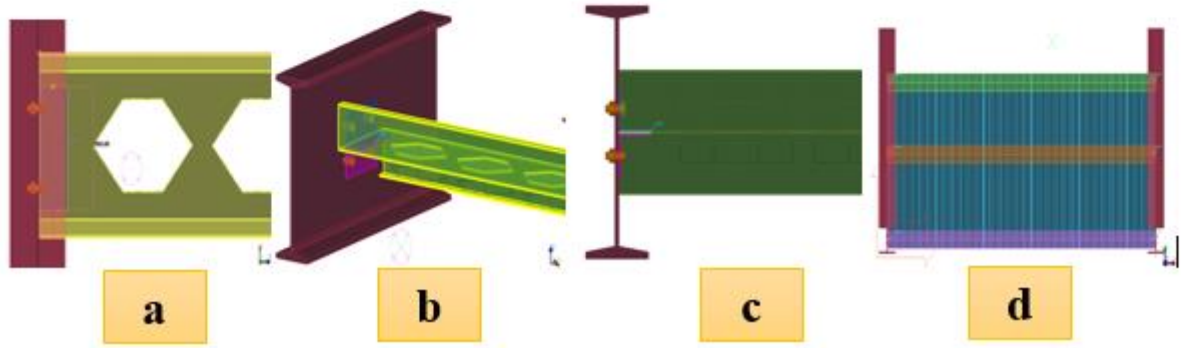

Fig. 3 - (a) Secondary beam column connection detailing in three dimensional view 1 to 3 was marked as a,b,c; (d) decking profile model + Secondary beam connection details

4.2 Dimensions of the Modelling

The following dimensions were taken into account to design the entire STAAD model. Span of the structure is 18.06 m, length of the building is 24.72 m, spacing between the bays are 8.06 m, spacing between the secondary beams are 1.25 m (max), height of the structure is 6.10 m, basic wind speed is 39 m/s and mezzanine plat form height is 3.05 m.

4.3 Connection Detailing

The castellated beam web portion connects with the column or beam members (main structural element) using the cleat angle – 75x75x6 mm on having 2 No's of 16 diameter bolt. The different three dimensional models of the pre-engineered building system STAAD model with castellated beam was represented in figure 3 (a) to 3 (b) correspondingly

4.4 STAAD Modelling

A Typical Pre-Engineered building model is chosen to make an analysis based on the warehouse loading condition as pinned connection. The section properties of the hot & cold formed steel sections were compared for their deflection values, bending moment values, shear forces. Complete pre-engineered building system, which is modelled with the help of STAAD software, is shown in figure.4 (a). Hot rolled steel section's complete dimensions and its geometric properties were illustrated in figure.4 (b) respectively. The complete dimensions and geometric property of **CFS** steel and the graphical output representation of CFS steel were illustrated in figure five (a) and 5 (b) respectively. Similarly, different outcomes which are attained from the STADD modelling such as graphical output representation of hot rolled steel section were depicted in figure.6 (a) to 6 (c) respectively. Interaction values between the castellated beams and pre-engineered buildings, which were accomplished from the STADD modelling for hot and cold formed steel sections, were represented in figure.7 (a) to 7 (b) respectively.

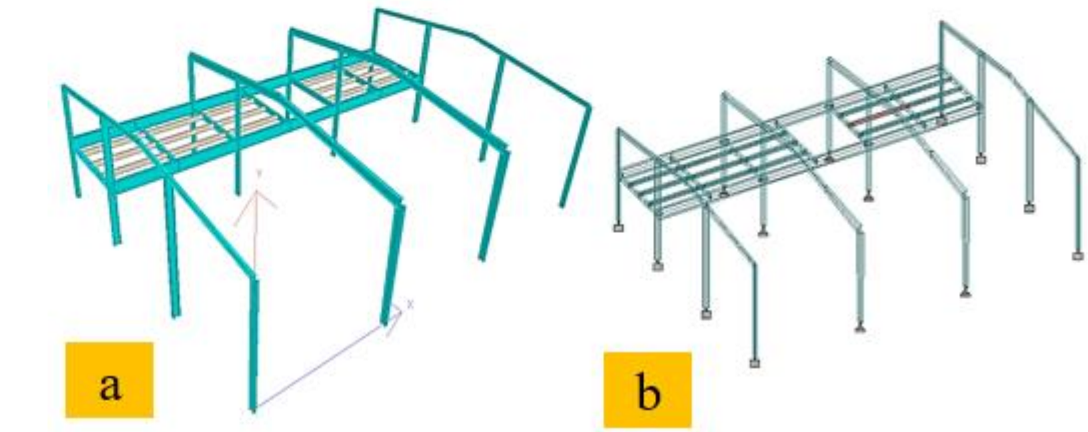

Fig. 4 - (a) Typical pre-engineered building system STAAD model; (b) dimensions & geometric properties of a hot rolled steel sections

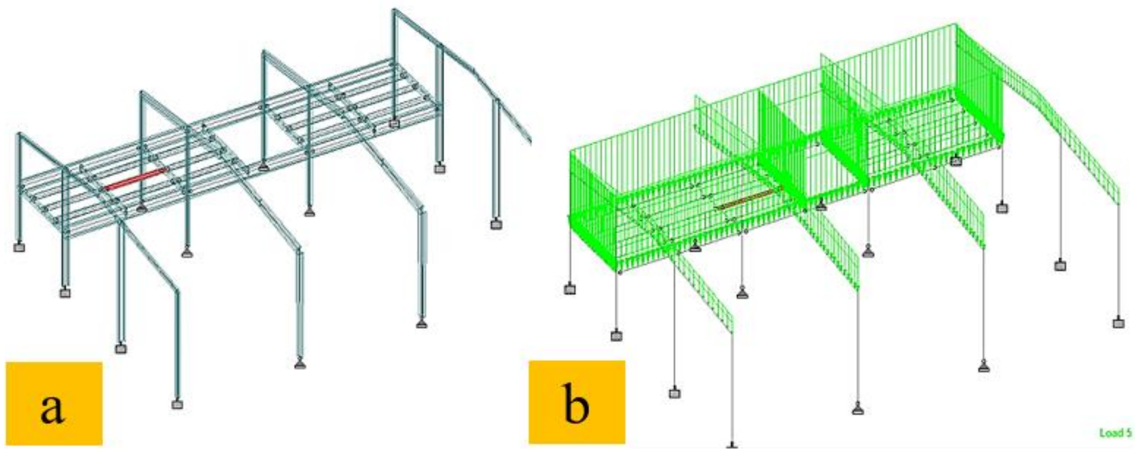

Fig. 4 - (a) Dimensions & Geometric properties of a Cold formed steel sections; (b) graphical output representation of cold formed steel section

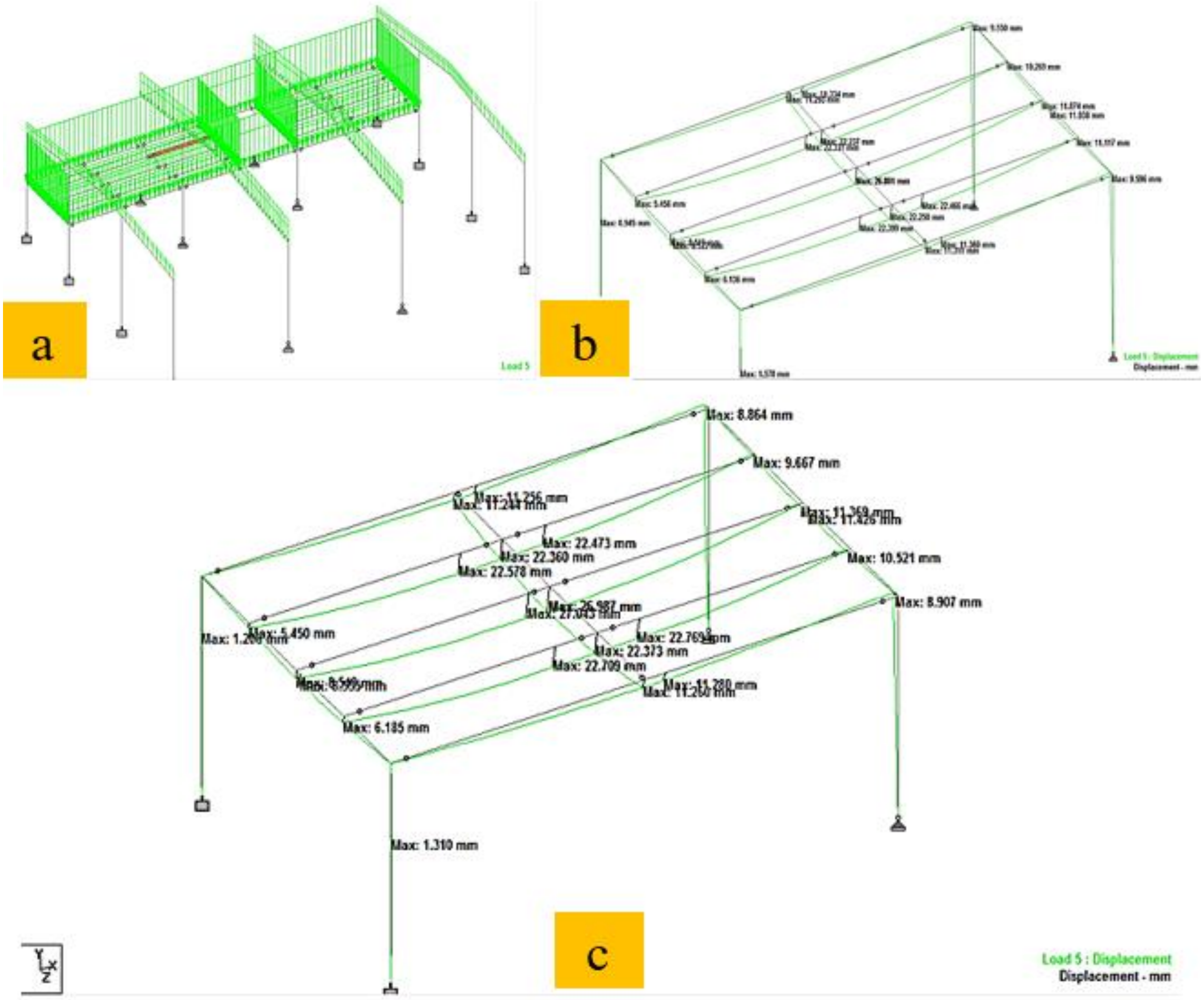

Fig. 5 - (a) Graphical output representation of Hot rolled steel section; (b) deflection value of CFS steel; (c) deflection value in hot rolled steel sections

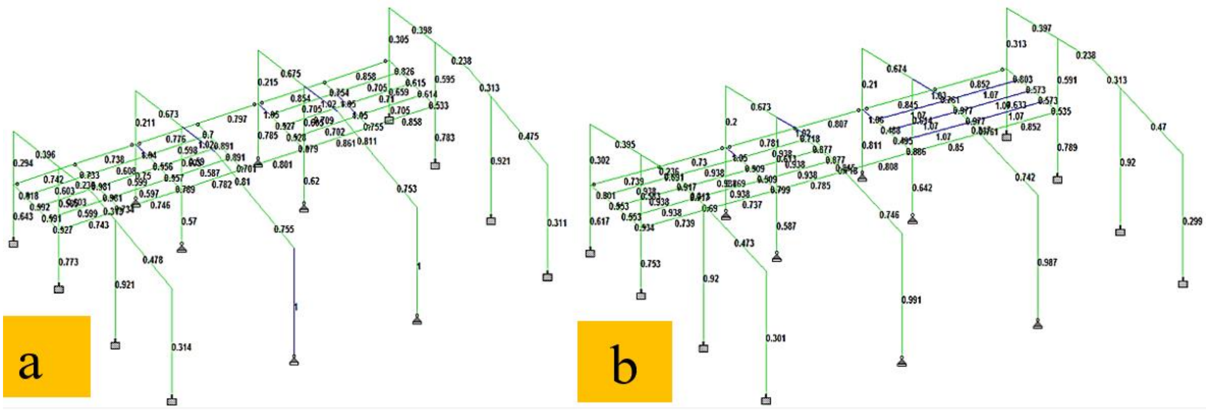

Fig. 7 - Interaction value of; (a) hot steel; (b) CFS steel sections

By using the STAAD modelling software, surface modelling of the castellated beams were equipped and it was depicted in figure.8 (a). All the supporting conditions were assigned on the required sides of the STAAD modelled castellated beams. Required pressure load was also applied on the flange side of the beams. Figure.8 (b) shows the applied load model of the STAAD modelled castellated beams. Stress distribution over the beams surface was computed for the applied load on the flange portion of the STAAD modelled castellated beams. Maximum stress distribution over the beams which is castellated was represented in Fig. 8 (c). Von-Misses yield stress formulation on the castellated beams web flange surface was computed in the STAAD software. Maximum stress indication of Von-Misses formulation for the STAAD modelled castellated beams were depicted in figure.8 (d).Stress distribution was found maximum in the exterior surfaces of the castellated beams also the minimum stress distribution was noticed in the interior surfaces of the beams flange.

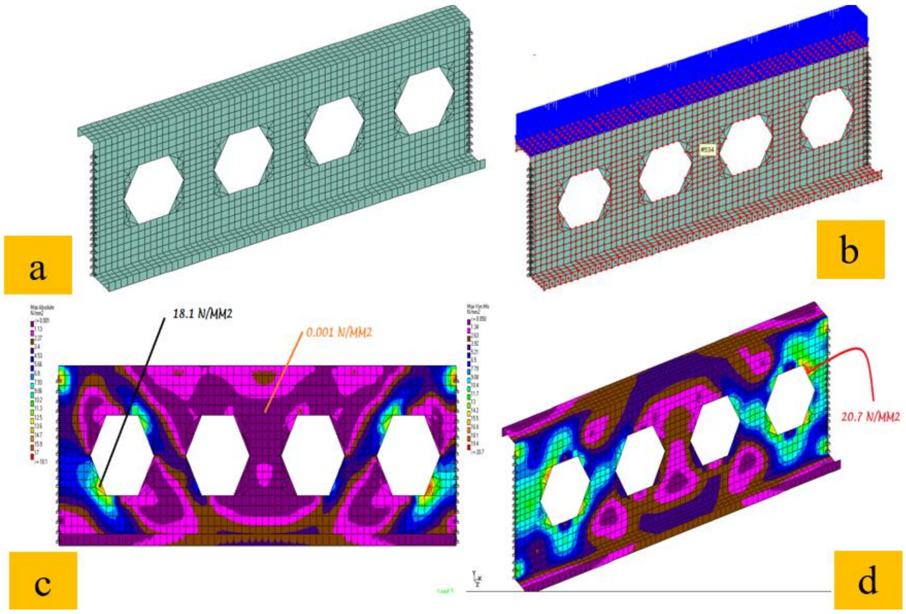

Fig. 8 - (a) Surface modelling & support condition in STAAD; (b) pressure load applied on the section top flange; (c) stress indication – max absolute case; (d) stress indication – max von-misses formulation

5. Results and Discussions

5.1 Experimental Results

Different outcomes that are perceived from the four-point flexural tests were illustrated in figure 9 (a) to 9 (b) correspondingly. Deflection attained by the two different cold formed steel section i.e., 200- and 250-mm length C steel sections due to the applied loads were represented as graph in figure.9 (a). this was analysed the capacity of load of the 250 C shaped cold formed steel section is higher than that of 200 C cold formed steel section. In concern with the 250 C shaped steel which is cool, the maximum load of 36000 N and maximum deflection of 6.99 mm were observed during the four-point flexural test. In concern with the 200 C shaped steel which is cool, the maximum load of 22000 N and maximum deflection of 6.35 mm were observed during the four-point flexural test. It was observed that, when compared to 200 C shaped steel which is cool, the capacity of load of the 250 C shaped steel which is cool and also higher because of the increasing web depth in the beam section. Stress and strain plot for the two different cold formed steel section i.e, 200- and 250-mm length C steel sections were represented as graph in figure.9 (b) and figure.9 (c) correspondingly. Maximum stress value of 34.88 MPa was observed in 250 C shaped cold formed steel sections, which is higher than that of 200 C shaped cold formed steel sections. In concern with the 200 C shaped cold formed steel sections, the maximum stress of 28.86 MPa and maximum strain of 0.0051were observed during the four-point flexural test. In concern with the 250 C shaped cold formed steel section, the maximum stress of 34.88 MPa and maximum strain of 0.0069 were observed during the 4 investigations. Due to the increasing web site of the 250 C shaped cold formed steel section, it reveals the maximum stress and strain than that of 200 C shaped cold formed steel section.

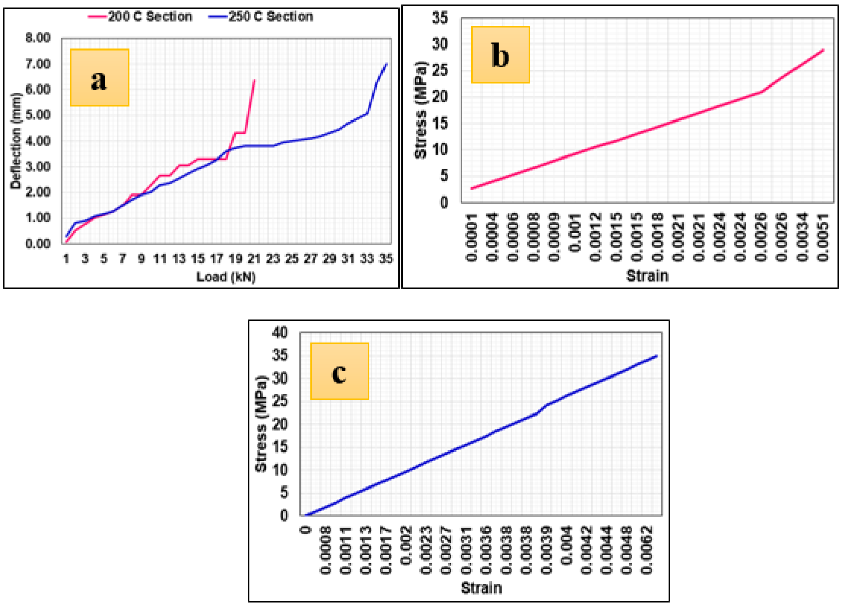

Fig. 6- (a) Deflection vs load curves for 200 C Section and 250 C Section; (b) stress vs strain curve for 200 C Section; (c) stress vs strain curve for 250 C Section

5.2 Finite Element Analysis Results

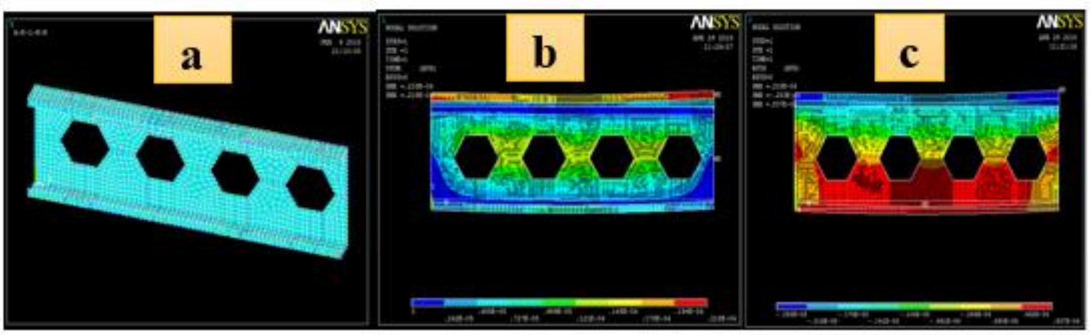

Fig. 7 - (a) Three dimensional area model view in ANSYS window; (b) displacement vector contour plot; (c) X-component degree of freedom solution

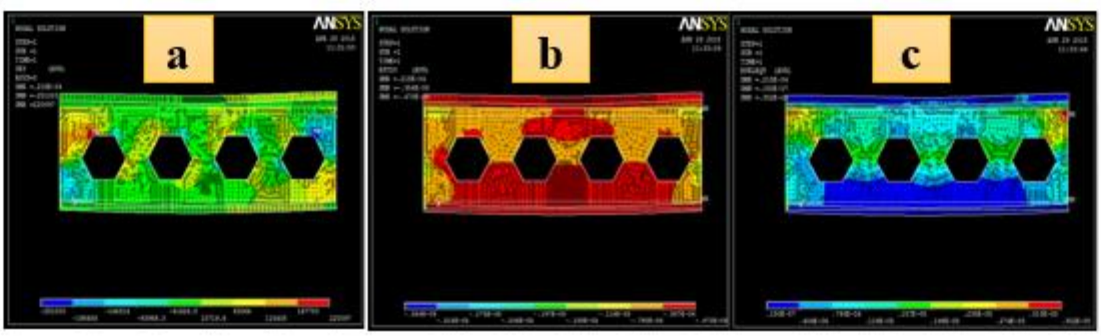

Fig. 8 - (a) XY shear stress contour plot; (b) third principal total mechanical strain; (c) von-misses elastic strain

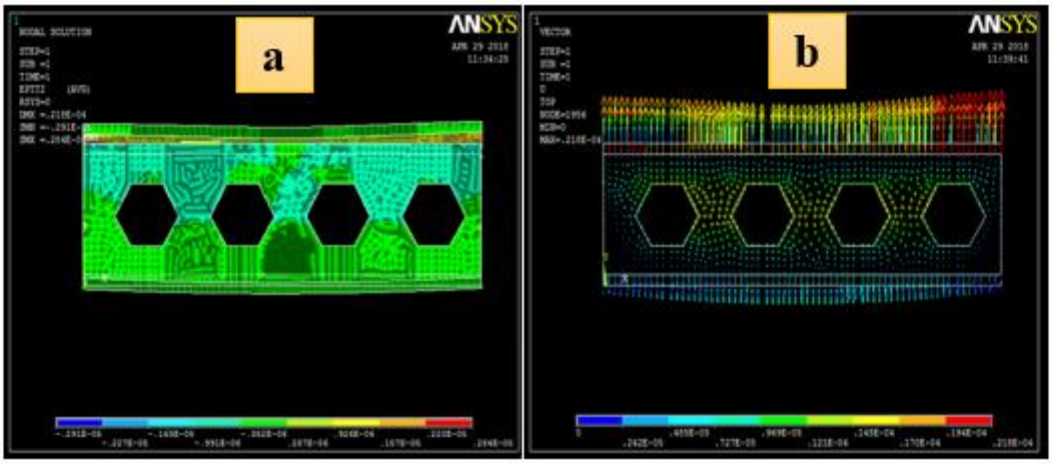

Fig. 9 - (a) Z-Component total mechanical strain contour plot; (b) predefined vector plot of the section

From the above experimental and analytical results, the discussion are as follows: On replacing the steel from hot to CFS steel structural weight will be optimized with retaining same structural performance.

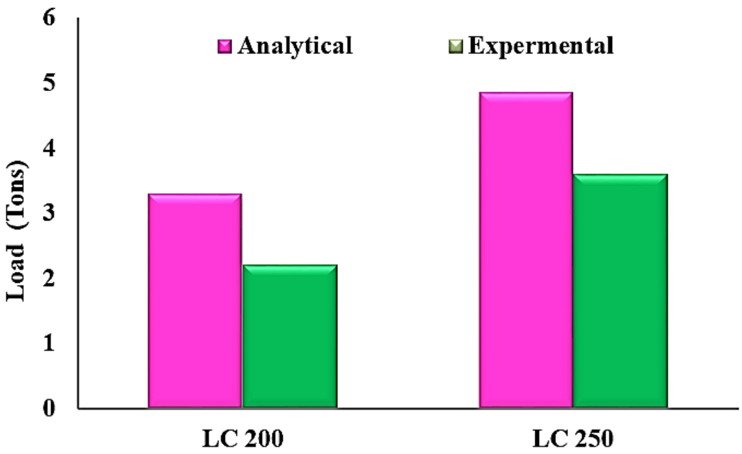

Fig. 10 - Comparison chart for load carrying capacity

On member design the equivalent commercial section has identified to match the requirement of the replacing sections. The graphical results that obtained from the model had resembled the same behaviour for their corresponding codal provisions. The geometrical parameter is completely satisfied by the light gauge section having 3 mm metal thickness. The weight reduction of the section by retaining the sectional properties is around 65 % of the conventional secondary beams. The area model for the finite element analysis is carried out by the software ANSYS by interconnecting mesh through the key points. The Critical stress regions were identified to sort out the points in stress reduction connection methodology. In the behaviour of top restrained flange condition has applied and the results were higher than the regular geometrical properties. In our analytical study, many of the models had worked out to get the perfect identity to suit with the industrial requirements. The allowable & actual deflection values for the applied load were calculated. The critical stress regions were pointed and special attention is carried to overcome the same. The load carrying capacity of the members was clearly identified through the four-point flexure loading test. The shear transformation behavior is investigated between the web in plane model as well as web in parallel plane alignment. On introducing the web parallel arrangement, the web buckling shall be very much minimized when comparing with the web in plane model. A capacity of load is enhanced to 1.65 times when we increasing the depth having the increment of 50 mm depth. Section will not undergo any yielding limit, before which the section fails by local flange/ web buckling through which the section stability can be ensured with connections. From the above investigation the cold formed steel sections is sufficient in replacing the secondary conventional I beam of the mezzanine steel structures. From the above plate & member modelling the behaviour of castellated beam had studied, on applying loading to hot steel& CFS steel the difference in strength, cost savings were comparatively good in cold formed sections.

The values of bending moment, shear force, deflection is all within the limits of Indian standards. The observed stress results in different axis are in the specified range.

6. Conclusion

The optimized sectional properties for the cold formed steel section (3 mm thickness) were obtained based on the experimental & analytical investigation. The transformation in these sections is necessary to meet the industrial requirements in the point of safe & economic aspects. On comparing the above stated experimental & analytical results the variation is around 25-30 % which is due to the boundary condition preference in site and applied format in Experimental testing series. The further study can be made using I, Z, Sigma sections instead of C section to know the exact behavior of formed profile dimensions as discussed. The castellated beam is solving the purpose of industrial needs such as service pipe lines, ducts lines, cable trays, electrical cables etc. and also in terms of structural the increase in sectional properties without increase in section weight contributes a lot in savings. The choice of web alignment is preferably parallel arrangement which is concluded from the experimental results.

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References

Kaustabh V. Raut, Samadhan G. Morkhade, Rushikesh R. Khartode, Dhiraj D. Ahiwale, Experimental study on flexural behaviour of light steel hollow flange beam with various stiffening arrangements, Innovative Infrastructure Solutions, 5:90, 2020, pp.01-07.https://doi.org/10.1007/s41062-020-00345-4.

Amir Hossein Gandomi, Seyed Morteza Tabatabaei, Mohammad Hossein Moradian, Ata Radfar, Amir Hossein Alavi, A new prediction model for the load capacity of castellated steel beams, Journal of Constructional Steel Research, 67, 2011, pp.1096–1105.https://doi:10.1016/j.jcsr.2011.01.014.

Ieva Misiunaite, Arvydas Rimkus, Ronaldas Jakuboskis, Aleksandr Sokolov, Viktor Gribniak, Analysis of local deformation effects in cold-formed tubular profiles subjected to bending, Journal of Constructional Steel Research, 160, 2019, pp.598–612.https://doi.org/10.1016/j.jcsr.2019.06.006.

Mario D'Aniello, Esra Mete Guneyisi, Raffaele Landolfo, Kasım Mermerdas, Analytical prediction of available rotation capacity of cold-formed rectangular and square hollow section beams, Thin-Walled Structures, 77, 2014, pp.141–152.http://dx.doi.org/10.1016/j.tws.2013.09.015.

Ehab Ellobody, Interaction of buckling modes in castellated steel beams, Journal of Constructional Steel Research, 67, 2011, pp.814–825.http://doi:10.1016/j.jcsr.2010.12.012.

Fatmir Menkulasi, Cristopher D. Moen, Matthew R. Eatherton, Dinesha Kuruppuarachchi, Investigation of Stiffener Requirements in Castellated Beams, Proceedings of the Annual Stability Conference, Structural Stability Research Council, Nashville, Tennessee, March 24-27, 2015, pp.01-18.

M.R. Soltani, A. Bouchair, M. Mimoune, Nonlinear FE analysis of the ultimate behaviour of steel castellated beams, Journal of Constructional Steel Research, 70, 2012, pp.101–114.http://10.1016/j.jcsr.2011.10.016.

Delphine Sonck, Rudy Van Impe, Jan Belis, Experimental investigation of residual stresses in steel cellular and castellated members Construction and Building Materials, 54, 2014, pp.512–519.http://dx.doi.org/10.1016/j.conbuildmat.2013.12.045.

Arizu Sulaiman, Noraini Mohd Salleh, Nuraziyati Sukardi, Tan Cher Siang, Anis Saggaff, Experimental Evaluation of Composite Beam-to-Column Joint Using Cold Formed Steel Sections, IOP Conf. Series: Materials Science and Engineering, Sriwijaya international Conference on Science, Engineering, and Technology, 620, 2019, pp.01-13.http://10.1088/1757-899X/620/1/012055.

Jin Ying Ling, Shin Lin Kong, Fatimah De'nan, Numerical study of buckling behaviour of cold-formed C-channel steel purlin with perforation, The Fifth International Conference of Euro Asia Civil Engineering Forum (EACEF-5), Procedia Engineering, 125, 2015, pp.1135–1141.

Rujuta A. Bhat, Laxmikant M. Gupta, Behaviour of hybrid steel beams with closely spaced web openings, Asian Journal of Civil Engineering, 2020, pp.01-08.https://doi.org/10.1007/s42107-020-00300-9.

Ehab Ellobody, A consistent nonlinear approach for analysing steel, cold-formed steel, stainless steel and composite columns at ambient and fire conditions, Thin-Walled Structures, 68, 2013, pp.01–17.http://dx.doi.org/10.1016/j.tws.2013.02.016.

Ali Nadjai, Olivier Vassart, Faris Ali, Didier Talamona, Ahmed Allam, Mike Hawes, Performance of cellular composite floor beams at elevated temperatures, Fire Safety Journal, 42, 2007, pp.489–497. http://10.1016/j.firesaf.2007.05.001.

S. Santosa, J. Banhart, T. Wierzbicki, Experimental and numerical analyses of bending of foam-filled sections, Acta Mechanica, 148, 2001, pp.199-213.

Ehab Ellobody, Ben Young, Nonlinear analysis of composite castellated beams with profiled steel sheeting exposed to different fire conditions, Journal of Constructional Steel Research, 113, 2015, pp.247–260.