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STUDY ON STRUCTURAL PERFORMANCE OF COLD FORMED STEEL BEAM MOMENT RESISTING CONNECTION

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Abstract - *Typical cold formed steel (CFS) moment resisting connection generally have relatively low local/distortional buckling resistance because of thin walled cold formed steel element and therefore may not be suitable for low to mid-rise construction. To address this issue a comprehensive numerical study is conducted on structural performance of bolted joints in cold formed steel beams moment resisting connection. The aim is to achieve higher moment carrying capacity and load carrying capacity through an appropriately designed bolted connection, postponing the initiation of local buckling in cold formed steel beams. The beam column connection consist of two back to back hot rolled channel column section and two back to back cold formed channel beam section. The proposed beam-column connection includes through plate which potentially limit the out of plane action of the forces transferred through the connection. By means of Finite Element Analysis (FEA), monotonic performance of cold formed steel bolted connection comprising with five types of beam sections are studied. The performance of cold formed steel beam with different types of flange sections are examined and compared with that of conventional shapes. The behaviour of both bolted cold formed beam-column connection and welded cold formed beam-column connections were studied and compared. The effect of various stiffener types with different beam depth and different through plate thickness were studied in detail. The result of the analysis showed that bolted beam column connections posses higher load carrying capacity than welded beam-column connection. The use of out of plane stiffeners inside the cold formed beam web portion results in improvement of moment-rotation behavior of the connection.*

***Key Words*: Cold Formed Steel, Finite Element Analysis, Finite Element, Beam-Column connection, Moment resisting frames.**

1. INTRODUCTION

Steel as a structural material has become the perfect option in the construction sector due to its innumerable advantages over other building materials, where the superior sustainable performance of steel members minimize the environmental impacts when measured through the entire life cycle. Moreover, steel is a basic material for construction in the evolution chain, where it is considered as a critical building material for the nation's energy, transportation and infrastructure and also for commercial and residential construction. In steel structures, mainly there are two types of steel that used to make structural members, sections and plates: hot- rolled steel (HRS) and cold-formed steel (CFS). Cold formed steel sections are produced by rolling or pressing of thin-walled steel sheets to form open cross sectional shapes at ambient temperature (cold working). It is a lightweight material available in different thickness ranging from 0.35 mm to 6.35 mm. They are widely used as secondary members, such as purlins in roofs, joists of medium span in floors, studs in wall panels, storage racking in warehouses, and hoarding structures in construction sites. Cold-formed steel members are either cold rolled or brake pressed into structural shapes. As a result, cold-formed steel sections are usually formed in singly, point, or non symmetric open shapes. The advantage of CFS lies in its ease of fabrication to any required structural shapes and can be used for a wide range of structural components such as individual structural framing members, panels and decks. Cold-formed steel framing has been primarily used in a wide range of construction applications including non-structural components, curtain walls, and gravity load-bearing structures. The ultimate tensile strength of the CFS sections ranges from 290 to 690 N/mm^2. Lipped C and Z sections are considered to be the most common sections with thickness varying from 0.9mm to 3.2mm. They usually used as flexural members in cold-formed design. The CFS members also called as "light gauge steel members".

1.1 Beam-Column connection

In this study a web bolted moment resistant type of connection is used for CFS beam-column connections. The components of the beam column connections under study are hot rolled steel C sections are used for columns and cold formed steel C sections are used as beams. Here the columns and beams are connected by means of through plates. The through plates are the main components of the connection, transferring the forces to both near and far sides of the column by in-plane action. It was shown by FE analysis that sets of out-of-plane stiffeners are needed to further improve the strength of the beam–column assembly. Curved flange beam sections were developed by introducing more bends in the flanges, a step by- step process that ultimately led to significant increase in moment resistance, stiffness and ductility, compared with flat flange beams.

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2. OBJECTIVES OF THE WORK

- To investigate the strength of CFS bolted moment resisting connections using various flange sections such as flat, stiffened, folded, lipped and curved flange sections.
- To study the behavior of welded beam column connection.
- To investigate the strength of bolted beam column connection with different through plate thickness.
- To investigate the strength of bolted beam column connection with different cold formed beam depth.

3. STUDY ON BOLTED BEAM-COLUMN CONNECTION

A total of five different flange sections were considered for the analysis. Here also hot rolled steel back to back channel sections were used for columns and cold formed steel back to back channel sections were used for beams. The geometrical specification of cold formed beam and hot rolled column are shown in Table-1. A through plate of size 720mm × 550mm was selected. Bolts of 18 mm diameter were selected for column to through plate interface and bolts of 20 mm diameter were selected for beam to through plate connection.

A non linear static analysis was done in ANSYS workbench 16.1 software for beam column connection. The hot rolled steel, cold formed beam, through plate and bolts are modeled by using SOLID 186 and the meshes used are triangular and rectangular mesh. The geometrical models of different flange sections and boundary conditions are shown in Fig 1, Fig 2, Fig 3, Fig 4, Fig 5 and Fig 6.

Table -1: Geometrical specification of model

Channel sections	Thickness of flange t_f (mm)	Thickness of Web, t_w (mm)	Width of flange (mm)	Height (mm)
Beam	3	3	100	200
Column	16	10	100	300

The bottom surface of the column was restrained against all degrees of freedom. The top of the column was free and a remote displacement was applied at the end of the beam. Here a pretension force Tm = 67 kN for the beam to through plate bolts (B–T) and Tm = 53 kN for the through plate to column (T–C) bolt connections is applied.

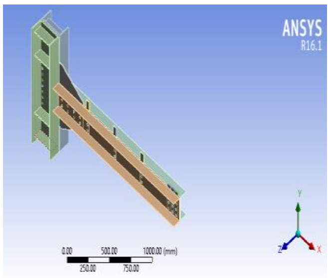


Fig-1 Flat flange section

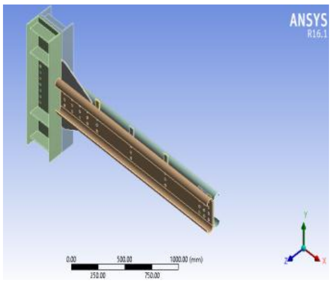


Fig-2 Curved flange section

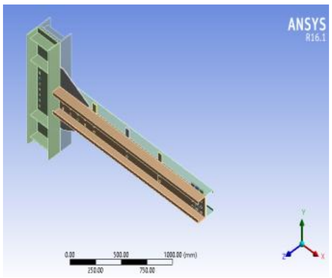


Fig-3 Lipped flange section

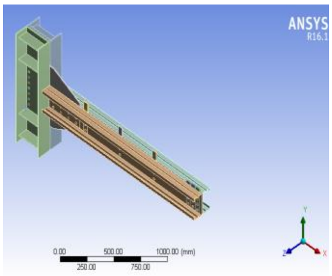


Fig-4 Stiffened flange section

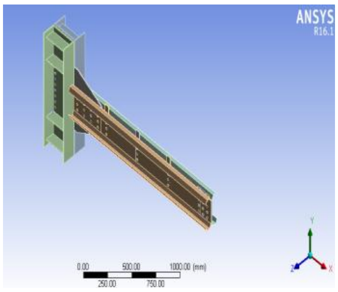


Fig -5 Folded flange section

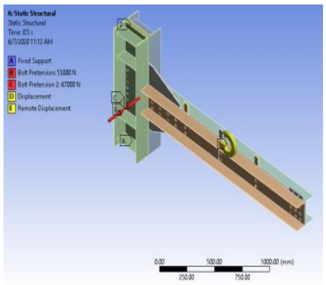


Fig-6 Boundary conditions

The models were used to analyse the monotonic loading behaviour by studying the equivalent stress distribution, deformation, load and moment carrying capacity. Combined graph of the moment v/s rotation of different flange sections in bolted beam column connection is showed in chart-1.

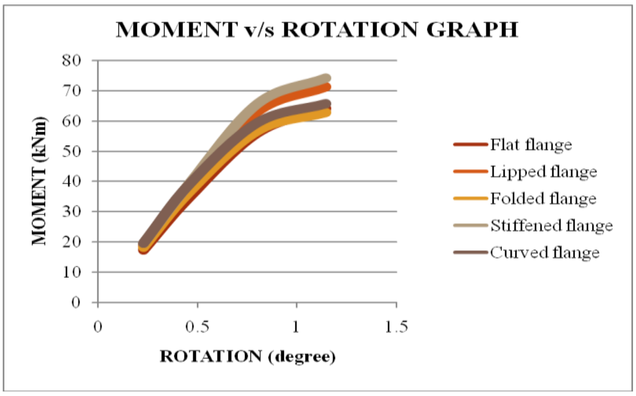


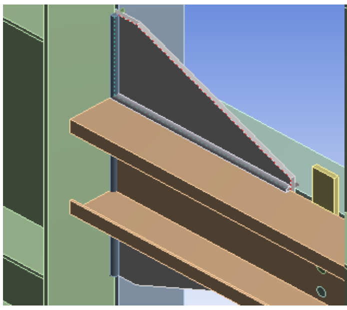
Chart-1 Moment v/s rotation graph of bolted connection

Here the stiffened flange section shows higher moment carrying capacity than other any other type of flange section.

Stiffened flange showed an increase of 15.95% in moment carrying capacity when compared with flat flange section. Whereas other flange sections such as lipped and curved shows an increase of 11.13% and 2.64% respectively. Folded flange shows 2.13% decrease in moment carrying capacity than flat flange section. From the study it was found that beam column connection made by stiffened cold formed beam sections showed higher load carrying capacity than any other flange sections. When considering the flat flange section as the base model, stiffened flange section showed an increase of 15.56% in load carrying capacity. Whereas lipped, curved and folded flange section showed an increase of 10.81%, 7.92% and 1.5% respectively.

4. STUDY ON WELDED BEAM-COLUMN CONNECTION

According to IS 800:2007 weld size and weld length are designed. A weld size of 8mm is adopted and a weld length of total 1800 mm is provided at beam to through plate interface. A non linear static analysis was done in ANSYS workbench 16.1 software for welded beam column connection. The hot rolled steel, cold formed beam, through plate and welds are modeled by using SOLID 186. Fig 7 and Fig 8 shows the closer view of convex and concave weld in lipped flange section.



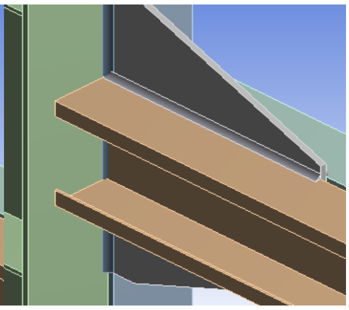
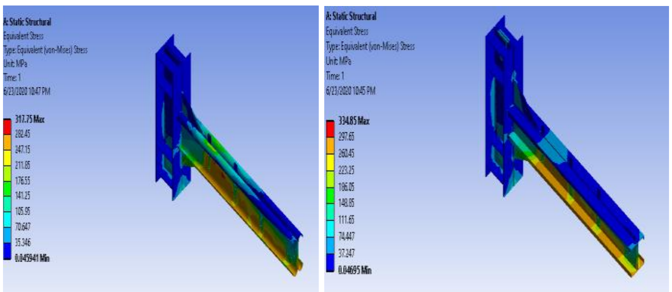
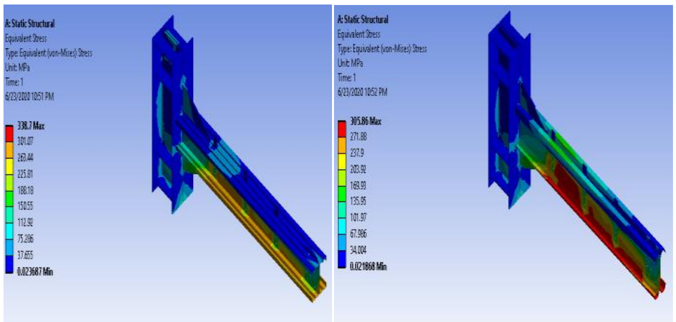


Fig-7 Convex welded **Fig-8** Concave welded

In case of Equivalent stress or Von Mises stress, the stress distribution was observed minimum in column portion and top of the beam flange portion, occurred maximum at middle of the cold formed beam web portion.



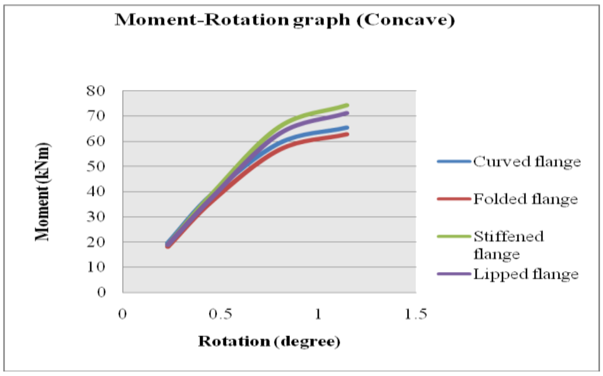
(a) Curved (b) Lipped



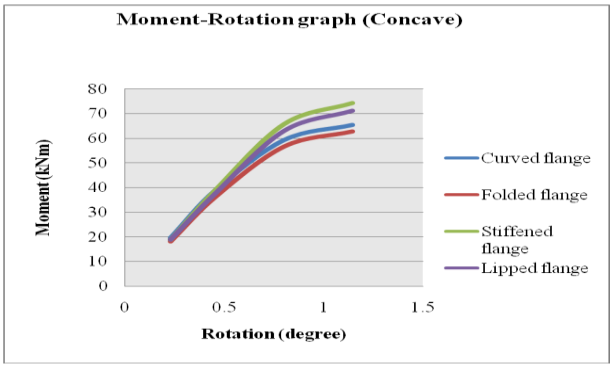
(c) Stiffened (d) Folded

Fig-9 Equivalent stress distribution

The equivalent stress distribution of convex welded connection for the model with flat, curved, lipped, stiffened and folded flange cold formed beam sections are shown in Fig 9 (a), (b), (c) and (d) respectively. The combined graph of the moment v/s rotation of different flange sections in convex and concave beam column connection is showed in Chart-2.



(a)Convex



(b) Concave

Chart-2 Moment v/s rotation graph of welded connection

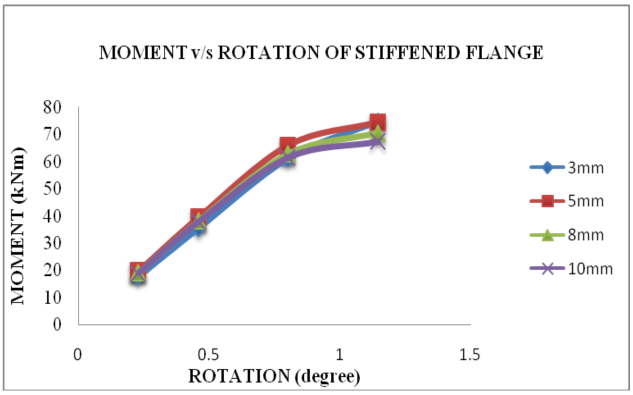
In convex welded beam-column connection stiffened beam flange sections shows higher moment carrying capacity than any other type of beam flange sections. 18.47% increase in moment carrying capacity is shown by stiffened flange when compared to folded flange section. And lower moment carrying capacity is obtained for folded beam flange section. Stiffened flange beam section showed 13.84% increase in load carrying capacity when convex weld beam column connection is provided. Whereas lipped and curved flange section showed an increase of 9.02% and 6.51% respectively.

In concave welded beam-column connection also stiffened beam flange sections shows higher moment carrying capacity than any other type of beam flange sections. 18.55% increase in moment carrying capacity is shown by stiffened flange when compared to folded flange section. And lower moment carrying capacity is obtained for folded beam flange section. Stiffened flange beam section showed 13.80% increase in load carrying capacity when convex welded beam-column connection is provided. Whereas lipped and curved flange section showed an increase of 9.09% and 6.19% respectively. In comparison with convex welded beam-column connection, equivalent stress value is low for concave welded beam column connection.

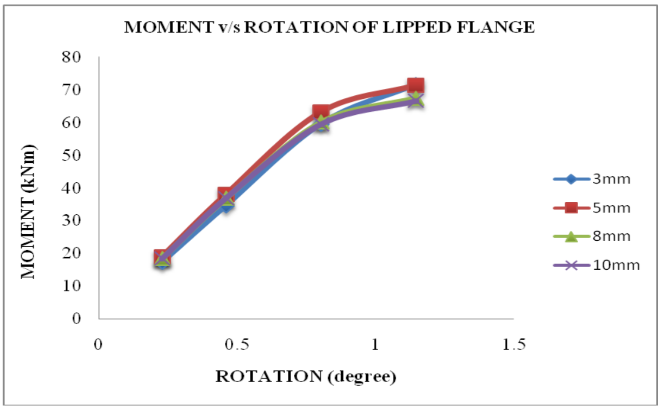
5. STUDY ON THICKNESS OF THROUGH PLATE IN BOLTED CONNECTION

Four different through plate thickness such as 3mm, 5mm, 8mm and 10mm were considered for the analysis of bolted beam-column connection. The through plates are the main components of the connection, transferring the forces to both near and far sides of the column by in-plane action and also it potentially limit the out of plane action of the forces transferred through the connection. From the above studies it is understood that stiffened and lipped flange beam sections shows higher load carrying capacity, so the through plate thickness study is analysed in stiffened and lipped cold formed beam section. Models were used to analyse the monotonic loading behaviour by studying the equivalent stress distribution, load carrying capacity and moment carrying capacity in bolted beam column connection.

Moment rotation graph of stiffened and lipped flange with four different thickness of through plate is shown in Chart-3.



(a) Stiffened Flange



(a) Lipped Flange

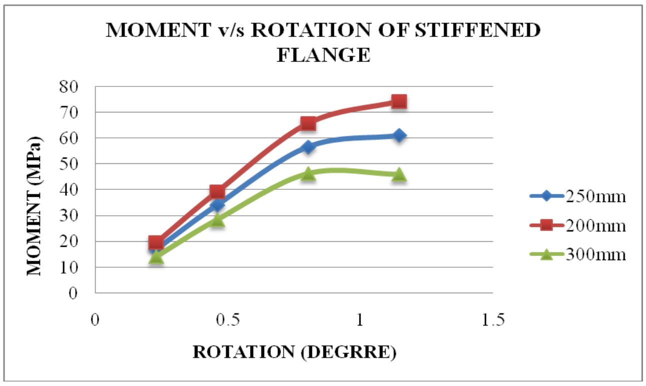
Chart-3 Moment v/s rotation graph with different through plate thickness

Here the moment carrying capacity of stiffened and lipped beam flange decreases with increase in thickness of through pate from 3mm to 10mm. There was an increase of 10.52% in moment carrying capacity of stiffened flange when 3mm thickness through plate is used and there was an increase of 7.49% in moment carrying capacity of lipped flange when 3mm thickness through plate is used. Also load carrying capacity decreases with increase in thickness of through plate. Since back to back channel sections are used, while increasing the thickness of through plate there may chance for creating a gap between back to back channel sections, which may lead to reduce the load carrying capacity of the beam.

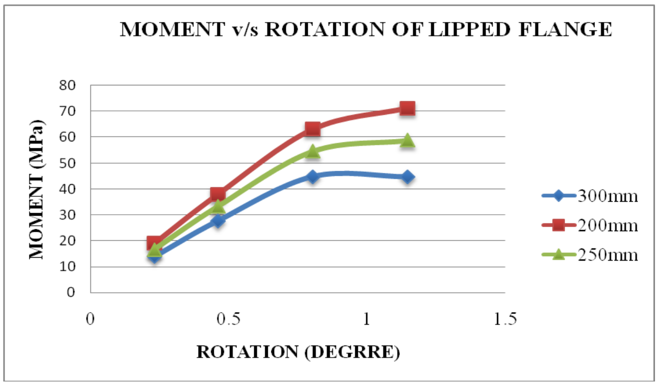
6. STUDY ON INFLUENCE OF DEPTH OF COLD FORMED BEAM IN BOLTED CONNECTION

Beam depth is the main parameter effecting the local bucking characteristics and load carrying capacity of the cold formed beam. This studies aims to improve the performance of cold formed beam by optimising the beam depth in order to control local/ distortional buckling. Three different cold formed beam depths such as 200mm, 250mm and 300mm were considered for the analysis of bolted beam-column connection. Thickness of the cold formed beam is 5mm for three types of beam depth.

The stiffened and lipped flange sections are analyzed with different cold formed beam depth and models were used to analyse the monotonic loading behaviour by studying the equivalent stress distribution, load carrying capacity and moment carrying capacity in bolted beam column connection. Moment rotation graph of stiffened and lipped flange with three different cold formed beam depths is shown in Chart-4.



(a) Stiffened Flange



(a) Lipped Flange

Chart-4 Moment v/s rotation graph with different cold formed beam depth

It was found that the load and moment carrying capacity of the beam decreases with increase in slenderness ratio of the beam. Since cold formed beam thickness are very small when compared with hot rolled steel, while increasing the depth of beam there may chance for the occurrence of local bucking. Bolted beam column connection with stiffened flange beam section showed 31.11% increase in load carrying capacity and that for a lipped flange section an increase of 29.83% is obtained. In case of moment carrying capacity bolted beam column connection with stiffened flange showed an increase of 61.521% and lipped flange showed an increase of 59.416%.

7. CONCLUSIONS

The study was carried out to analyse the structural behaviour of bolted and welded beam-column connection under different type of flange sections. Based on the result from the finite element analysis conducted on the beam column connection, the following conclusions were drawn:

The bolted beam column connection with stiffened beam flange sections shown higher moment carrying capacity than that of flat, curved, folded and lipped flange sections. 15.95% increase in moment carrying capacity is shown by stiffened flange and 13.5% increase in moment carrying capacity is shown by lipped flange when compared to flat flange section. Also when again compared to flat flange section stiffened flange showed an increase of 15.56% and lipped flange showed an increase of 10.6% in load carrying capacity. It was found that while providing bolted beam column connection there is a considerable reduction in local buckling failures.

In welded beam column connection, when stiffened flange sections are considered, convex weld showed an increase of 13.84% and than that of concave weld which shown an increase of 13.8% in load carrying capacity. In lipped flange section convex weld shown an increase of 9.07% and than that of concave weld shown an increase of 9.09% in load carrying capacity. Increase in moment carrying capacity of stiffened flange with convex and concave weld are 18.4% and 18.5% respectively and than that of lipped flange shown an increase of 14.8% and 13.4% respectively. Compared to concave and convex weld connection, it is better to prefer concave weld connection because severe stress concentration was observed in convex weld.

In comparison with bolted and welded beam column connection, bolted beam column connection showed better performance in case of stress distribution and moment carrying capacity. In bolted beam column connection it was found that while increasing the thickness of through plate there is considerable reduction occurred in the moment carrying capacity of the beam column joint. Reduction in load carrying capacity is occurred because while increasing the thickness of through plate there may chance for presence of gap between back to back channel sections which may lead to destruction in load transference from beam to connection. When taking different cold formed beam depth, slender beam showed higher load carrying capacity and good buckling resistance. Here stiffened flange section shown 61.5 % increase moment carrying capacity and than that of lipped flange section shown an increase of 59.39% in ultimate moment capacity.

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