Behaviour of Cold-Formed Steel Moment Connections under Cyclic Loading

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***Abstract*— Building structures from cold-formed steel (CFS) members are now widely popular due to their economy and efficiency in using light weight structural members. This form of construction is now known as the industrialized building system (IBS) and it has become a common mode of construction for low- to medium-rise structures and residential houses. This is because the cold formed steel possesses high strength to weight ratio. Scope of this paper is to investigate the effect of seismic load on moment caring capacity of cold formed moment connections with varying gusset plate thickness. The connection consists two back to back CFS channel beam sections. In this project, three numbers of connections were analysed by varying the gusset plate thickness and beam sections using ANSYS 19.0. It also compares the ductility of CFS flat flanged beam connections. The results of the analysis showed that connection with plate thickness of 6mm possess higher moment carrying capacity and ductility as compared to other connections.**

Keywords*— *Cold-formed steel, finite element analysis, moment resisting connections, bolted connection connections.

I. INTRODUCTION

Cold-shaped steel (CFS) parts are formed at room temperature by rolling or pressing thin-walled steel sheets into open cross sectional shapes (cold working). In general, due to inherent advantages such as a high strength-to-weight ratio, flexibility and ease of construction, and particularly greater versatility in manufacturing various cross sectional profiles and sizes, CFS elements can be more economical and effective than hot-rolled counterparts (1-3). It's a thin material with thicknesses ranging from 0.35 to 6.35 mm having yield strength of 230 to 420 Mpa.

According to the studies (2,3), using suitable connection information for CFS beam-column connections, such as gusset plates, CFS double back-to-back channel sections can achieve relatively high moment resistance. However, after reaching the peak bending moment, no ductile capacity was achieved in this form of beam to column connection.

Conventional double back to back channel beam sections incorporated inside topping concrete were shown to have a degree of ductile ability in dissipating seismic energy by achieving rotations greater than 0.04 rad in a recent study by the authors (4), meeting the criteria for special moment frames (7). CFS members have also been used as primary structural components in low- to mid-rise multi-story buildings (7), as well as CFS portal frames with bolted-moment connections (8,9). Bolted moment connections made of CFS sections have shown to have good strength and stiffness, as well as sufficient deformation capability for seismic applications, in both experimental and numerical studies (9,10).

This paper aims to develop efficient design configurations for moment resisting CFS bolted beam-to-column connections to improve their moment carrying capacity and ductility and therefore facilitate their practical application in earthquake resistant frames. Detailed nonlinear FE models are developed by taking into account, gusset plate thickness and beam sections which are known to affect the moment carrying capacity of the connection.

II. BEAM-COLUMN CONNECTION

The CFS beam-column connections in this study are made with a web bolted moment resistant connection. Hot rolled steel C sections are used for columns, and cold formed steel C sections are used as beams, in the beam column connections under the study. Here the beam and column are connected by means of gusset plate. The gusset plate is the main component of the connection; it was shown by FE analysis that the increasing the plate thickness the moment carrying capacity also increasing.

III. OBJECTIVES OF THE WORK

- To study the seismic effect on moment caring capacity of cold formed moment connections with varying gusset plate thickness.
- To compare the ductility of connections with varying gusset plate thickness.

IV. STUDY ON BEAM-COLUMN CONNECTION

A total of two different flange sections and three different plate thicknesses 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 nonlinear static analysis was done in ANSYS workbench 19.0. software for moment connection. The hot rolled steel, cold formed beam, through plate and bolts are modeled by using SOLID 186 and the meshes used are hexahedron mesh. The geometrical models of different flange sections are shown in Fig 3 and Fig 4 and Fig 1 shows the beam sections.

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	4	4	100	200
column	16	10	100	300

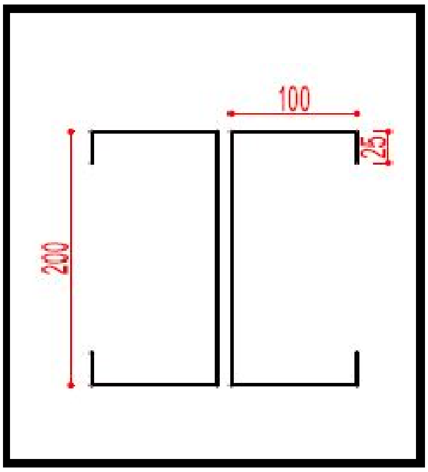


Fig. 1. Flat flanged beam

A. *Geometry, boundary conditions and element types*

The hot rolled steel, cold formed beam, through plate and bolts are modeled by using SOLID 186 and the meshes used are hexahedron mesh. the mesh size 10 mm is selected to balance accuracy and computational efficiency. The translational degrees of freedom UX and UY at the top of the back-to-back channel column are restrained, while the bottom of the column is considered to be pinned.

B. *Loading protocol*

Cyclic loading was applied through a hinge connection at the end of the beam using a loading protocol (Fig. 2) given in section S6.2 of AISC Seismic Provisions [13] for qualifying beam-column moment connections in special and intermediate moment frames. The center of the plastic hinge region, used for calculating the bending moment, M, and the rotation, h of the beams, is assumed to be at the end of the gusset plate (Fig. 4).

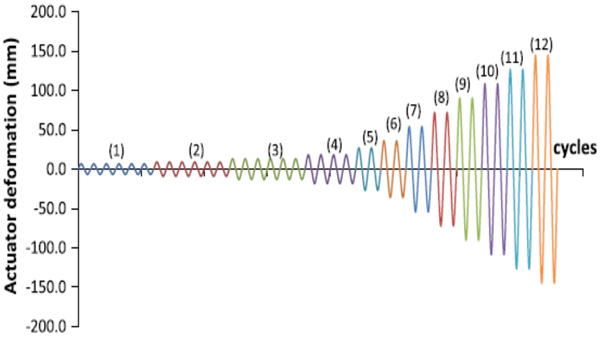


Fig. 2. Loading cycles

V. FINITE ELEMENT ANALYSIS OF THE CONNECTION

A. *Modeling of connection*

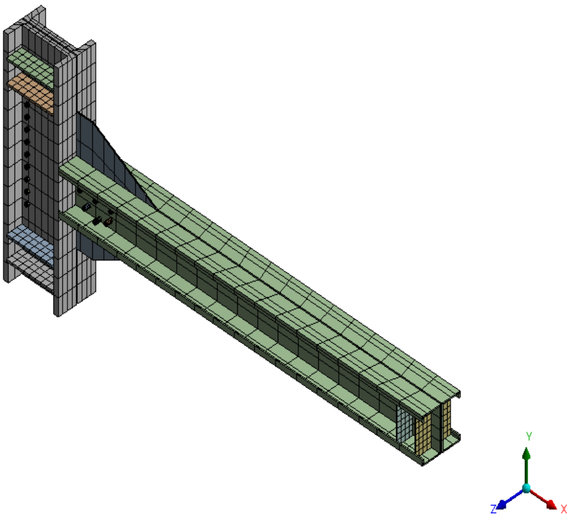


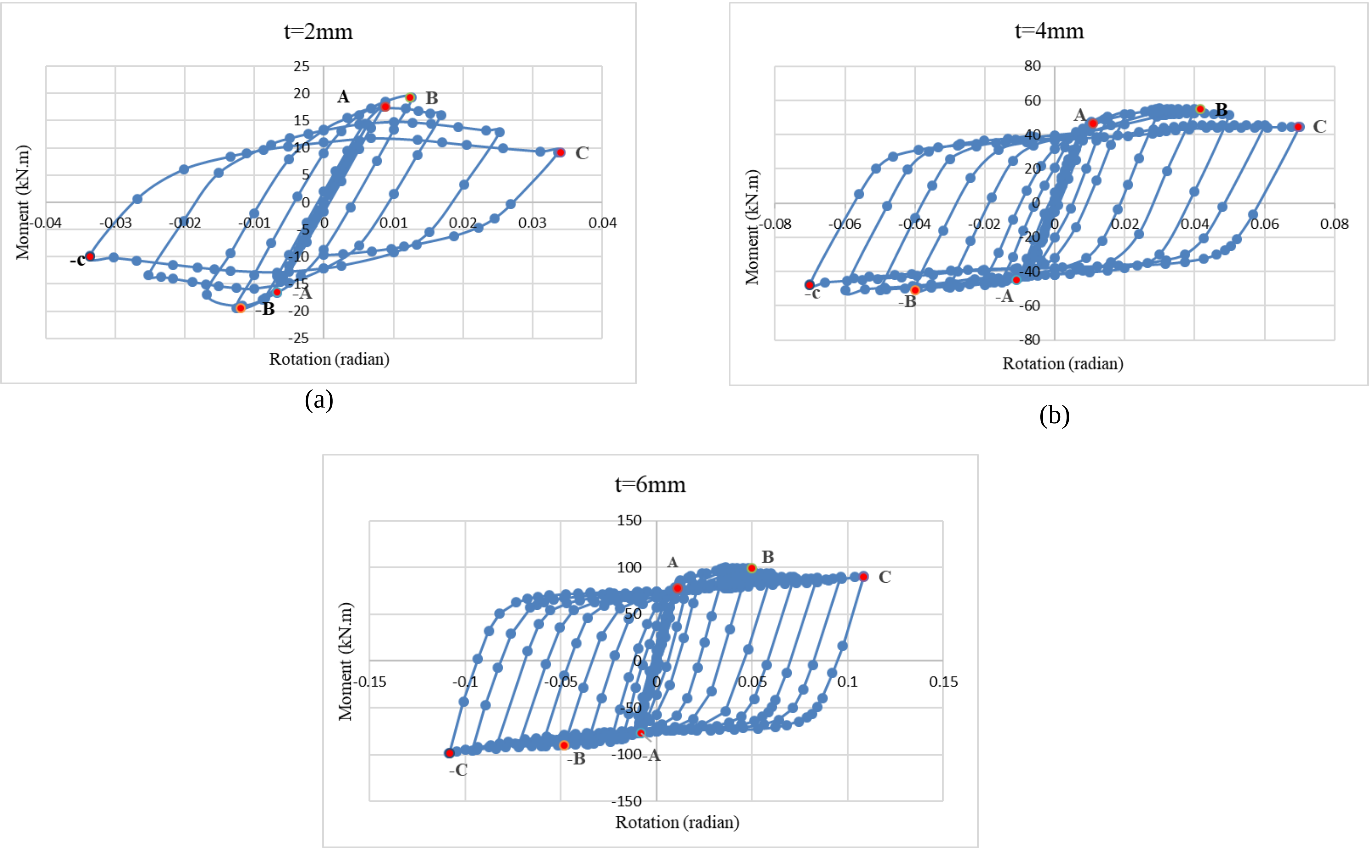
Fig.3. Flat flanged beam column connection

The models were used to analyse the cyclic loading behaviour by studying the moment carrying capacity and ductility of the connection.

B. *Results and Discussions*

1) *Moment capacity of the connections*

- Fig.4 compares the moment capacity of the CFS connections with different cross-sections, plate thicknesses.
- Fig.5 shows the envelop curve of the connections and it gives the moment and rotation values as shown in table 2.
- Also the table 2 shows the moment rotation relationship and ductility of the connection.



(a)

(b)

(c)

Fig. 4. Cyclic moment-rotation relationship curves of the connections with flat flange beam section

TABLE 2. CHARACTERISTIC PARAMETERS OF THE CFS FLAT FLANGED CONNECTIONS USING FEMA MODELS.

Plate thickness ***t (mm)***	***Yield moment*** ***My1 (kN.m)***	***Maximum moment*** ***My2 (kN.m)***	***Yield rotation*** ***θy (rad)***	***Ultimate rotation*** ***θu (rad)***	***Ductility*** ***μ***
6	88.2	100.1	0.014	0.11	7.85
4	44.67	59.8	0.013	0.065	5
2	18.96	19.9	0.0095	0.036	3.78

2) Ductility ratio of the connections

In seismic resisting systems, moment resisting connections should have enough ductility to withstand and redistribute seismic loads**.** fundamental definition of ductility ratio (μ) is the ratio of the ultimate rotation (θu) to the yield rotation (y), as follows:

$$\mu = \theta u \, / \theta y \; > 1$$

The ductility ratio of the CFS connections in this study is calculated based on the results of the FEA models.it shows that the plate thickness influences the ductility of the connection, with increase in plate thickness the ductility increasing. The 6mm plate connection shows higher ductility as compared to other connections.

3) Effect of thickness of gusset plate

Three different through plate thickness such as 2mm, 4mm and 6mm were considered for the analysis of bolted beam-column connection. From the studies it is understood that the connection with 6mm plate shows higher moment carrying capacity. Models were used to analyse the seismic loading behavior by studying the ductility and moment carrying capacity in bolted beam column connection.

From the table 2 shows that the moment carrying capacity of flat flange beam connection increases with increase in thickness of gusset pate and the beam connection with plate thickness 6mm shows the highest moment carrying capacity.

Moment rotation graph of flat flange with three different thickness of gusset plate is shown in Fig.4. Here the moment carrying capacity of flat flange beam connection increases with increase in thickness of through pate from 2mm to 6mm.

Fig.5. Envelop curve of connection with varying thickness

A, B, C are the yield moment, maximum moment and ultimate rotation of the connection respectively

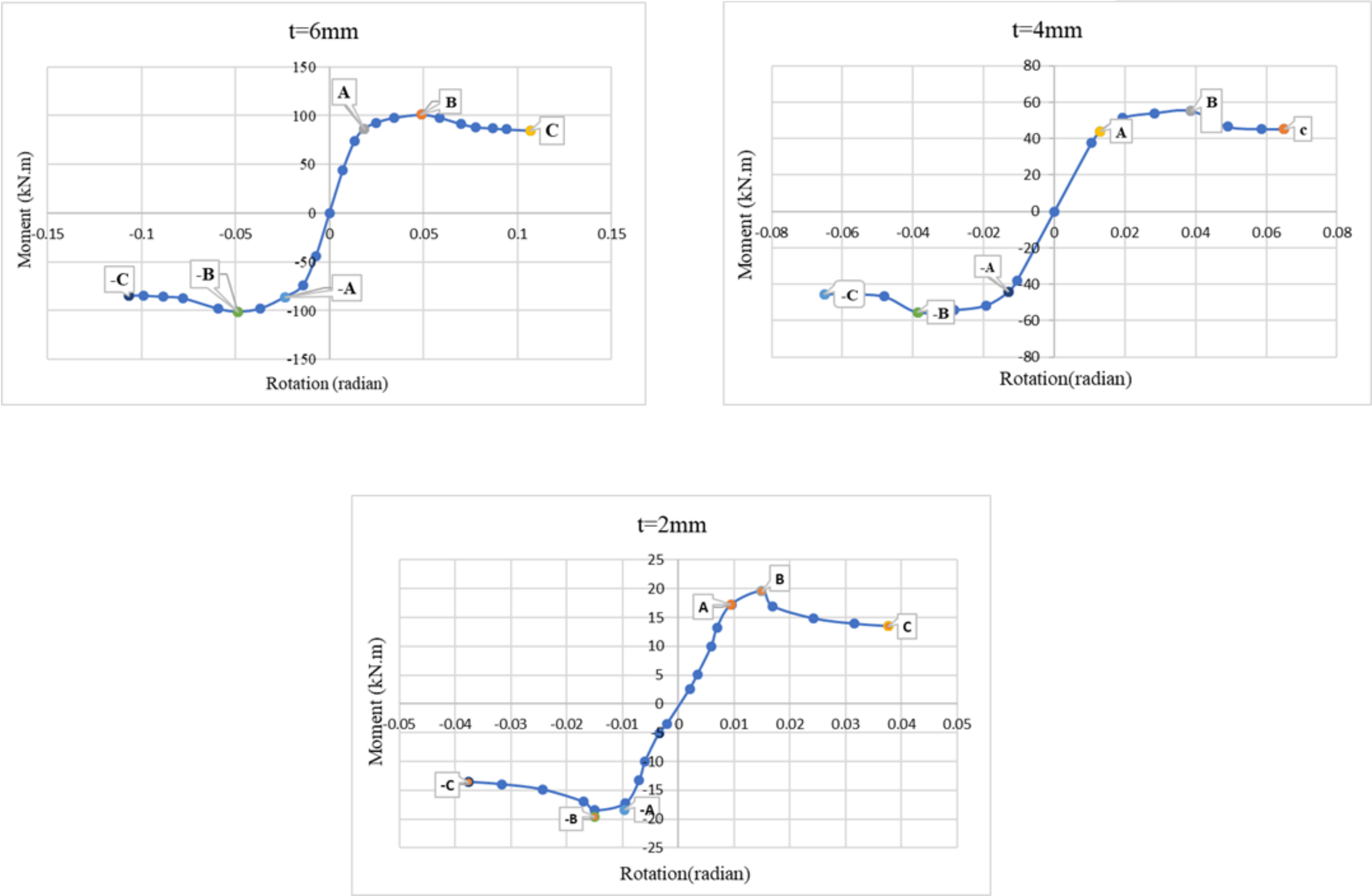


Fig.5. Envelop curve of connection with varying thickness

A, B, C are the yield moment, maximum moment and ultimate rotation of the connection respectively

CONCLUSIONS

The study was carried out to analyse the seismic behavior of bolted moment connection under flange section with varying gusset plate thickness. Based on the result from the finite element analysis conducted on the moment connection, the following conclusions were drawn:

The thickness of the gusset plate influences the connection performance, where the higher the thickness of the gusset plate, the higher is the moment resistance of the connection. AISC stipulates that the bolted-moment connections should be able to undergo at least 0.04 rad rotation with less than 20% drop from their ultimate moment (Mu). The members of thickness 4 mm and 6 mm satisfied the seismic requirements of the AISC for seismic moment frames (SMF). but in case of 2mm plate it don't satisfy the requirement of AISC, so that it is not acceptable in seismic regions. In case of 6mm plate connection, it performs higher ductility as compared to other two connections and it shows the ductility value increases with increase in plate thickness.

REFERENCES

[1] L. Fiorino, O. Iuorio, R. Landolfo, "Designing CFS structures: the new school bfs in naples", Thin Wall Struct. 78 (2014) 37–47.

[2] H. Moghimi, H.R. Ronagh, "Performance of light-gauge cold-formed steel strapbraced stud walls subjected to cyclic loading", Eng. Struct. 31 (2009) 69–83.

[3] S.-H. Lin, C.-L. Pan, W.-T. Hsu, "Monotonic and cyclic loading tests for cold-formed steel wall frames sheathed with calcium silicate board", Thin-Walled Struct. 74 (2014) 49–58.

[4] M. Zeynalian, H.R. Ronagh, S. Hatami, "Seismic characteristics of K-braced coldformed steel shear walls", J. Constr. Steel Res. 77 (2012) 23–31.

[5] Z. Xu, Z. Chen, B.H. Osman, S. Yang," Seismic performance of high-strength lightweight foamed concrete-filled cold-formed steel shear walls", J. Constr. Steel Res. 143 (2018) 148–161.

[6] L. Fiorino, M.T. Terracciano, R. Landolfo, "Experimental investigation of seismic behaviour of low dissipative CFS strap-braced stud walls", J. Constr. Steel Res. 127 (2016) 92–107.

[7] L. Fiorino, O. Iuorio, R. Landolfo, "Designing CFS structures: the new school bfs in naple"s, Thin Wall Struct. 78 (2014) 37–47.

[8] J.B.P. Lim, D.A. Nethercot, "Finite element idealization of a cold-formed steel portal frame", J. Struct. Eng. 130 (2004) 78–94.

[9] J.B.P. Lim, D.A. Nethercot," Ultimate strength of bolted moment-connections between cold-formed steel members", Thin Wall Struct. 41 (2003) 1019–1039.

[10] J.B. Lim, G.J. Hancock, G.C. Clifton, C.H. Pham, R. Das,"DSM for ultimate strength of bolted moment-connections between cold-formed steel channel members", J. Constr. Steel Res. 117 (2016) 196–203.

[11] A. Bagheri Sabbagh, M. Petkovski, K. Pilakoutas, R. Mirghaderi, "Experimental work on cold-formed steel elements for earthquake resilient moment frame buildings", Eng. Struct. 42 (2012) 371–386.

[12] M.H. Serror, E.M. Hassan, S.A. Mourad, "Experimental study on the rotation capacity of cold-formed steel beams", J. Constr. Steel Res. 121 (2016) 216–228.

[13] ANSI/AISC, 341-16, "Seismic provisions for structural steel buildings, american institute of steel construction" (AISC), 2016.