ANALYSIS OF COLD FORMED STEEL CONNECTIONS USING FEM

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Abstract - *The main aim of the study is to increase the use of cold form steel in steel structure by studying cold form steel connections. Cold formed steel sections are used as secondary structural members, Usually cold form steel is used only in purlins of truss non load bearing walls floor deck system etc. But now day's cold formed structural steel tubular sections are being used in many developing countries like Canada, India, Hong Kong and Australia. These are offering light weight to high strength and width to thickness ratio is very less. In this paper the attempt have been made to study the application of cold form steel beam-column screwed connection using beam column connector by determining its load carrying capacity of various connection configuration .In this project Experimental results are compared with Analytical results .Models in analytical method are analysed through FEM Software ANSYS.*

***Key Words**: Cold Formed steel, Ansys, Finit element analysis, Hypermesh.*

1. INTRODUCTION

The use of steel structure in now a day's construction being very popular as compared to RCC structures because of the fact that they provide high strength, very fast in construction, they are light in weight so easy erection and installation etc.

Based on the manufacturing process structural steel is classified into two types; hot rolled sections and cold formed light gauge steel structures. There are mainly two meth0ds 0f f0rming light gauge steel secti0ns, c0ld r0lling for use in mass production formed at room temperature and pressing in press-brakes use in small quantities also for producing some special shapes. These members are then connected by bolts, rivets, screws, welds or by special fasteners. Cold formed light gauge steels are very thin and thickness varies from 0.75 to 4 mm and having yield strength of 230 to 420 Mpa. The steel is coated with zinc or a mixture of zinc and aluminum to protect it from decay of material. Thickness of this coating depends on environmental condition and marine environments require more protection. Cold formed light gauge members are divided into (i) framing members such as studs, joists, beams etc (ii) long span roof deck, floor and wall panels (iii) wall claddings and standard roof deck. The cold form light gauge steel structure are used as a secondary members such as side rails, roof purlins and wall cladding, and they are connected to the primary members through web cleats.

1.1. Advantages of light gauge steel sections

1. Cold formed sections are light in weight therefore it is easy to handle; also it reduces cost of construction.
2. Steel provides higher strength and stiffness compared to other building material.
3. Like RCC structures it does not require any formwork, hence fast and easy erecti0n and installation
4. Required shapes can be produced, ease of pre-fabrication and mass production.
5. It is easy to remodel this construction at any point in its lifespan.
6. Cold formed light gauge sections can also be used in flooring, wall cladding and roofing.

1.2. Disadvantages of cold formed light gauge steel sections

1. Height of structural system is restricted to 3.6m due to less thickness of sections; modified sections are used for the system having higher height.
2. It will lose its strength in case of fire; adequate fire protection must be used.

2. Objectives

- The major objective our study is to increase the use of cold formed steel in steel structures by studying cold form steel connections.
- Cold formed steel is typically used in purlins of truss, non load bearing wall, partition walls, floor deck system etc.
- Here we have made an effort to study the application of cold form steel in partially restrained beam-column bolted connection by determining its load carrying capacity of various connection configurations.
- Initially the connection is designed as per British code BS 5950-5:1998 (part 5 code of practice for design of cold formed thin gauge sections) based on the semi-rigid criteria.
- The models are fabricated and experimental analysis is carried out. Later FEM analysis is done. Results from both the studies are compared. Depending on these results conclusion is being done.

3. Modeling

3.1. Modeling of connection

The tubular section required for beam and column are formed by connecting two channel sections with the help of self tapping screw. The sections used for testing and connecting members are listed below.
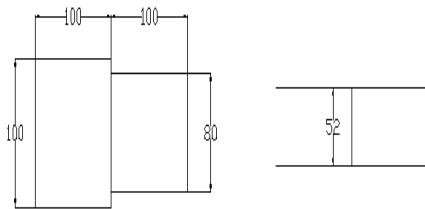
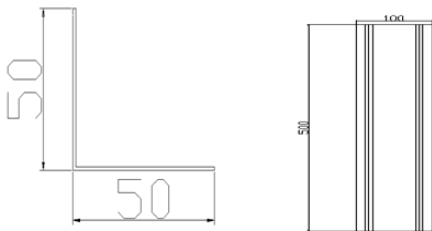

Fig.1: Beam Section

Fig. 2: Beam Column Connector

Fig.3: Sections

The four different types of connections were made by using above sections, the beam column connector is a special type of connector used to connect beam column and this connector is welded back to back.
Following are the various connection configurations that are studied:

1. Connection with single row of screws using beam column connector at the junction (C1)

In this type of connection beam and column are connected using 4 numbers of screws using beam column connector at the junction

2. Connection with double row of screws using beam column connector at the junction (C2)

In this type of connection beam and column are connected using 8 numbers of screws using beam column connector at the junction

3. Connection by angle plate along with beam column connector at the junction using single row of screws (C3)

In this type of connection beam and column are connected by angle plate along with beam column connector at the junction using 4 numbers of screws.

4. Connection by angle plate along with beam column connector at the junction using double row of screws (C4)

In this type of connection beam and column are connected by angle plate along with beam column connector at the junction using 8 numbers of screws.

3.2 FINITE ELEMENT ANALYSIS OF THE CONNECTION

The four different types of connection are first modeled using CATIA software. These models are imported to Hypermesh as it is a high performance meshing software, here meshing of the models are done using 2D quadrilateral element. After meshing these models are exported in 'cdb' format to ANSYS for analysis purpose.

Following are the properties of the 2D quadrilateral element used in the meshing.

1. Element type : 2D quadrilateral element
2. Global size of element is 5mm.
3. Minimum length of the element : 20
4. Jacobian : 0.7
5. Warpage : 5
6. Aspect ratio : 5
7. Quadrilateral angles: Minimum angle is 45° and maximum angle is 135°.
8. Skew : 60

Following are the steps involved in FEA analysis by taking connection (C2) as an example

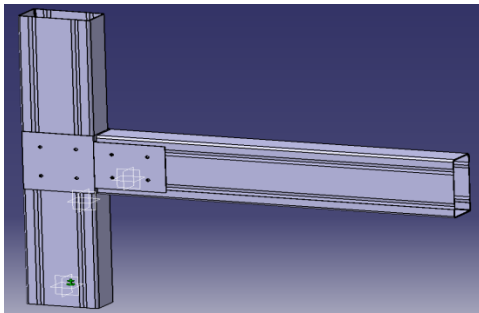1. Models from CATIA are imported to Hypermesh as a plane without any material properties.

Fig – 4: CATIA model

2. The whole connection is separated making part by part like column, beam, beam column connector and angle plate.
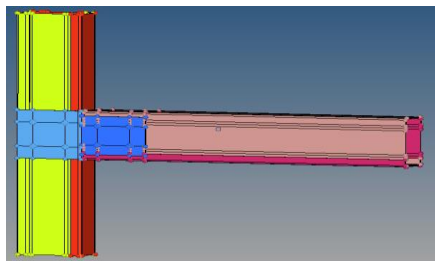

Fig- 5: Separated sections

3. Mid surface is extracted from separated elements. The thickness of section is very small so we meshed the outer part first then by giving offset half the thickness will get meshing for mid surface.
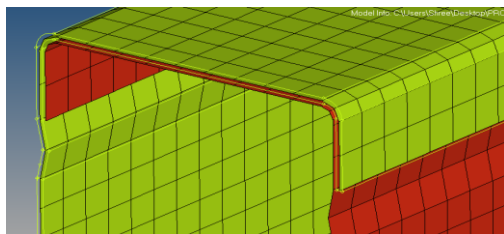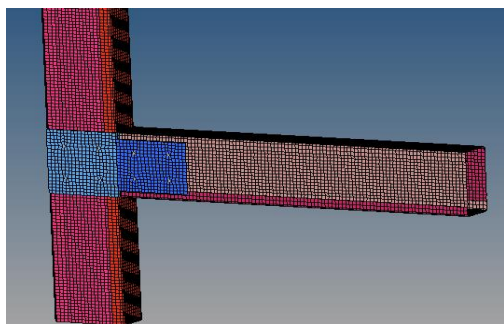

Fig – 6: Mid surface

Fig – 7: Meshed model

4. After extracting mid surface from separated elements meshing is carried out. In the pace of screw rigid spider elements are used.
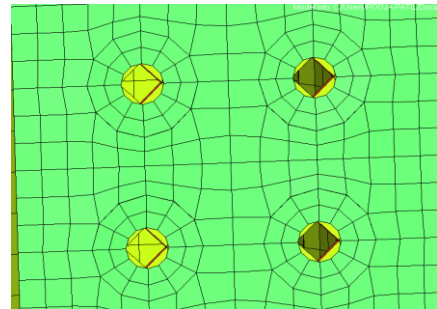
Fig – 8: Rigid spider model

5. Isotopic material properties are assigned to the elements. Following values are entered before assigning material property.
(a) Density 'ρ' = 7.9 X 10^{-5} N/mm^3
(b) Y0ung's M0dulus 'E' = 2.05 X 10^5 N/Mm^2
(c) P0isson's Rati0 'υ' = 0.3

6. Sectional properties are assigned to the elements are 2-D type therefore thickness to the section is given.

7. The boundary conditions are imposed to the assembly. The column is restrained at top and bottom in all the 6 DOF (degree of freedom) as shown in the figure below.
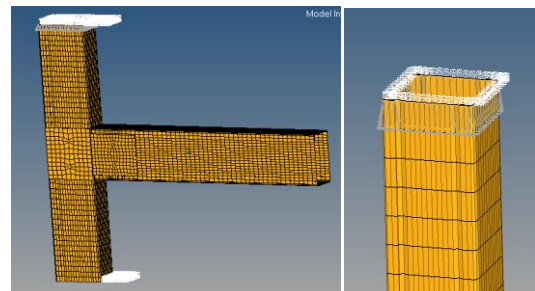

Fig – 9: Boundary conditions

8. The user profile is then changed to ANSYS then the model is exported to ANSYS as cdb format. The model is then imported in ANSYS and the load is applied at free end of the beam as shown in the figure.
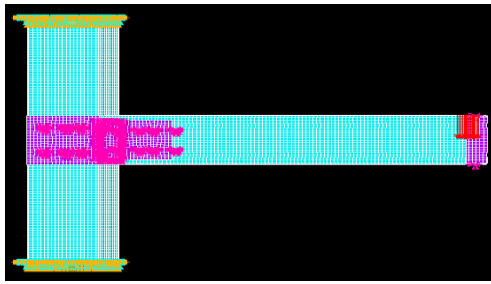
Fig – 10: Point load at free end of the beam

9. After this the results are obtained from the ANSYS software. The results obtained in the form of displacement of the beam, rotation of the beam, Von Mises Stress and Strain.
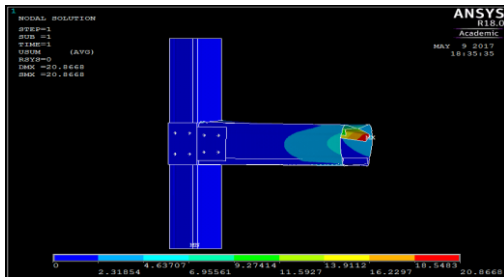

Fig – 11: Ansys results

Similarly, for all the other three types of connections are analysed by the same process as explained above. The following are the meshed models of all four types of connections.
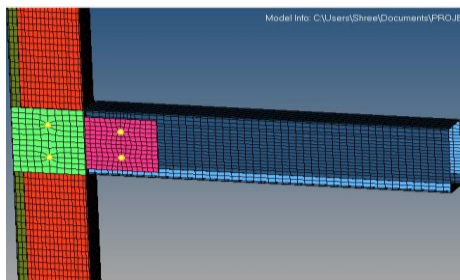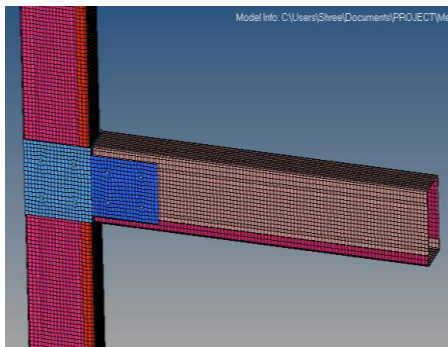

Fig – 12: Meshing of Connection (C1)

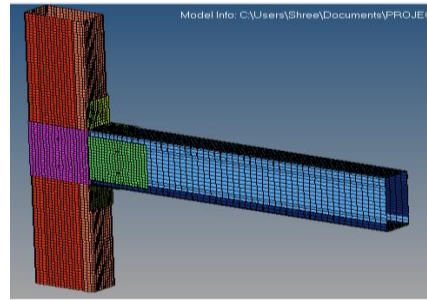

Fig – 13: Meshing of Connection (C2)
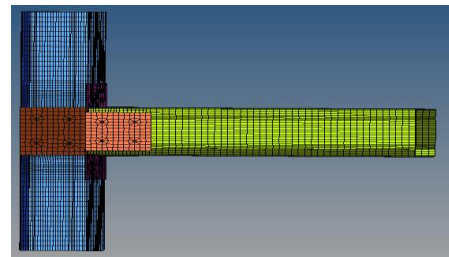

Fig – 14: Meshing of Connection (C3)

Fig – 15: Meshing of Connection (C4)

4. Results and Discussions

4.1 FEM analysis of all four types of connection.

1) FEM results of Beam and column connection with single row of screws using beam column connector at the junction (C1)

Table- 1: FEM results of connection (C1)

Loads (KN)	Deflection (mm)	Moment (KN-m)	Rotation (degree)	Rotation (radian)
0	0	0	0	0
0.1	2.488	0.004438	2.16	0.037704
0.2	4.976	0.007966	4.33	0.075582
0.4	9.952	0.031881	8.67	0.151339
0.6	14.928	0.047864	13.01	0.227096
0.8	19.904	0.063780	17.35	0.302853
1.0	24.88	0.079729	21.69	0.378611
1.2	29.856	0.0956786	26.03	0.4543681

Initial Stiffness $= \frac{(0.09568-0.00444)}{(0.454368111-0.037704)} = 0.218$ kN-m/rad
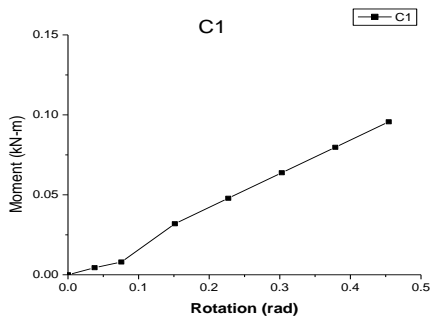
Fig – 16: Moment v/s rotation of C1 connection

This connection gives maximum load carrying capacity of 1.2kN and the maximum displacement 29.856 mm. The initial rotational stiffness is measured from graph by measuring slope of curve. The failure of beam-column connector at 1.2kN load is shown below.
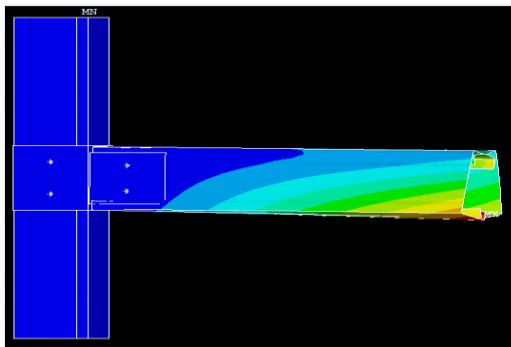

Fig – 17: Failure of connection C1

2) FEM results of Beam and column connection with double row of screws using beam column connector at the junction (C2)

Table- 2: FEM results of connection (C2)

Loads (KN)	Deflection (mm)	Moment (KN-m)	Rotation (degree)	Rotation (radian)
0	0	0	0	0
0.1	2.318	0.005531	1.2259	0.0214
0.2	4.637	0.01093	2.401	0.042
0.3	6.955	0.016330	3.551	0.062
0.4	9.274	0.021729	4.726	0.0825
0.5	11.592	0.02716	5.9007	0.103
0.6	13.911	0.032527	7.0579	0.1232
0.7	16.229	0.03801	8.2208	0.1435
0.8	18.548	0.043326	9.395	0.164
0.9	20.866	0.048725	10.541	0.184

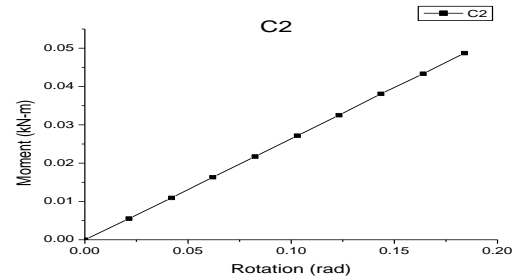Initial Stiffness $= \frac{(0.048725-0.00553)}{(0.184-0.0214)} = 0.266$ kN-m/rad

Fig – 18: Moment v/s rotation of C2 connection

This connection gives maximum load carrying capacity of 0.9kN and the maximum displacement 20.866 mm. The initial rotational stiffness is measured from graph by measuring slope of curve. The failure of beam-column connector at 0.9kN load is shown below.
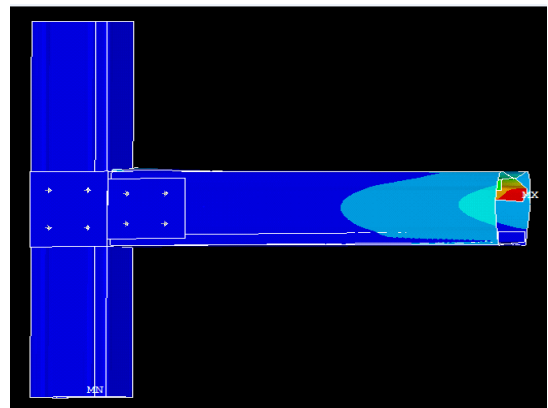

Fig – 19: Failure of connection C2

3) FEM results of Beam and column connection connected by angle plate (50x50x1) along with beam column connector at the junction using single row of screws (C3)

Table- 3: FEM results of connection (C3)

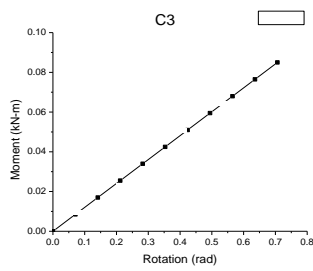| Loads (KN)	Deflection (mm)	Moment (KN-m)	Rotation (degre)	Rotation (radian)
0	0	0	0	0
0.2	1.944	0.00849	4.04	0.07052
0.4	3.888	0.01699	8.09	0.14121
0.6	5.838	0.02548	12.13	0.21173
0.8	7.779	0.03398	16.19	0.28260
1.0	9.725	0.04248	20.23	0.35312
1.2	11.671	0.05097	24.28	0.42382
1.4	13.616	0.05947	28.32	0.49434
1.6	15.561	0.06797	32.37	0.56503
1.8	17.506	0.07646	36.42	0.63573
2.0	19.451	0.08497	40.46	0.70625

Fig – 20: Moment v/s rotation of C3 connection

This connection gives maximum load carrying capacity of 2kN and the maximum displacement 19.415 mm. The initial rotational stiffness is measured from graph by measuring slope of curve. The failure of beam-column connector at 2.0kN load is shown below.
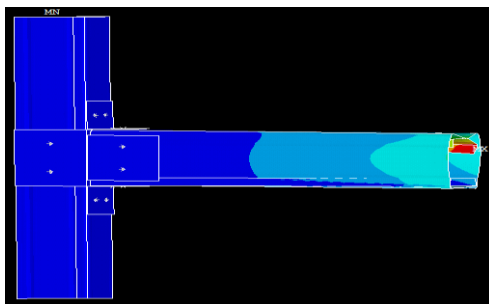

Fig – 21: Failure of connection C3

4) FEM results of Beam and column connection connected by angle plate (50x50x1) along with beam column beam connector at the junction using double row of screws (C4)

Table- 4: FEM results of connection (C4)

Loads (KN)	Deflection (mm)	Moment (KN-m)	Rotation (degree)	Rotation (radian)
0	0	0	0	0
0.2	1.212	0.005382	2.0254	0.03535
0.4	2.637	0.014177	4.0198	0.07016
0.6	4.814	0.021944	8.1395	0.14207
0.8	8.838	0.030325	12.215	0.21321
1.0	10.92	0.0388710	16.384	0.28599
1.2	12.31	0.048443	20.654	0.36052
1.4	14.01	0.057221	24.598	0.42937
1.6	16.71	0.065668	28.756	0.50195
1.8	18.23	0.074495	32.354	0.56475
2.0	24.26	0.091057	42.126	0.73533
2.5	29.99	0.099388	52.635	0.91877
3.0	35.23	0.109093	59.235	1.03397
3.4	39.56	0.11949	69.789	1.21820

Initial Stiffness = $\frac{(0.119494-0.005382)}{(1.2182057-0.035354482)}$ = 0.096 kN-m/rad
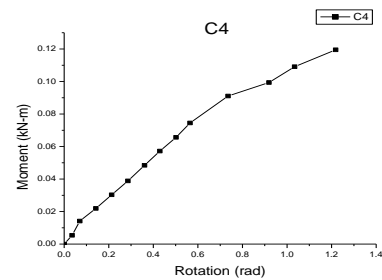

Fig – 22: Moment v/s rotation of C4 connection

This connection gives maximum load carrying capacity of 3.4kN and the maximum displacement 39.56 mm. The initial rotational stiffness is measured from graph by measuring slope of curve. The failure of beam-column connector at 3.4kN load is shown below.
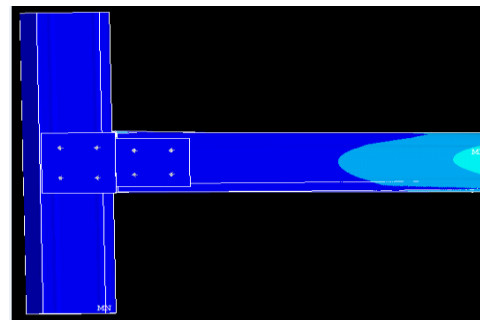

Fig – 23: Failure of connection C4

4.2 DISCUSSION

Summary of FEM Results

Table- 5: Summary of FEM Results

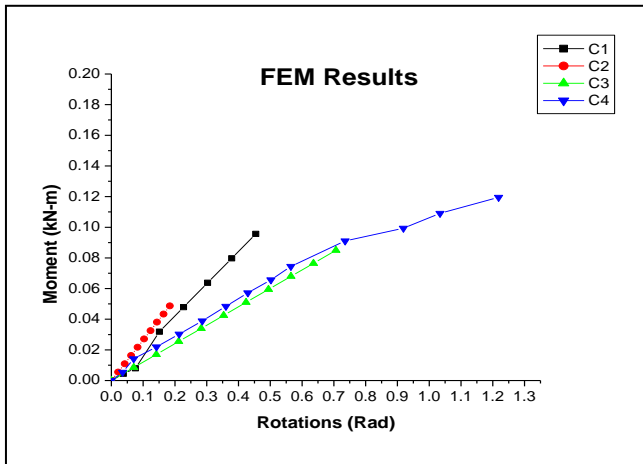| Type of connection	Load (kN)	Displacement (mm)	Ultimate moment (kN-m)	Rotational stiffness (rad)
C1	1.2	29.856	0.0956	0.45436
C2	0.9	20.866	0.048	0.00937
C3	2.0	19.451	0.0849	0.70625
C4	3.4	39.56	0.1194	1.21820

Fig – 24: FEM results of all connections

The graphs are plotted against moment v/s rotation based on the results obtained for each connection. The failure of a connection in FEM analysis is considered when the stress reaches the yield strength of the section, the yield strength of the section used is 550 N/mm^2.

The failure of connections in FEM analysis is due to the buckling of the beam at the point of application of load. The failure of connection C3 and C4 is at a higher load as compared to that of connections C1 and C2, this is due to the presence of angle plate.

5. CONCLUSION

1. Connection C1 and C2 have more rotation at less amount of load than the connections C3 and C4, therefore it is not recommended.
2. The failure of connection in FEM analysis is due to the torsional buckling of the beam at the point of load applied.
3. The failure of the connection C3 and C4 is due to the distortion of angle plates as well as distortion of beam-column connector.
4. The connections C3 and C4 have high ultimate moment capacity than connections C1 and C2.

6. REFERENCE

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