Experimental and Analytical Investigation of Bolted Angle Joints for Cold - Formed Steel Double Channel Sections

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Abstract— Cold formed steel in light steel framing design can serve as alternative for industrialized building system , by extending steel work construction into residential housing. There is a lack in depth of study on the joints behavior of cold formed steel structures by assuming that beam-to-column joints are either pinned or rigid. These assumptions allow a great simplification in structural analysis and design, but unfortunately the true behavior of the joints being neglected. In steel structures, moment resisting steel frames are highly regarded for their seismic performance. This regard is based on their ductility and inelastic performance, since inelastic deformation is used to dissipate energy during major earthquakes. This dissipation of energy is predominantly required in the connections like beam column joints. This is carried out with the influence of stiffener. Such a study of the inelastic behavior of steel connections would help in an economical and simpler design of connections in steel frames. This project develops a three dimensional finite element model using ANSYS and the results are compared with the experimental results.

Key words: Analytical Investigation of Bolted Angle Joints, Formed Steel Double Channel Sections

I. Introduction

Steel is one of the most widely used construction material for structural systems in modern construction. The wide usage of steel as construction material is contributed by the properties it possesses such as high strength, uniformity, elasticity, ductility, flexibility in fabrication, time saving as well as its after-demolished value. Steel is a material that has high strength per unit of weight which means that with smaller weight, it gives high strength therefore resulting in lower self-weight to the section. This fact is significant for long-span bridges, multi-storey buildings and for structures having poor foundation condition.

The manufacturing of steel in a stringent quality controlled condition in the factory, is uniform and homogenous in terms of its properties. It also can be controlled flexible and accurately according to the desired form or specifications. In addition, steel is an elastic material and it behaves closely to the design assumptions as it follows the Hooke's Law up to fairly high stress. Moreover, since steel is ductile, it can withstand extensive deformation without sudden failure and if large deflection ever occurs, it will give visible evidence therefore sudden failure can be avoided.

Aseismic design of structures is being the most popular topic recently. The construction industry in India is yet to use steel as construction material though the awareness on its structural properties is widely spread recently. Moment resisting steel frames are highly regarded for their seismic performance due to its ductility and inelastic performance. Inelastic deformation is used to dissipate energy during major earthquakes.

A. *Reason for Cold-Formed Steel*

Cold formed steel is environment friendly and is the need of the hour. It has high stability, light weight and ease of construction. It has a good consistent quality and high strength to weight ratio. Comparing to conventional framing –it requires a same amount of skill. It is more resistance to fire, rot and termites. Large open plans, straighter walls, easier electrical and mechanical installation is appreciable using cold formed steel.

B. *Steel Connections*

Steel sections are manufactured and shipped to some standard lengths, as governed by rolling, transportation and handling restrictions. However, most of the steel structural members used in structures have to span great lengths and enclose large three-dimensional spaces. Hence connections are necessary to synthesize such spatial structures from one- and two-dimensional elements and also to bring about stability of structures under different loads. Thus, connections are essential to create an integral steel structure using discrete linear and two-dimensional (plate) element. A structure is only as strong as its weakest link. Unless properly designed, the connections joining the members may be weaker than the members being joined. However, it is desirable to avoid connection failure before member failure for the following reasons:

– To achieve an economical design, usually it is important that the connections develop the full strength of the members.
– Usually connection failure is not as ductile as that of steel member failure.
  – Hence it is desirable to avoid connection failure before the member failure.
  – Therefore, design of connections is an integral and important part of design of steel structures.

Thus designing for adequacy in strength, stiffness and ductility of connections will ensure deflection control during service load and larger deflection and ductile failure under over-load.

C. *Objectives of the Study*

The main objective of the project is given as follows:

– To identify a joint in a steel frame with configuration and type of members and connection – single sided beam column joint with suitable section and connection details.
– To analyze the behavior of the semi rigid connection using inelastic analysis - Moment resistance and deflection using Finite Element Software.
– To study the strength of cold formed steel with stiffener plates

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D. Scope of the Project

Although the semi-rigidity concept was introduced many years ago, steel structures are usually designed by assuming that beam-to-column joints are either pinned or rigid. Aseismic design of buildings is being the most researched area currently and especially in India. Research in Reinforced concrete structures for seismic performance is done vigorously with various parameters already. Steel structures are very few in India compared to reinforced concrete structures. In steel structures, moment resisting steel frames are highly regarded for their seismic performance. This regard is based on their ductility and inelastic performance, since inelastic deformation is used to dissipate energy during major earthquakes. This dissipation of energy is predominantly required in the connections like beam column joints. The internal forces and moments produced in these connections influence the behavior of the overall structure.

II. SUMMARY ON REVIEW OF LITERATURE

The behavior of cold-formed sections are deeply studied, with help of literature different points had been taken for the project.

- beam-to-column is connected using gusset plate and failure is occurred at the gusset plate
- Among three different type of connection such as screw, bolt and rivet bolt connection is effective
- Due to action of load the member get buckled
- Angle sections are used in different pattern
- Mostly failure occurred at the joints and tilt in the fastener.

III. BOLT

Bolt size are calculated from IS 4000 (1992) Code of practice for Bearing strength bolts in steel structures. From the code book t*6.35 mm to t*3.175 mm for cold form steel where t is said to thickness of cold formed steel .the range lies between 20mm to 10mm. Hence the bolt diameter is 12mm.metric bolt M12 ansd grade 4.6 is used bolt hole is 13 mm. Hex head bolt is used

A. Strength of Bolt

Bolt strength can be determined by the shear capacity of bolt and bearing capacity of bolt.

B. Shear Capacity of Bolt

The design strength of the bolt, V_{dsb} as governed shear strength is given by:

$$V_{dsb} = V_{nsb} / \gamma_{mb} = 20.372 / 1.25 = 16.297 \text{ kN}$$

C. Bearing Capacity of Bolt

The design bearing strength of a bolt on any plate, V_{dpb} as governed by bearing is given by:

$$V_{dpb} = V_{npb} / \gamma_{mb} = 23.247 / 1.25 = 18.597 \text{ kN}$$

Smaller might be the strength of bolt so shear capacity of bolt is strength of bolt.

D. Bolt Specification

Bolt speciation is calculated from is 800 -2007.

Edge distance is 25 mm, 1.5 * d_h or 40 mm. End Distance is 25 mm, 1.5 * d_h or 40mm. Pitch distance is 50mm, 2.5 * d or 300mm. Gauge distance is 50mm, 16 * t or 200 mm.

IV. DESCRIPTION OF BEAM AND COLUMN

Beam and Column are in C section. Two C section back to back interconnection are made. Fillet weld is used to connect the C section Web of C beam is 150 mm, bottom and top Flange is 50 mm, Thickness is 3.15mm. Length of beam is 500 mm and length of column is 1000 mm. stiffener plate is placed at beam at certain distance of 200 mm and four stiffener plate is placed in column. First stiffener plate is placed at a distance of 317.5 mm from the top. Second stiffener placed at a distance of 100 mm from the first stiffener plate. Third stiffener plate is at distance of 165 mm from the above plate. Fourth plate is placed at a distance of 100 mm from the above plate. Inclined stiffener plate is also used column. The inclined stiffener plate is connected between the second and third stiffener plate. All stiffeners with a thickness 3.15 mm were welded to the beam and column

A. Angle Section

Three type of angle section is used .Such as web cleat (wc), flange cleat (fc) and web flange cleat (wfc) .web cleat as L section (A*B*T) is (50*50*2) mm. flange cleat in L section (A*B*T) is (100*100*2) mm.

V. SOFTWARE

The software's such as CREO and ANSYS is used .CREO software is used for modeling and ANSYS is used to Analysis.

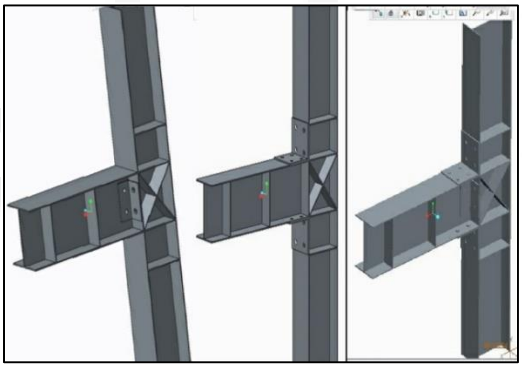

Fig. 1: Web cleat (wc), flange cleat (fc), web flange cleat (wfc)

Model created and then converted to IGES file format and then imported to ANSYS software.

A. Meshing

Meshing can be done by auto meshing

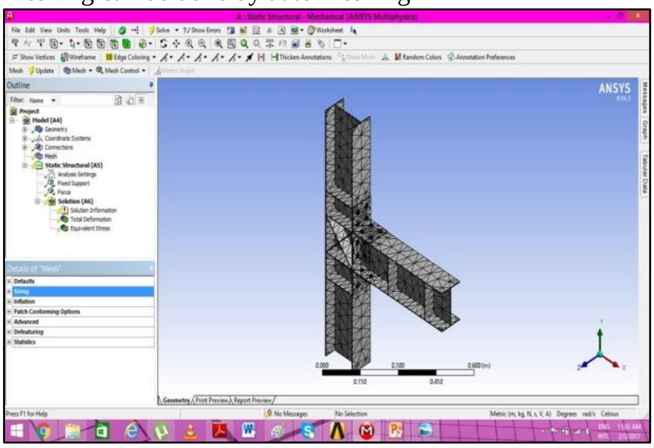

Fig. 2: Meshing

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B. Loading

Loading is said to be cantilever action. Point load is given at the end of the beam. Increase the load from 2kN to the Ultimate load. Hence it reach the 33 kN.

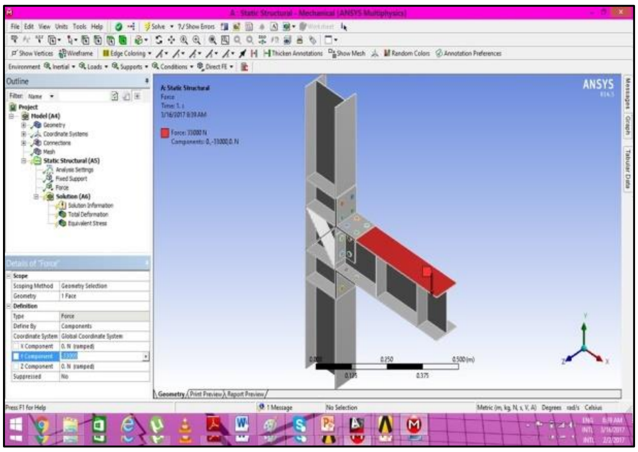

Fig. 3: Loading

Moment of Resistance = Load x distance = 33 kN x 0.5m = 16.5 kNm

C. Results Obtained from Software

Connection type	Moment of Resistance (kN m)
	2 mm
Web – Cleat (WC)	8.50
Flange – Cleat (FC)	11.75
Web – Flange- cleat (WFC)	16.50

Table 1: Moment of Resistance

VI. EXPERIMENTAL PROGRAM

Cold-formed steel lipped channel sections are used as the beam and column members of steel frame. The grade of steel is 350 N/mm2 and the thickness of each channel section is 3.15 mm. The depth of the sections is 250 mm. All specimens were cut into desired length and bundled up to transport to the structural laboratory Two lipped channel sections were placed back-to-back to form an I-section, with welding beam and column sections are made in ratio of 1 : 2 beam sections of 0.5- meter length, and column sections of 1-meter length. These beam and column are named as Double Channel sections. Fasteners used in the study are non-preloaded bolts M12 Grade 4.6 with two washers. The bolt holes were standardized to 13 mm in prevention of abrupt deformation due to wide hole-spaces between the steel members.

A total of three tests were carried out in the Magnus Frame. The out-of plane movement of the test specimens was restrained by bracing system. The load was applied using hydraulic jack and recorded. The loading was applied with an increment of 0.2 kN. The ‘failure’ condition was deemed to have been reached when any of the following situations mentioned below occurred:

1) An abrupt and significantly large reduction in the applied load being attained.
2) An abrupt and significantly large increment in the deflection of the beam being attained with significant deformation of the connections.
3) Excessive deflection of the beam, which is over 150 mm or reaching the DT’s limit.

Fig. 4: Loading Frame set up and applying load

Fig. 5: Failure pattern

A. Experimental Result

Connection type	Moment of Resistance (kNm)
	2 mm
Web – Cleat (WC)	09.00
Flange – Cleat (FC)	13.00
Web – Flange- cleat (WFC)	18.00

Table 2: Moment of Resistance

Failure mostly occur at the cleat angle, hence increase the thickness of cleat angle 2mm to 4mm and 6mm. it is done in software.

Connection type	Moment of resistance (kNm)		
	2 mm	4mm	6mm
Web – Cleat (WC)	08.50	10.25	13.00
Flange – Cleat (FC)	11.75	13.50	18.50
Web – Flange- cleat (WFC)	16.50	20.50	24.25

Table 3: Thickness of Cleat Angle

VII. CONCLUSION

All specimens were failed due to loss of joint strength and stiffness, leading to excessive deflection of beam. By increasing the angle-cleat size from 2 mm to 6 mm, the moment resistance would increase for in the range of 4.45kNm for web cleat 6.75kNm for Flange cleat and 7.75kNm for Flange web Cleat.

ACKNOWLEDGEMENT

The inception and the rudimentary concepts of project are ascribable to my guide Mr.T.Sakthi Subramanian, M.Tech., Assistant Professor, Department of Civil Engineering, without whose invaluable guidance, patient and encouragement, anything would have materialized. I owe my gratitude to him.

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