Finite element analysis of cold form perforated steel beam column connection

Amit M. Chavan[1], Dr.S.S.Angalekar[2],

[1]*Student of 2nd year ME Civil (Structure) of the Sinhgad College of Engineering, Pune, Maharashtra, India*
[2] *Associate Professor, Dept. of Civil Engineering, Sinhgad College of Engineering, Pune, Maharashtra, India*

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Abstract - *The aim of this paper is to present a simple and accurate three dimensional finite element Model (FE) capable of predicting the actual behaviour of beam-to-column joints in cold form perforated steel frame subjected to static loads. The software package ANSYS is used to model the joint. The beam-column type connection is used for study. This is chosen for its complexity in the analysis and their inheritable non-linear behaviour. The experimental test in the literature for normal section was chosen to verify the finite element model. The results of normal section of model in literature were compared with normal section of analytical model. Then the normal section of analytical model compared with perforated section of analytical model, to check the compatibility of the perforated section. The structural behaviour of the connection including the moment – rotation relation, Load -deflection curve, the yield strength, and ultimate moment capacity of the connections were studied. The main parameters considered in this study were the thickness of section for the constant span and number of bolts and its arrangement for the connection.*

Key words: finite element Model, Cold formed, perforated section, ANSYS, Connection, Bolted, Bearing failure, Flexural failure, moment rotation relation, Load- deflection curve

1. Introduction

One of the most exciting developments in structural steelwork during recent years has been the widespread and increasing use of cold-formed members as main structure in the construction of steel framing. Their strength, light weight, versatility, non-combustibility, and ease of production have encouraged architects, engineers, and contractors to use cold-formed steel products which can improve structural function and building performance, and provide aesthetic appeal at lower cost. Common shapes of cold formed steel sections used in structural framing are channels(C-sections), Z-sections, angles, hat sections. In general, the depth of cold-formed individual framing members ranges from 51-305 mm, and thickness of material ranges from 1.2 to about 6.4 mm. Most of modern code and standards do not considered connection between cold form steel section to be moment resisting and thus many new cold form steel product are developed from experimental testing rather than from design method due to lack of relevant design method.

2. Applications of cold-formed steel

Cold-formed steel products find extensive application modern construction in both low-rise and high rise steel buildings. Primary as well as secondary framing members in low-rise construction are fabricated using cold –formed steel sections, while in tall buildings, roof and floor decks, steel joists, wall panels, door and window frames, and sandwich panel partitions built out of cold-formed steel sections have been successfully used.

The main attractions of cold-formed steel sections are their lightness, high strength and stiffness mass production, fast and easy erection and installation, substantial elimination of delays due to weather, more accurate detailing, non-shrinking and non ambient temperatures, absence of formwork, protection from termites and rot, uniform quality, economy in transportation and handling, and non realistic modelling of a steel frame, therefore, requires the use of realistic connection modelling if an accurate response of the frame is to be obtained.

The aim of this paper is to present a simple and accurate three dimensional finite element Model (FE) capable of predicting the actual behaviour of beam-to-column joints of perforated cold form steel frame subjected to static loads.

3. Literature Survey and background to research

Literature studied in relevance to the objectives of the present study. There are various studies carried out by the researchers on Cold formed steel bolted connections, different models with different geometry have been developed that are based on conceptual representation using finite element method. In (2012), Bayan A., Sariffuddin S. et al. [1] carried out work on Structural Performance of Bolted Moment Connections among Single Cold-Formed Channel Sections.

The type of test arrangement employed for the isolated tests in this study was the cantilever arrangement. The software package ANSYS is used to model the joint. The experimental tests in the literature were chosen to verify the finite element model for normal section. The results of model in literature were compared with analytical model for normal section. Then the same is checked for the model having perforated section and decided the compatibility of section. The beam and column members are formed from single channel sections which are bolted back to back at the joint. It is expected that the proposed structure will offer efficient and economic connecting system and further insight on behaviour of single channel sections. Case A: The connection test specimens consisted of beam-column sub frame formed by single cold-form channel with a member thickness of 1.6 & 2 mm respectively. For all specimens, bolts grade 8.8 of 12mm diameter were used. Channel sections were connected back to back at the joint as simple and effective means to connect beam to columns in steel constructions as indicated in Figure 1. The applied loads at the loaded points, rotations and deflections of the test specimens were recorded during the tests. Loads are taken from the research work done on literature. With respect to available data, flange width thickness, no of bolts. Lipped and without lipped channel is used to study the structural behaviour.

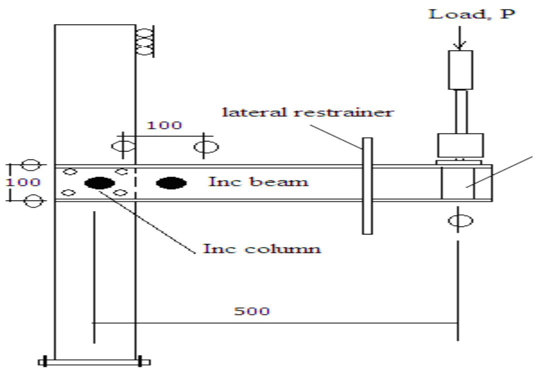

Fig.1:Experimental Setup

Modes of failure of the specimens

BFcsw: Bearing failure in section web around bolt hole,
FFcs: Flexural failure of connected section,

Aim of Study

To study the behavior of perforated; cold form steel beam-column, bolted moment connection using finite element analysis.

Objective of Study

Following objectives were finalized for the present study:

1. To study the behaviour of beam column connections of cold form section from existing literature.
2. To study the moment resistance and deformation characteristics of the models considered in the study.
3. To study the effect of number of bolts and placing of bolt on the response of beam-column connection.

4. Finite element modelling using ansys

Create two blocks of desired size one vertical and another horizontal by using BLOCK Command. Assign proper element i.e. shell element.

SHELL63:- It has both bending and membrane capabilities. Both in-plane and normal loads are permitted. The element has six degrees of freedom at each node: translations in the nodal x, y, and z Directions and rotations about the nodal x, y, and z axes. Stress stiffening and large deflection capabilities are included. A consistent tangent stiffness matrix option is available for use in large deflection (finite rotation) analyses. ANSYS input: - mp, ex, 1, 203 mp, nuxy, 1, and 0.3 after giving the material properties it is necessary to create proper mesh members with a proper size. Meshing helps the element to break into smaller pieces which can be solved further by using finite element method and proper variation in meshing sizes gives accurate results of stresses, displacement, reactions, buckling loads etc. Finer the meshing accurate is the result. ANSYS input: - esize, 3 amesh, all.

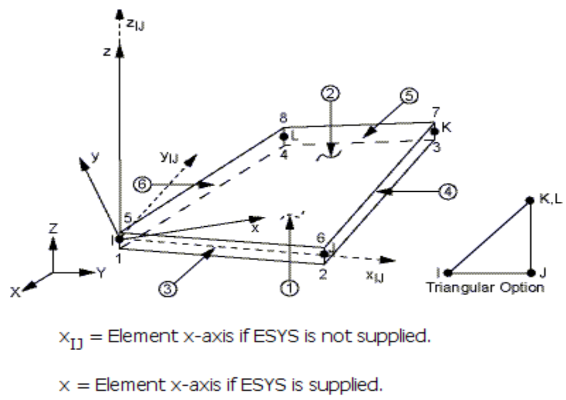

Fig.2: SHELL63

CONTA173 Element: CONTA173 is used to represent contact and sliding between 3-D "target" surfaces (TARGE170) and a deformable surface, defined by this element. The element is applicable to 3-D structural and coupled field contact analyses. It has the same geometric characteristics as the solid or shell element face with which it is connected. Contact occurs when the element surface penetrates one of the target segment elements (TARGE170) on a specified target surface.

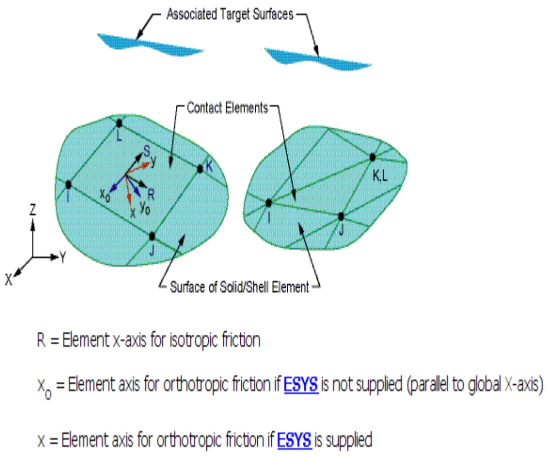

Fig.3: CONTA173 Element

TARGE170 Element: TARGE170 is used to represent various 3-D "target" surfaces for the associated contact elements (CONTA173, CONTA174, CONTA175, CONTA176, and CONTA177). The contact elements themselves overlay the solid, shell, or line elements describing the boundary of a deformable body and are potentially in contact with the target surface, defined by TARGE170. This target surface is discretized by a set of target segment elements (TARGE170) and is paired with its associated contact surface via a shared real constant set. The target surface can either be rigid or deformable. For modelling rigid-flexible contact, the rigid surface must be represented by a target surface. For flexible-flexible contact, one of the deformable surfaces must be over layed by a target surface.

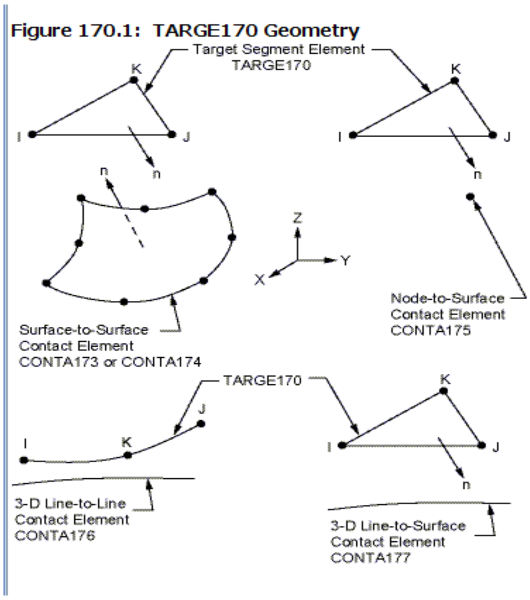

Fig.4: TARGE170 Element:

Proper supports are given using D command. Fixed support is given at bottom and top of column restrained in x direction. After modelling evaluation is done using solve command, and results are obtained.

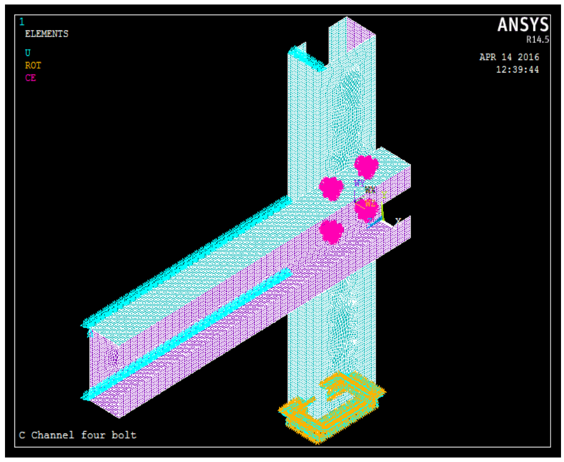

Fig.5: ANSYS modelling

5. Analytical results:

The validation of test Results: Experimental tests on beam column connection using single cold formed lipped channel sections with bolted moment connection were carried out by [3]Bayan Anwer Ali, SariffuddinSaad, MohdHanim Osman "Cold-Formed Steel Frame with Bolted Moment Connections." In their study they carried out tests on two specimens 100*50*1.6mm & 100*50*2mm with 15mm lipped sections. In this the beam section of 500mm size and the column section of 500 mm size are used. Edge distance, e=20mm, Bolts: M8.8 ø16 Pitch- 60 mm

In this part results are discussed by considering following parameters for the easy comparison among the test specimens, the moment rotation curves for beam column connection and load displacement relationships obtained and will be presented in this part.

1.1 Comparison of analytical results with available literature
1.2 Prediction of analytical results with different bolt Arrangement of 12mm bolt dia.
1.3 Prediction of analytical results with perforated section and with different perforations pattern for the different bolt Arrangement.

1.1 Load deflection curve can be obtained directly from the modal result file by extracting the data from loadings and nodal displacements for the moment rotation curve. Both the load deflection curve and moment rotation analytical curves were plotted for direct comparison. Load displacement relations for beam column connection of case 1.1 has been studied. In nonlinear analysis, a maximum load of 8.7kN was taken and the solution was converged at the 12th sub step. On comparing the analytical and experimental results it can be seen that for the same load, the deflection is slightly more in the experimental result. This may cause due to the slip in the bolt. The slip at bolt effect was not simulated analytically.

1.2 In this part analysis of connections with different bolting arrangement is carried out for particular section. In this case for refinement the model descritized at 3mm element and the rigidity effect also applied to the bolt to avoid the slippage of bolt. Numbers of bolts are changed for each case ultimately pitch of bolts is changed with 20mm edge distance. Load deflection and moment rotation curve is plotted. Constant bolts dia. M8.8 ø 12mm used for different bolt arrangement and obtained different result for the every case of bolt arrangements. 5 Nos bolt of diagonal placing with single centre bolt and 4 Nos bolt of diagonal shows lower values for load deflection curve as well as for moment rotation curve also where as for the 4 Nos bolt of square placing as well as 5 Nos bolt with single placing at centre and 6 Nos of bolt with circular placing gave effective result for Load deflection curve as well as moment rotation curve also.

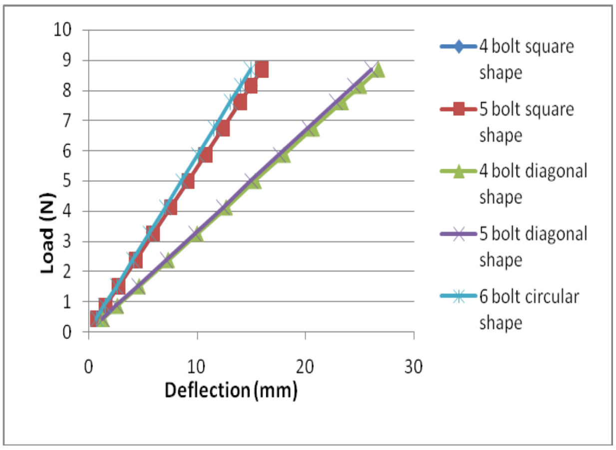

Chart -1: Load Deflection Curve

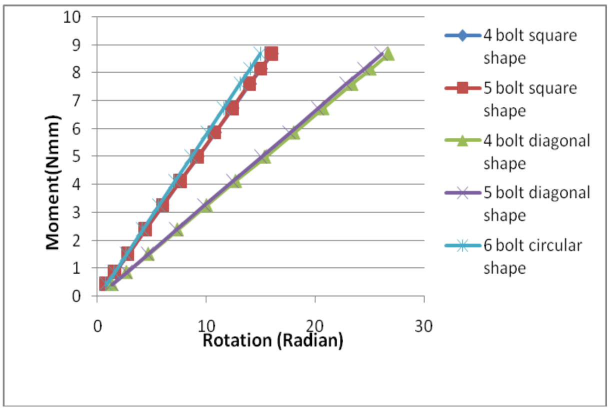

Chart -2: Moment Rotation Curve

1.3 In this analysis, model with perforated section having constant opening area 1800sqmm, for circular and rectangular openings with the 75mm c/c spacing in between couple of opening has been analyzed. Connection of the model keep similar as the normal section and the result compared with the same, which shows slightly changes in result which is allowable. All the result are shown in the form of graphical representation. The load deflection curve shows the relationship of load and deflection of normal section. This is similar to the perforated section; from this we can conclude that the perforated section is capable for the allowable deflection. And same for moment rotation curve the square opening shows slightly lower result as compare to normal section as well as circular perforated section which can conclude that the sectional property of the said section is not capable to take the moment.

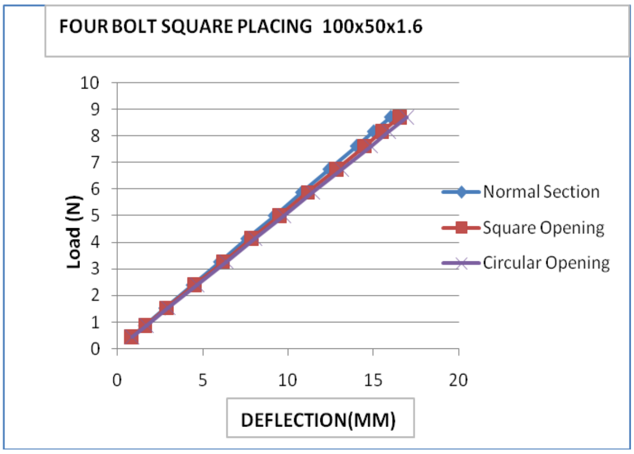

Chart -3: Load Deflection Curve

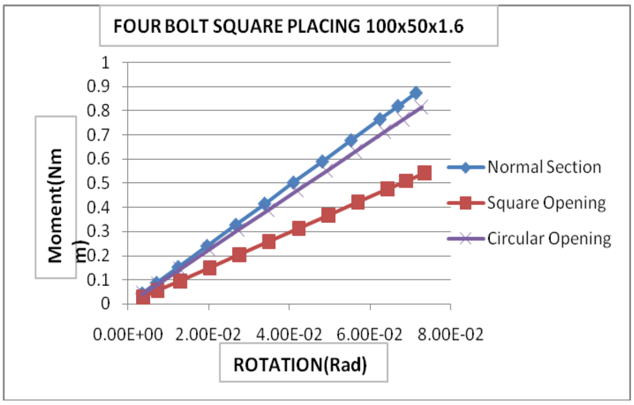

Chart -4: Moment Rotation Curve

6. Conclusion

1. Slippage of bolt is affecting the delectation of the beam member which crosses the limiting deflection value.
2. The experimental model gives deflection value 62 mm and the analytical model gives the deflection value 60 mm which is near about 95% of the experimental value, but the both value got from the model in which slippage of bolt has been occurred.
3. For the section 100X50X1.6 with the circular placing of six bolts (type 5) gives less value as compare to other four cases

i.e. 14.929mm and same section gives less value of rotation i.e.0.0689 radian. Simultaneously for the bolt square placing with four bolt and five bolt (type 1 & 2) gives near about same value for the deflection i.e. 16.016mm and 15.974mm and rotation 0.0712 radian for both the sections.

4. While comparing the two perforated section with the normal section for the section size 100X50X1.6 with four bolt (type 1) arrangements the normal section gives deflection 16.016mm, circular perforated section gives deflection 16.932mm and square perforated section gives deflection 17.488mm. Simultaneously the rotation for the same section is 0.0712 radian (Normal section), 0.0727radian (circular perforated section) &0.0734 radian (square perforated section). For the remaining type of section and bolt placing give same form of results.

5. From the above, the perforated section gives result near about normal section the circular perforation gives 5% more deflection as compare with the normal section and the square perforated section gives 10% more deflection as compare with the normal section which concludes that the perforated section can be used in the replacement of normal section.

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