Finite Element Analysis of Perforated Beam – Column Connections

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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 connection of perforated steel frame subjected to static loads. The software package ANSYS is used to model the joint. The beam- column bolted connection is used for study. The experimental test in the literature for conventional section was chosen to verify the finite element model. The results of conventional section of model in literature were compared with conventional section of analytical model. Then the conventional 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 Load -deflection curve, von mises stresses is studied. In this paper beam column connection with circular & hexagonal opening is studied.*

***Key Words*: Finite element model, beam column connection, perforated section, web opening, ANSYS, load deflection curve**

1. INTRODUCTION

Steel structure building are becoming more and more popular due to their many advantages such as the better satisfaction with the flexible architectural, durability, strength, design, low inclusive cost and environmental protect as steel is manufacture to precise and uniform shapes. While designing a power plant structure or a multi-storied building, the traditional structural steel framing consists of beams and girders with solid webs. This obstructs the provision of pipelines and air conditioning ducts, electrical wiring required for satisfactory functioning for which the structure is put up. The provision of beam column connections with web openings has become an acceptable engineering practice, which will eliminates the probability of a service engineer cutting holes subsequently in inappropriate locations.

2. LITERATURE SURVEY & BACKGROUND TO RESEARCH

Literature studied in relevance to the objectives of the present study. There are various studies carried out by the researchers on perforated beam column connections, different models with different geometry have been developed that are based on conceptual representation using finite element method. In (2014), Rahul Manaloor & Dr. R. K. Gajjar carried out work on behaviour of connections during progressive collapse and their failure conditions using FEM analysis.

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 conventional section. The results of model in literature were compared with analytical model for conventional 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 I- sections which are bolted connections. It is expected that the proposed structure will offer efficient and economic connecting system and further insight on behaviour of I-sections. The steel beam and column both are made up of ISMB 100. For the experimental set-up, the steel material of columns, and beams was of grade Fe 250. 10 mm diameter bolts were used. The beam was fixed in a horizontal position. A vertical load was applied at the end of the beam. The load was increased gradually until huge deformations occurred in the connections. The load was applied on the extreme end of the beam.

Fig.1: Experimental Setup

2.1 Aim of study

To study the behaviour of perforated beam-column bolted connection using finite element analysis.

2.2 Objective of study

Following objectives were finalized for the present study:

i. Finite element analysis using ANSYS of steel perforated web beam column connections.

ii. Finite element analysis of conventional beam column connections and perforated beam column connections for circular web openings.

iii. Analysis of perforated web beam column connection with circular web opening & hexagonal opening.

iv. To study the deformation characteristics of the models considered in the study.

3. FINITE ELEMENT MODELLING USING ANALYSIS

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.

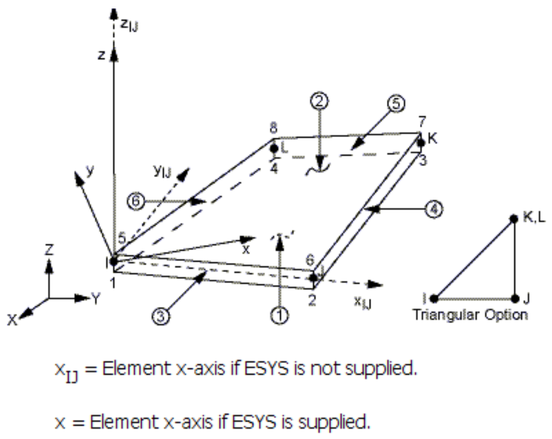

Fig.2: SHELL63

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.

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.

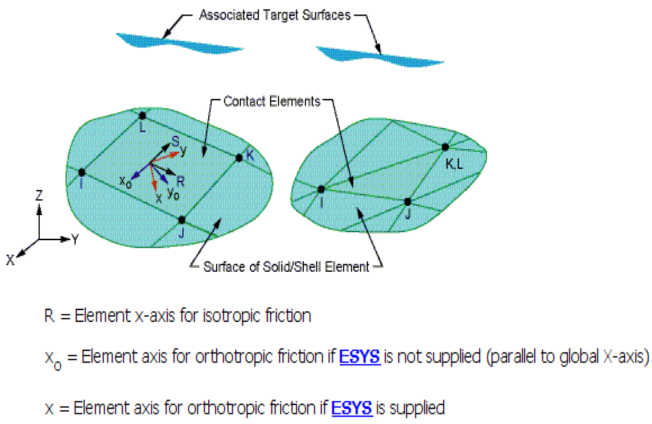

Fig.3: CONTA173 Element

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.

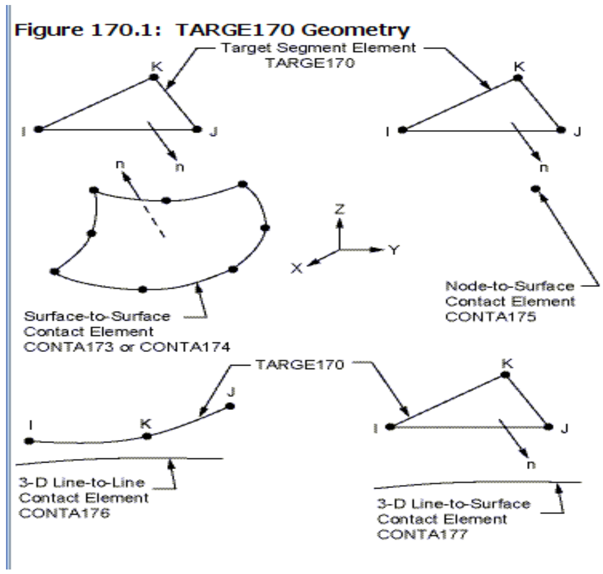

Fig.4: TARGE170 Element

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.

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.

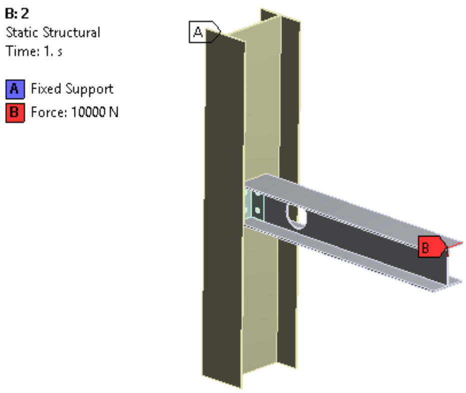

Fig.5: ANSYS modeling

4. ANALYTICAL RESULTS

The validation of test Results: Experimental tests on beam column connection using I- sections with bolted connection were carried out by [8] Rahul Manaloor & Dr. R. K. Gajjar carried out work on "behaviour of connections during progressive collapse and their failure conditions using FEM analysis". In their study they carried out tests on specimens 100*50*4.2mm I- section. Edge distance, e=20mm, Bolts: ø10 Pitch- 60 mm.

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

1.1 Comparison of analytical results with available literature

1.2 Comparison of analytical result with conventional & perforated beam column connection

1.3 Prediction of analytical results with different no of openings

1.4 Comparison of beam column connection with circular & hexagonal opening

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. The load deflection curves were plotted for direct comparison. Load displacement relation for beam column connection of case 1.1 has been studied. In nonlinear analysis, a maximum load of 8.5kN was taken and the solution was converged at the 10th 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 of analysis conventional beam column connection compared with the perforated beam column connection. For this comparison three different cases are studied. Material properties for all three cases are same. For this analysis 4 bolts arrangement is used. For the both, type von mises stress and deformation is studied and also load deflection curve is plotted. For the both, conventional and perforated beam column connection a maximum load of 8.5 KN was taken and the solution was converged at the 10th sub step. Results show that, deflection for conventional and perforated section is slightly differing. Also, perforated section gives maximum stress as compared to conventional section.

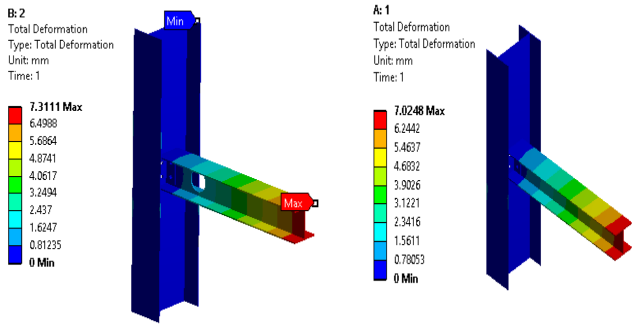

Fig.6: Total deformation for perforated & conventional beam column connection

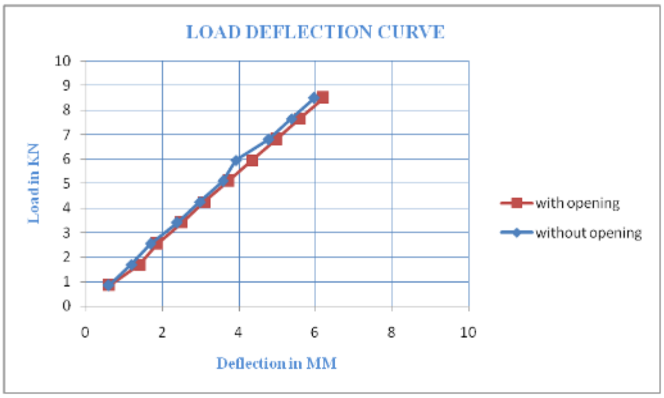

Fig.7: Load deflection curve

1.3 In this part analysis of perforated connections with different no of web opening arrangement is carried out for particular section. For this, three cases are studied. Every case is tested for no-1 opening, no-2 opening & fully web opening. Load deflection curve is plotted. Constant bolts dia. M8.8 ø 12mm used for different opening arrangement and obtained different result for the every case of opening arrangements.

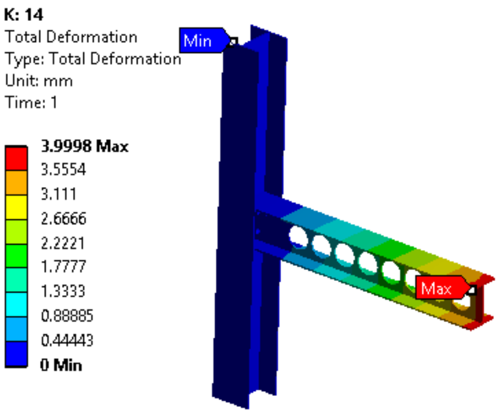

Fig.8: Fully web opening

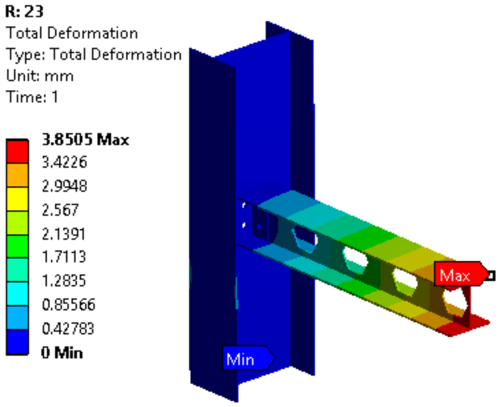

Fig.11: Fully hexagonal web opening

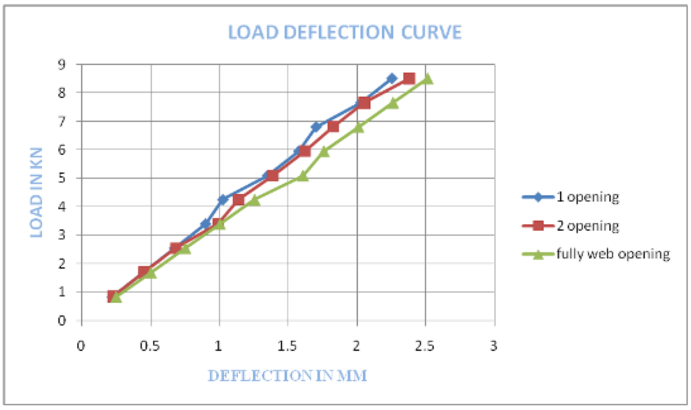

Fig.9: Load deflection curve for no of openings

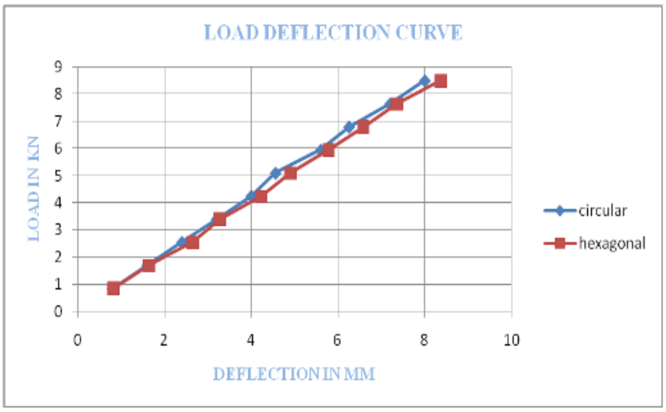

Fig.12: Load deflection curve for circular & hexagonal opening

1.4 In this analysis, model with perforated section having circular opening & hexagonal opening has been analyzed. Connection of the model keeps similar for the both section and the result compared with the same, which shows slightly changes in result. All the results are shown in the form of graphical representation. The load deflection curve shows the relationship of load and deflection for circular & hexagonal section. From this we can conclude that the perforated section is capable for the allowable deflection.

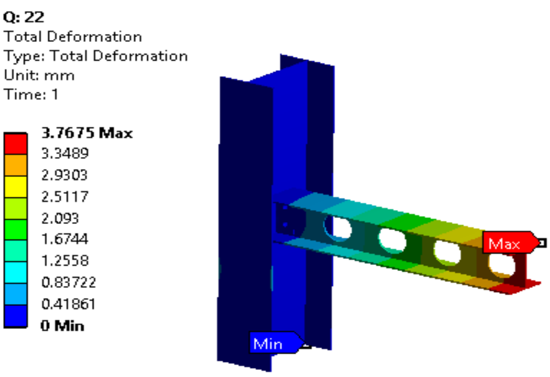

Fig.10: Fully circular web opening

5. CONCLUSIONS

- Slippage of bolt is affecting the delectation of the beam member which crosses the limiting deflection value.
- The experimental model gives deflection value 40 mm and the analytical model gives the deflection value 18.65 mm which is near about 55% of the experimental value, but the both value got from the model in which slippage of bolt has been occurred.
- From the results of comparison between the beam column connection with web opening and without web opening, the deflection and von mises stresses concluded that there is nominal difference in beam column connection with web opening and without web opening.
- The results in the analysis are having a comparable value with both the models. Little higher value observed in von mises stress in case of model with perforations

- It helps to reduce its self-weight, holes can accommodate plumbing, electrical, and heating conduits in the walls and ceilings of buildings. Thermal bridging effect can be reduced.

- We can use perforated beam column connection instead of conventional beam column connection. Beam column connection with web opening is economical. By using this, we save the material cost.

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