International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 09 | Sep-2016 www.irjet.net p-ISSN: 2395-0072

# Parametric Study of Beam to Column Bolted Connection with Cellular Beams

**Anju Mohan[1], Dr. K. A Abubaker[2], Lakshmi G Das[3]**

*[1]Department of Civil Engineering, IIET, Nellikuzhy*
*[2]Chief Consultant, SAFE, Edappally*
*[3]Asst. Professor, Dept. of Civil Engineering, IIET, Nellikuzhy, Kerala, India*

---***---

**Abstract -** *This project intent a comprehensive finite element analysis of extended end plate beam to column connections, with cellular beam or castellated beam. The models are created with circular and hexagonal shaped web openings along the length of beam. The behaviour of such connection is evaluated by conducting a parametric study in which the parameters introduced were the distance of the first web opening from the face of the column, and the web opening shape. ANSYS software is used for the analysis. Nonlinear dynamic FE analysis was conducted for the study. The analysis result shows that castellated beam with hexagonal shaped web opening gives better result in terms of stress distribution and less deflection than that with circular web openings. The ideal distance of first web opening from the column face was also identified.*

***Key Words***: **Cellular beam, Web opening, Non linear analysis, stress distribution, deflection...**

## 1. INTRODUCTION

In recent years, researchers study alternative connection designs for steel seismic-resistant frames by reducing the beam section in different ways including that of creating web opening along the length of beam (castellated beam). This project intent a finite element (FE) analysis of extended end-plate beam-to-column connections, with circular web opening (cellular beam) and hexagonal shaped web openings introduced along the length of the beam. The parameters introduced to evaluate the performance were the distance of first web opening from the face of the column (S), and the web opening shape.

## 2. FINITE ELEMENT ANALYSIS OF BEAM TO COLUMN BOLTED CONNECTION

The model of steel beam column joint was created based on the study conducted by Konstantinos Daniel et al., I sections are used for creating steel beam and column. The details of the connections are shown in the table below.

**Table -1:** Dimension of the connection (All in mm)

| Beam (IPE300) | | End Plate | | Column (HE160B) | | Bolt | |
|---|---|---|---|---|---|---|---|
| $b_{fb}$ | 150 | $l_p$ | 70 | $b_{fc}$ | 160 | $d_0$ | 20 |
| $h_b$ | 300 | $b_{ep}$ | 150 | $h_c$ | 160 | $e,e_x$ | 30 |
| $L_b$ | 6000 | $h_{ep}$ | 380 | H | 3625 | P | 200 |
| $t_{fb}$ | 10.7 | $t_{wc}$ | 20 | $t_{fc}$ | 13 | P | 90 |
| $t_{wb}$ | 7.1 | | | $t_{wc}$ | 8 | W | 90 |

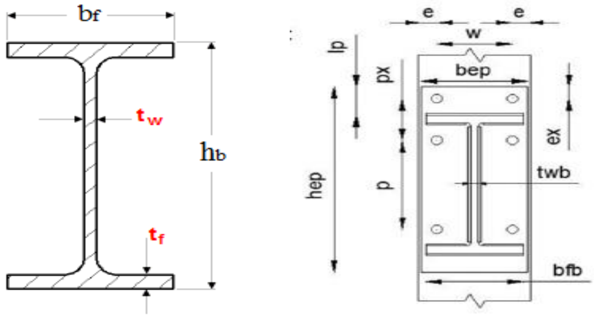


**Fig-1:** Detailed configuration of extended end plate connection

### 2.1 Element Types and Material Properties

Shell 181 elements are used to model beam, column, and plate and beam 4 elements are used to model bolts. The young's modulus of steel is $2.1x10^5$ N/mm$^2$, Poisson's ratio is 0.3 and density of steel is taken as 7850kg/m$^3$.

**Table -2:** Mechanical properties of the connection (all in MPa)

| Beam | | Column | | Plate | | Bolt | |
|---|---|---|---|---|---|---|---|
| $f_y$ | 308.5 | $f_y$ | 289.4 | $f_y$ | 291.5 | $f_y$ | 900 |

### 2.2 Specimen Geometry, Modeling and Meshing

The modeling was done using ANSYS 14.5 finite element software. A total of 8 models were created.

**Table -3:** Parameters considered for the study

| Model | Shape of web opening | Distance of first web opening from the column face (S) (mm) |
|---|---|---|
| 1 | Circular | 200 |
| 2 | Circular | 350 |
| 3 | Circular | 400 |
| 4 | Circular | 520 |
| 5 | Hexagonal | 200 |
| 6 | Hexagonal | 350 |
| 7 | Hexagonal | 400 |
| 8 | Hexagonal | 520 |

For all parametric analyses, the web opening diameter, do, was taken as equal to $0.8h_b$, where $h_b$ is the height of the beam; and $S_0/d_0$ is taken as 1.2 where $S_0$ is centre to centre distance between adjacent web openings

For shell 181 element the mesh set up such that quadrilateral elements were created.

## 2.3 Boundary conditions and Loading

The top and bottom end of the column were fixed, the cantilever end of the beam was kept free. The specimen was loaded cyclically following the SAC loading protocol. Beam end displacements were applied at the location of 4.84 m from the face of the column on the beam with an upward and a downward displacement producing one cycle of the loading protocol. A total of 32 cycles, equivalent to 128 applied displacements, were computed. The SAC loading protocol is shown in Table-3 summarises the displacements values, $\Delta_{LC}$, applied as load-steps.

**Table -3:** Beam end displacement for cyclic loading sequence

| No of cycles | Load step (accumulative) | End displacements $\Delta_{LC}$ (m) |
|---|---|---|
| 6 | 24 | 0.0116297 |
| 6 | 48 | 0.0155063 |
| 6 | 72 | 0.0232594 |
| 4 | 88 | 0.0310125 |
| 2 | 96 | 0.0465188 |
| 2 | 104 | 0.0620250 |
| 2 | 112 | 0.0930375 |
| 2 | 120 | 0.1240500 |
| 2 | 128 | 0.1550625 |

## 3. ANALYSIS AND RESULTS

The analysis was carried out on the models and the results were obtained. Non linear dynamic analysis was conducted for the analysis. The study analyzes the deflection, maximum principle stress, and von mises stress of the different models created.

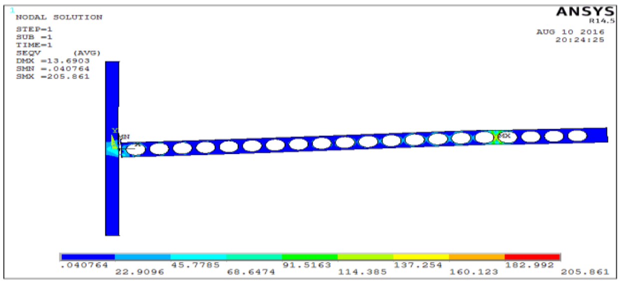


**Fig-2(a):** Von mises stress

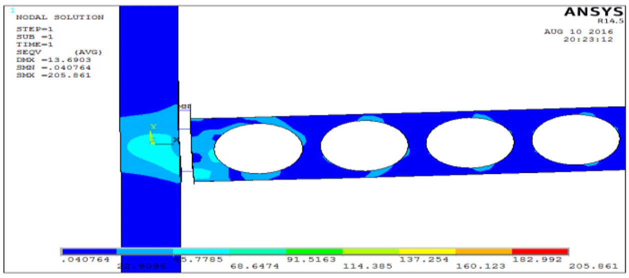


**Fig-2(b):** Von mises stress at the joint

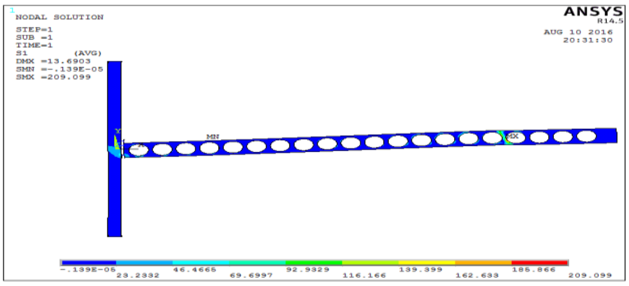


**Fig-2(c):** Max. principal stress

**Fig-2:** Analysis result of a typical model with circular web opening (model 1)

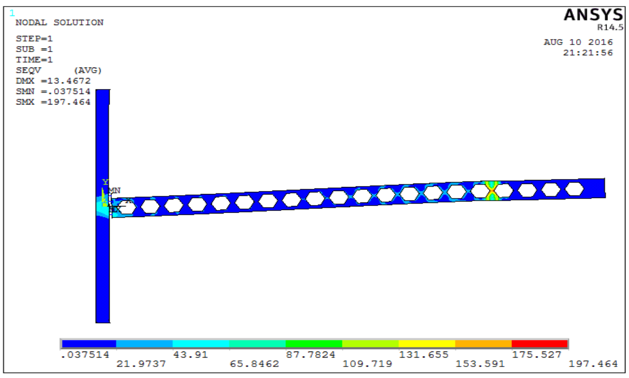


**Fig-3(a):** Von mises stress

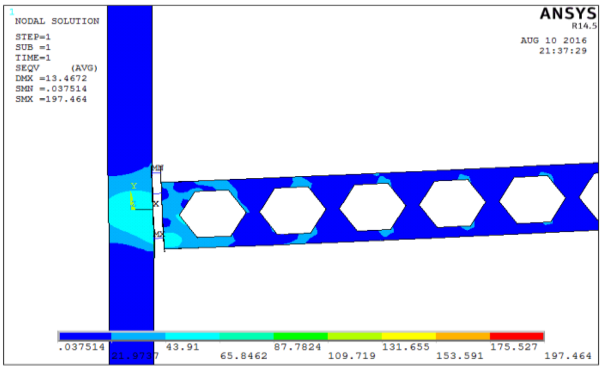


**Fig-3(b):** Von mises stress at the joint

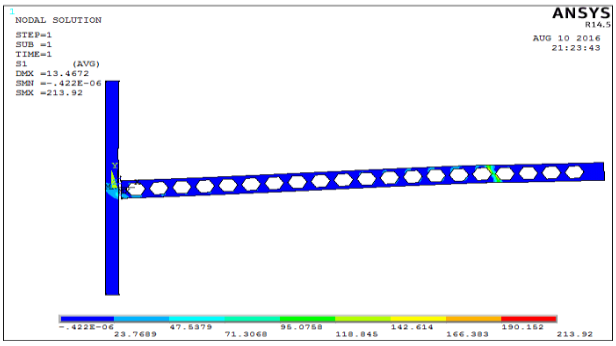


**Fig-3(c):** Max. principal stress

**Fig-3:** Analysis result of a typical model with hexagonal shaped web opening (model5)

## 4. COMPARISON OF RESULTS

A total of 8 models are analyzed and the results were compared.

**Table-4:** Results of FE models

| Model | Von-Mises Stress (MPa) | Deflection | Max.principal stress (MPa) |
|---|---|---|---|
| 1 | 205.861 | 13.69 | 209.099 |
| 2 | 289.368 | 13.89 | 325.933 |
| 3 | 221.761 | 13.87 | 222.825 |
| 4 | 215.983 | 13.68 | 217.969 |
| 5 | 197.464 | 13.46 | 231.92 |
| 6 | 207.584 | 13.69 | 225.162 |
| 7 | 193.597 | 13.62 | 213.771 |
| 8 | 200.467 | 13.47 | 217.476 |

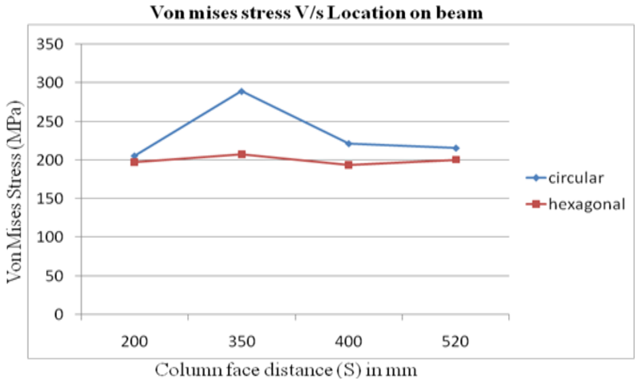


**Fig-4:** Von mises V/s Location on beam

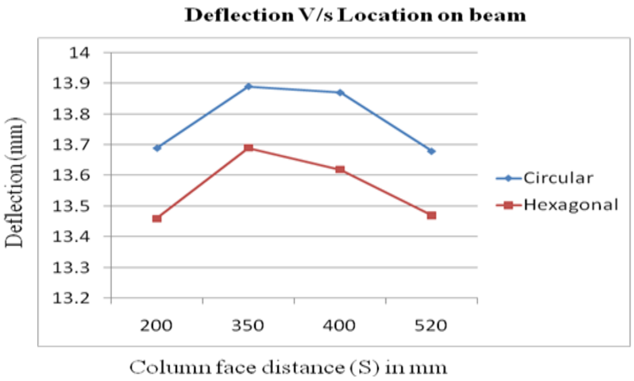


**Fig-5:** Deflection V/s Location on beam

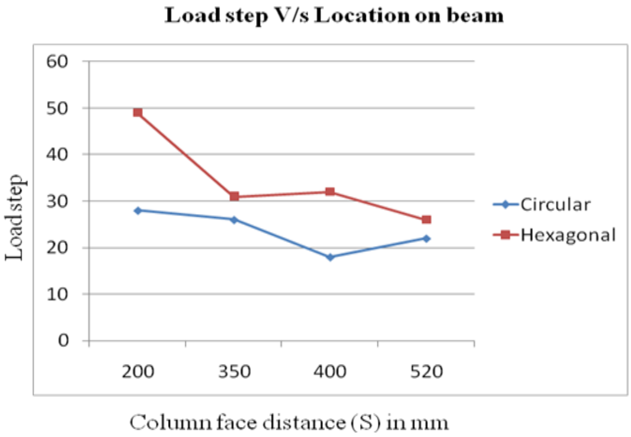


**Fig-6:** Load step V/s Location on beam

To find the safe distance of first web opening, a node in between the joint and first web opening was selected and the corresponding von mises stress was noted. The von mises stresses of similar nodes of other models were also noted and the values were compared. (Table-5 and 6).

**Table-5:** Von mises stress of models with circular web opening

| Model | Column face distance,S (mm) | Von mises stress (MPa) |
|---|---|---|
| 1 | 200 | 60.55 |
| 2 | 350 | 17 |
| 3 | 400 | 20.56 |
| 4 | 520 | 20.33 |

**Table-6:** Von mises stress of models with hexagonal shaped web opening

| Model | Column face distance (mm) | Von mises stress (MPa) |
|---|---|---|
| 5 | 200 | 53.35 |
| 6 | 350 | 6.08 |
| 7 | 400 | 25.74 |
| 8 | 520 | 23.40 |

From the above table it is clear that the column face distance, S of 200 mm for the first web opening resulted in the critical stress concentration close to the column face while larger distance of 520mm resulted in the early ending of FE analysis. Therefore the ideal column face distance, S being identified as 350mm where the stress was found to be minimum.

## 5. CONCLUSION

- An extensive literature survey were conducted
- Eight models of the beam column joint are prepared in ANSYS software
- Dynamic nonlinear analysis is conducted
- Von mises stress, Max. principal stress, deflection etc. are selected for comparison
- The values of von mises stress and maximum principal stress are lower in the models with hexagonal shaped web opening
- Deflections are lesser in models with hexagonal shaped web opening
- Lowest 'S' results in concentration of stress close to the joint
- Larger 'S' results in early ending of FE analysis
- Ideal column face distance 'S' was identified as 350mm
- Models with hexagonal shaped web openings shows better results.

## REFERENCES

[1] Konstantinos Daniel, Theodore Papadopoulos, "A FE parametric study of RWS beam-to-column bolted connections with cellular beams", *Journal of Constructional Steel Research,* Vol. 116, 2016, PP 92–113.

[2] Jamadar A. M., Kumbhar P. D, "Parametric study of castellated beam with circular and diamond shaped openings", *International Research Journal of Engineering and Technology (IRJET),* Vol.2, 2015, PP 715-722.

[3] P.D. Kumbhar, and A.M. Jamadar, "Optimization of opening size for castellated beam with sinusoidal openings", *International Journal of Optimization in Civil Engineering,* Vol.5, 2015, PP 301-313

[4] R. Rahnavard, A. Hassanipour, N. Siahpolo, "Analytical study on new types of reduced beam section moment connections affecting cyclic behaviour", *Case Studies in Structural Engineering*, Vol. 3, 2015, PP 33–51.

[5] Konstantinos Daniel Tsavdaridis, "Application of structural topology optimisation to perforated steel Beams", *Computers and Structures,* Vol.158, 2015, PP 108–123.

[6] Fattouh M.F. Shaker and Waseem M. Abd Elrahman, "Analytical Behavior of Steel Pre-tensioned Bolted Connections with Flushed and Extended End Plates under Bending", *World Applied Sciences Journal* ,Vol.30,2014,PP 673-684.

[7] Bernice V. Y. Wong, Ian W. Burgess, "The influence of tensile membrane action on fire-exposed composite concrete floor-steel beams with web-openings", *Procedia Engineering*, Vol.62, 2013, PP 710 – 716.

[8] Y.Q. Wang, L. Zong, Y.J. Shi, "Bending behavior and design model of bolted flange-plate connection", *Journal of Constructional Steel Research*, Vol.84, 2013, PP 1–16.

[9] Abdelrahim Khalil Dessouki, Ahmed Hassan Youssef, Mohamed Mostafa Ibrahim, "Behavior of I-beam bolted extended end-plate moment connections", *Ain Shams Engineering Journal,* Vol.4, 2013, PP 685–699.

[10] M. Saranik, L. Jézéquel, D. Lenoir, "Experimental and numerical study for fatigue life prediction of bolted connection", *Procedia Engineering,* Vol.66, 2013, PP 354 – 368.

[11] S. Durif, and A. Bouchaïr, "Behavior of cellular beams with sinusoidal openings", *Procedia Engineering*, Vol. 40, 2012, PP 108 – 113.

[12] J. E. Jam, N. O. Ghaziani, "Numerical and experimental investigation of bolted joints", *International Journal of Engineering,* Vol. 3, 2011, PP 285-296

[13] Elsayed Mashaly, Mohamed El-Heweity, Hamdy Abou-Elfath, Mohamed Osman, "Finite element analysis of beam-to-column joints in steel frames under cyclic loading", *Alexandria Engineering Journal,* Vol.50, 2011, PP 91–104.

[14] J.G. Williams, R.E. Anley, D.H. Nash, T.G.F. Gray, "Analysis of externally loaded bolted joints: Analytical, computational and experimental study", *International Journal of Pressure Vessels and Piping,* Vol.86, 2009, PP 420–427.

[15] Jeong Kim, Joo-Cheol Yoon, Beom-Soo Kang, "Finite element analysis and modeling of structure with bolted joints", *Applied Mathematical Modelling,* Vol.31, 2007, PP 895–911.

[16] Ramin Vafaeipour Sorkhabi, Alireza Naseri, and Masoud Naseri, "Optimization of the Castellated Beams by Particle Swarm", *Algorithms Method APCBEE Procedia,* Vol.9, 2014, PP 381 – 387.

[17] Resmi Mohan, Preetha Prabhakaran, " Finite Element Analysis to Compare the Deflection of Steel Beam with and without Web Openings", *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE),* 2016, PP 7-11.

[18] Prof. R. R. Jichkar, Prof. N. S. Arukia, Prof. P. D. Pachpor, " Analysis of Steel Beam with Web Openings Subjected To Buckling Load", *Int. Journal of Engineering Research and Applications,* Vol. 4, May 2014, PP 185-188.

[19] B. Anupriya, Dr.K.Jagadeesan, "shear strength of castellated beam with and without stiffeners using FEA (ansys 14)", *International Journal of Engineering and Technology (IJET),* Vol 6, 2014, PP 1970-1981.