Numerical Analysis of Unstiffened Spherical Bolt End-Plate Moment Connection with Web and Flange Opening under Thermal Condition

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Abstract – *This study of numerical analysis discuss about spiral bolt connection in beam column joint with and without flange opening and flange removal connection for seismic application. And also discuss about the temperature influence in beam and column with and without open condition. Then it will find out a suitable dimension of web and flange opened spiral beam column connection. Then next step is the study of web and flange opening condition in unstiffened I beam . Here, modeling and analysis is done by finite element software ANSYS .This model used elastic-plastic analysis to follow the behavior upon formation of up to four plastic hinges involved in the entire yielding mechanism.. Strain hardening and truss action are included in this method. . The comparison of the analytical results gave the method which provides a curve , which is usable to make nonlinear element models for beam column connections composed.*

Key Words: **Numerical Analysis, Spiral Bolt Connection, Web, Flange, Ultimate Strain criteria, Plastic Hinge**

1. INTRODUCTION

By using fully tensioned high-strength bolts,moment end plate connection is connected to the beam end. The connection may join two beams or a beam and a column. End- plate moment connections are divided as either flush or extended, with or without stiffeners, and again divided depending on the number of bolts at the tension flange. A flush connection is in which the end plate does not extend beyond the beam flanges and all bolts are located between the beam flanges. Extended end plates may be used with or without a stiffener between the end plate and the tension beam flange in the plane of the beam web. Extended end plates are used for beam-to-column moment connections. A typical connection used in steel moment frames is the fully welded connection, with complete joint penetration (CJP) groove welds connecting the beam flanges to the column flange, and fillet welds connecting the beam web to column flange, as shown in Fig. 1.Bolted extended end-plate (BEEP) moment-resisting connections are ready for use in special and intermediate moment frames. Bolt Extended End Plate connections remove the problems in field welding, winter erection . [1][2]
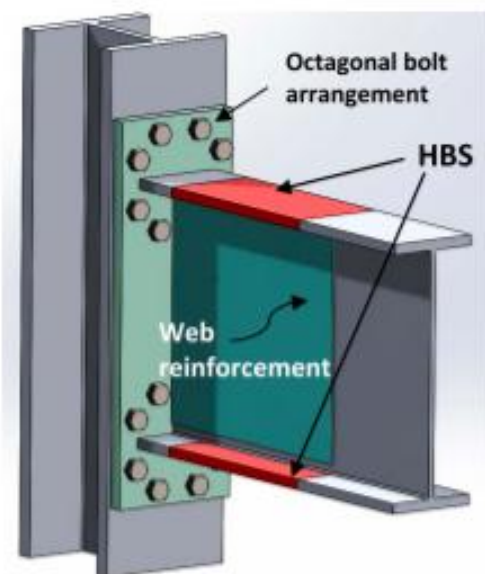

Fig-1 Standard connection

1.1 The Project's Scope

- The Bolt Extended End Plate connection can provide ductility and energy dissipation.

- BEEP connections have been ready for use in special and intermediate moment frames

- Mainly in multi-storey buildings based on their superior ductility and energy dissipation capacity during a strong ground earthquake

1.2 Objectives

   Main objectives are to study the performance of load carrying capacity through with and without web opening and to study the performance of load carrying capacity through with and without flange opening. Another objective is to find the best suitable position for hole which helps in seismic application.

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2. METHODOLOGY

The following is the methodology used for the project:

Literature survey: A detailed review of the literature on this topic is done through many journals. It gave some findings regarding the project topic. A literature review was undertaken using journals, textbooks, and conference papers etc.

Fixing the objectives: The next step is to fixing the objectives that means to identify what we are going to do. After the modeling and analysis, we get the answer for our objectives.

Numerical validation: It is done by using finite element software ANSYS based on the journal am selected for validation.

Development of analytical model of structure in ANSYS workbench : The model for analysis is developed in ANSYS workbench. It is a finite element analysis tool used for structural analysis for linear, non-linear and dynamic studies.

Analysis of model : First analysis is based on changing the diameter of the hole and after that the position of hole is changed. Then, delaying strength degradation technique is used.

Comparison of result and Interpretation : After the analysis, all the models get compared and reached in a final conclusion.

3. VALIDATION

ANSYS workbench is a software which is used for doing analysis of structural, thermal, and electromagnetic. ANSYS structural analysis software helps to solve structural engineering problems and make result faster. Validation is done on the basis of the journal An Unstiffened Eight-Bolt Extended End-Plate Moment Connection for Special and Intermediate Moment Frames, Journal of Structural Engineering, Volume 145 Issue 7 published by Machel L. Morrison, Doug Q. Schweizer, Shahriar Quayyum and Tasnim Hassan (2021). [1]

3.1 Geometry Details

The details of geometry and connections are shown in fig 2.1.

  i.   Beam: W 760X220 ASTM A992
 ii.   Column: W 360x382 ASTM A992
iii.   Bolt: 38.1 mm dia ASTM A490
 iv.   End plate: 1124x387x44.5 mm ASTM A572 Gr 50
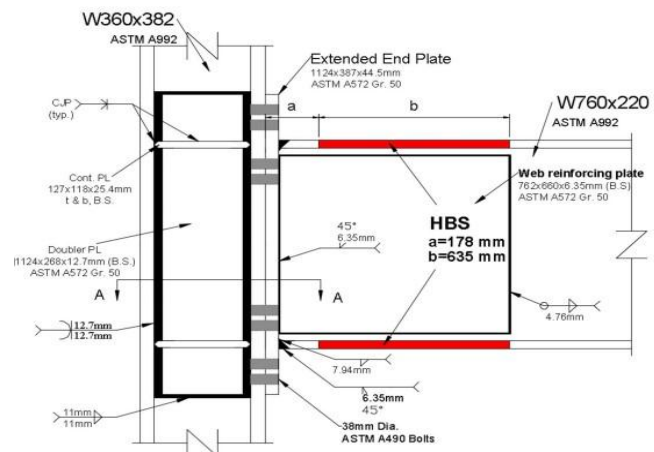 v.   Web reinforcement plate: 762x660x35 mm ASTM A572 Gr 50
 vi.   HBS

Fig 3.1. Connection details

3.2. Material Properties

The properties of different structural elements like beam, column, bolt, HBS, end plate is shown in table 4.1.

Table -1: Material Properties of Elements

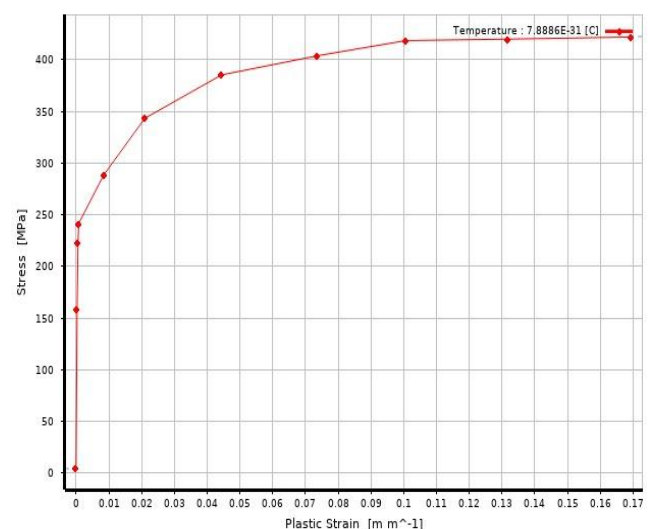| Properties	Value
Density	7850 kg/m^3
Coefficient of thermal expansion	1.2e-05 c^{-1}
Young's modulus	2e+11 Pa
Poissons ratio	0.3
Tensile yield strength	2.5e+08 Pa
Isotropic thermal conductivity	60.5 Wm^{-1}c^{-1}
Specific heat constant pressure	434 Jkg^{-1}c^{-1}

Fig 3.2. Stress strain relationship

The stress strain relationship is obtained from the fig 2.2 and the values are noted in a tabular column as shown in tabe 2.

Table 2 Values of plastic strain and stress

Plastic strain	Stress (MPa)
0	5
0.000311	158.45
0.00059	223.39
0.0008	241.68
0.00844	288.6
0.021	343.44
0.0444	385.38
0.07369	403.91
0.10074	418.61
0.1318	420
0.1693	422

3.3. Modelling

Geometry of the modelled is developed using ANSYS Workbench 21. The model of proposed beam column joint is shown in fig 2.3
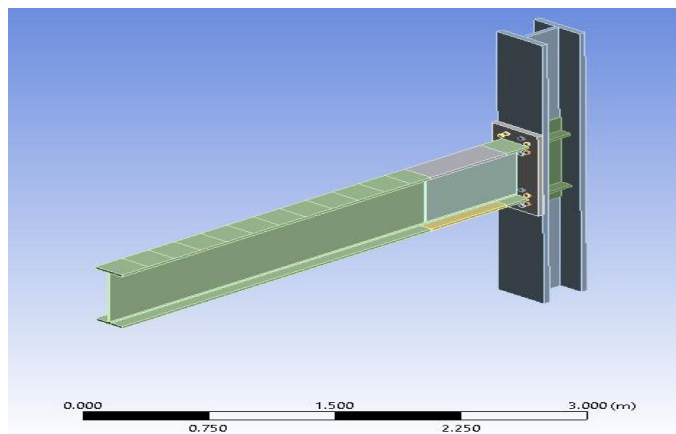
Fig 3.3. Model of proposed beam column joint

3.4 Meshing

Meshing is an important step in the analysis using ANSYS Software. The Beam, column, end plate, and beam to end-plate CJP weld were modelled using 8-noded solid elements and the Bolts were modelled using 20-noded solid elements. Solid 186 is the element type used for meshing. The structure after meshing is shown in 2.4.
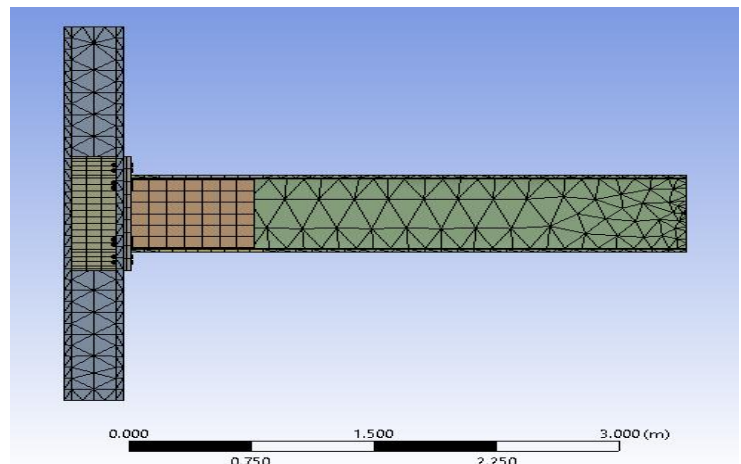
Fig 3.4 Meshing

3.5 Boundary Condition and loading

Once meshing is done, boundary condition is assigned to the structure here it is fixed along the column and a remote displacement on tip of the beam along x direction as shown in fig 2.5 and 2.6. Cyclic loading is given at the last face of split of beam.
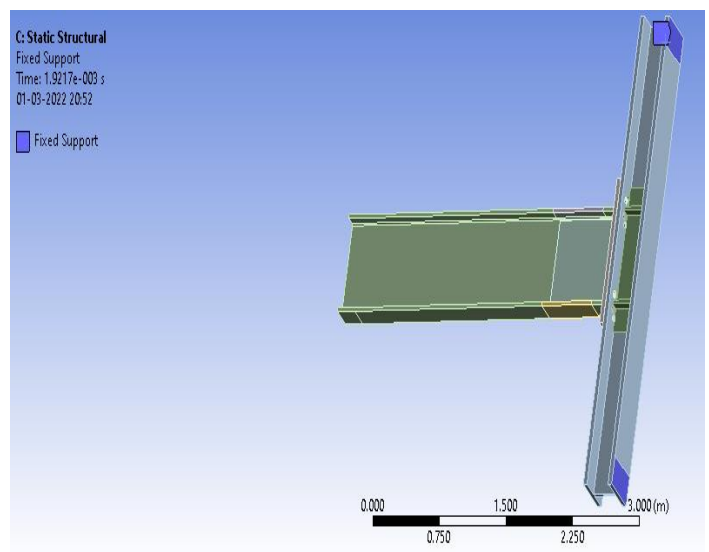
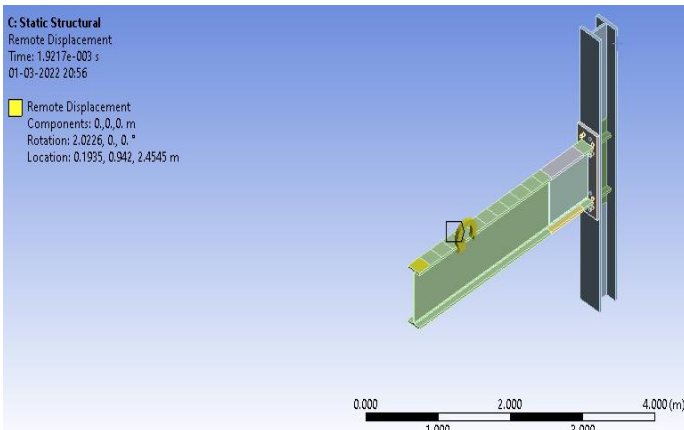

Fig 3.5. Support condition

Fig 3.6. Remote displacement

3.6 Solution

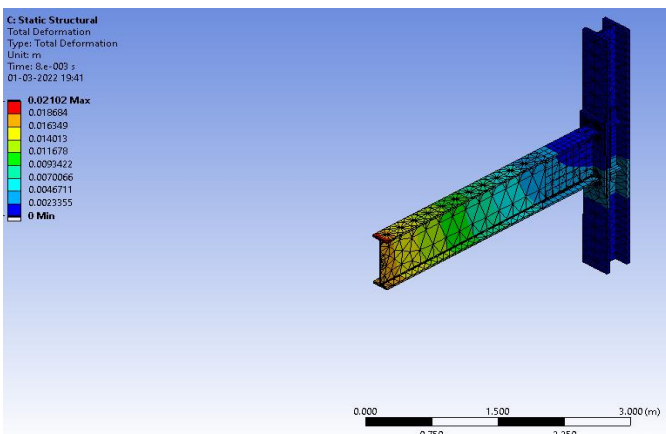After the validation it is obtained that the total deformation obtained is about 0.02102mm.

Fig 3.7. Remote displacement

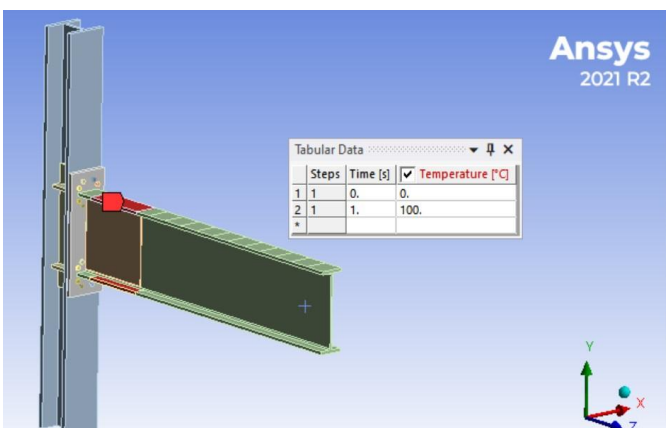The temperature that provided for the analysis is about 100^0.

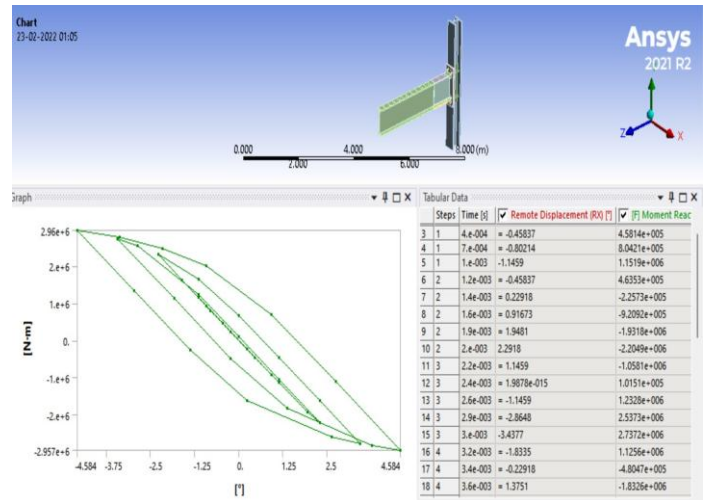**Fig 3.8.** Remote displacement

Hysteresis Curve is provided below.

Fig 3.9. Remote displacement

3.7. Validation Result

The experimental maximum moment from the journal graph is 3.2 MN-m. Maximum moment from the validation graph is 2.96 MN-m. So the percentage difference between the maximum moments from the two graph is 0.925 %. Hysteresis curve is obtained as similar to the curve in the group which is shown in fig 3.10
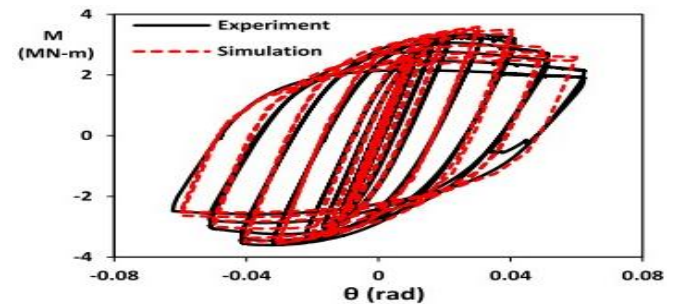

Fig 3.10 Moment Response graph

4. MODELLING AND ANALYSIS

The most popular finite element analysis software is ANSYS workbench R 21. The element type used is SOLID 186 for the model.
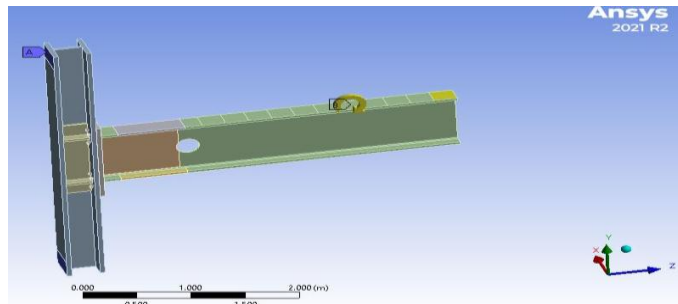
4.1 Parametric study of opening section

Fig 4.1. Model 1

In first case the diameter of the hole is increased by 223mm. The property of this connection is the arrangement of bolts in an octagonal pattern as shown in Fig. 4.1 T By systematic FE analysis of stiffened and unstiffened eight-bolt extended end-plate connections with various bolt arrangements, octagonal pattern is developed. Tensile forces from the beam flange and web will cause biaxial bending of the end plate in this connection..The octagonal bolt pattern carries this biaxial bending and increases uniform force distribution in the bolt group.

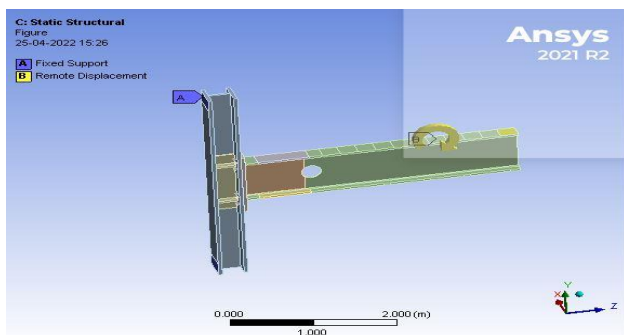In second case the diameter of the hole is increased by 245.3 mm.

Fig 4.2 Model 2

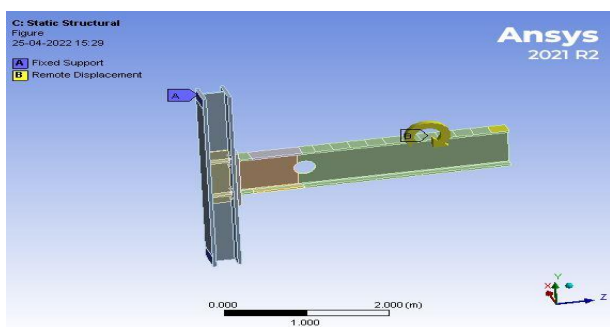In third case the diameter of the hole is increased by 269.83 mm.

Fig 4.3 Model 3

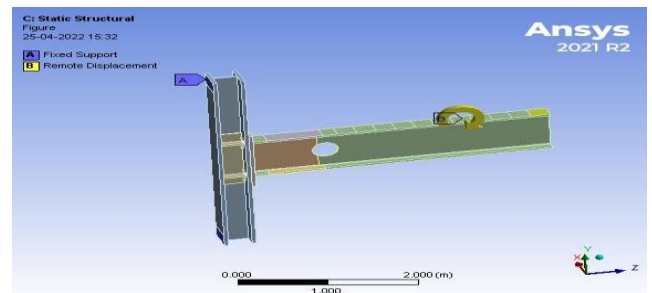In fourth case the diameter of the hole is increased by 296.81 mm.

Fig 4.4 Model 4

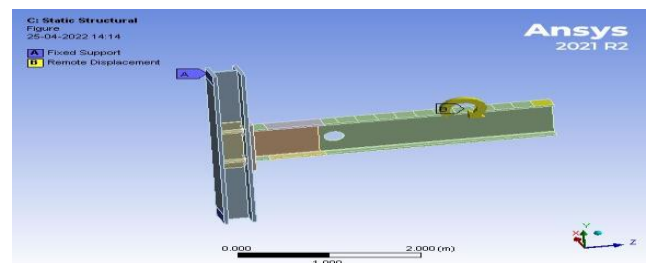In fifth case the parametric study was based on changing the position of holes by 935 mm.

Fig 4.5. Model 5

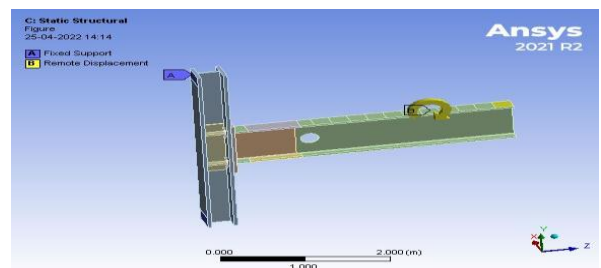In sixth case the parametric study was based on changing the position of holes by 1028.5 mm.

Fig 4.6 Model 6

In seventh case the parametric study was based on changing the position of holes by 1131.35 mm.
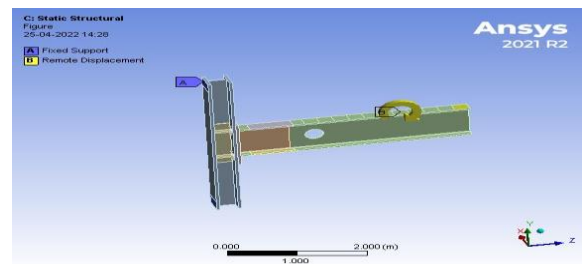

Fig 4.7 Model 7

In eighth case the parametric study was based on changing the position of holes by 1244.48 mm.
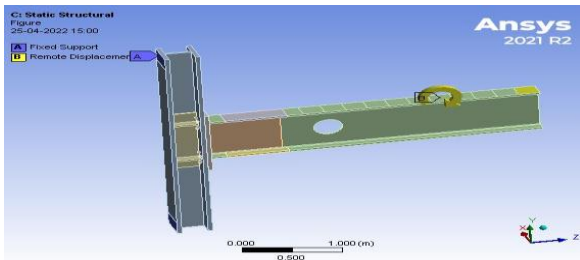

Fig 4.8 Model 8

4.2 Performance of BC with flange opening

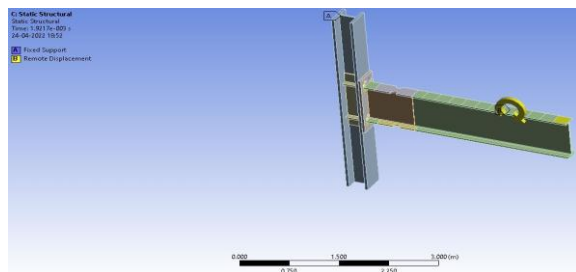In ninth case the flange removal is at a diameter of 110mm.

Fig 4.9 Model 9

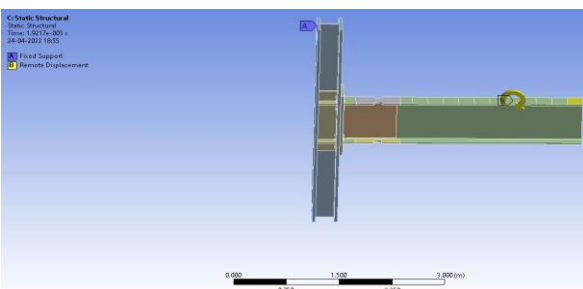In tenth case the flange removal is at a diameter of 121mm.

Fig.4.10 Model 10

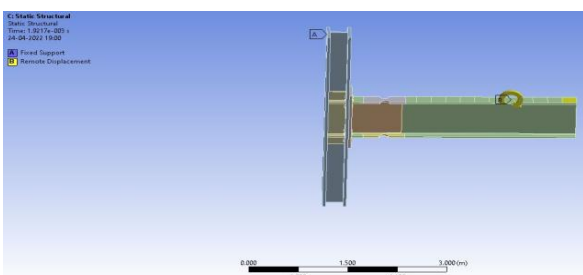In this case the flange removal is at a diameter of 133.1mm.

Fig 4.11 Model 11

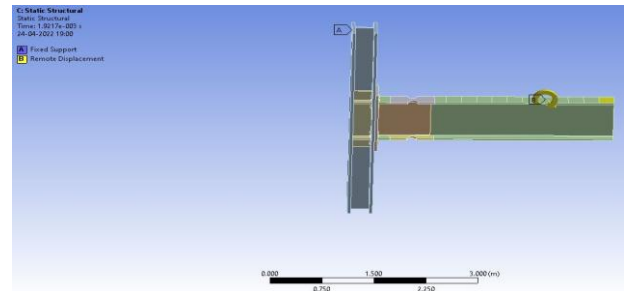In this case the flange removal is at a diameter of 146.41mm.

Fig 4.12 Model 12

5. RESULT AND DISCUSSION

After the changes are made in the model, analysis were done. Analysis are mainly done to determine the moment reaction, Von mises stress (Pa), Buckling load (N) of various model.

Table 3 Increasing diameter of hole by various diameter

Model No	Diameter of hole (mm)	Moment reaction (Nm)	Von mises stress (Pa)	Buckling load (N)	Inference
Model 1	223	2.88e+6	3.8275e8	2.1291e+6 x 2.3187 = 4936744.17	Buckling load resistant capacity improved by providing web opening
Model 2	245.3	2.855e+6	3.8365e8	2.3154 x 2.1211e+6 = 4911194.94	
Model 3	269.83	2.8287e+6	3.8361e8	2.3193 x 2.1109 e+6 = 4895810.37	
Model 4	296.81	2.7885e+6	3.917e8	2.2948 x 2.097e+6 = 4812195.6	

From the table above it is clear that the model 1 having high buckling load as compared to others. So buckling load resistant capacity can be improved by the web opening.

Table 4 Changing the position of hole by various diameter

Model no	Position of hole (mm)	Moment reaction (Nm)	Von mises stress (Pa)	Buckling load (N)
Model 5	935	2.9023e+6	3.8374e8	2.2785 x 2.133e+6 = 4860040.5
Model 6	1028.5	2.9216e+6	3.8153e8	2.2952 x 2.1353e+6 = 4900940.56
Model 7	1131.35	2.9361e+6	3.8375e8	2.3298 x 2.1384e+6 = 4982044.32
Model 8	1244.48	2.9456e+6	3.8789e8	2.3212 x 2.142e+6 = 4972010.4

From the table it is clear that the model 7 have high buckling load as compared to others.

Table 5 Removing the flange hole by various diameter

Models	Diameter of hole (mm)	Moment reaction (Nm)	Von mises stress (Pa)	Inference
Model 9	110	2.7284e+6	3.9097e8	• Less Stress less failure
Model 10	121	2.6785e+6	3.9094e8	
Model 11	133.1	2.6133e+6	3.9077e8	
Model 12	146.41	2.5329e+6	3.907e8	

From the table above it is clear that the model 16 with flange removal is from a hole diameter of 146.41mm shows less moment reaction as compared to others. So in this case less stress as well as less failure will occur.

7. CONCLUSIONS

This study report discuss about an unstiffened different types of bolt arrangement for seismic applications. The connection provides a bolt arrangement which help to increase uniform distribution of forces throughout the bolt group. It describes the results of testing of the unstiffened different types of bolts by using ANSYS Workbench. The details of experimental developments are done using the ANSYS software. It is clear that model 1 and model 7 having high buckling load as compared to others. So buckling load resistant capacity can be improved by using the web opening. Model 16 with flange removal is from a hole diameter of 146.41mm shows less moment reaction as compared to others. So in this case less stress as well as less failure will occur.

ACKNOWLEDGEMENT

REFERENCES

[1] Machel L. Morrison, Doug Q. Schweizer, Shahriar Quayyum and Tasnim Hassan (2021), "An Unstiffened Eight-Bolt Extended End-Plate Moment Connection for Special and Intermediate Moment Frames", Journal of Structural Engineering, Volume 145 Issue 7

[2] Xiaohui Zhang, Shansuo Zheng, Xuran Zhao (2019), Seismic performance of steel beam to-column moment connections with different structural forms, "Journal of Constructional Steel Research, Volume 158, Pages 130-142, ISSN 0143-974X.

[3] Yasin Onuralp Özkılıç, Cem Topkaya (2021), "The plastic and the ultimate resistance of four-bolt extended end-plate connections", Journal of Constructional Steel Research, Volume 181, 106614, ISSN 0143-974X

[4] Vlada Gašić, Aleksandra Arsić, Nenad Zrnić (2021), "Strength of extended stiffened end-plate bolted joints: Experimental and numerical analysis," Structures, Volume 33, Pages 77-89, ISSN 2352-0124

[5] Xiaoyi Lan, Shuai Li, Ou Zhao (2021), "Local buckling of hot-rolled stainless steel channel section stub columns after exposure to fire", Journal of Constructional Steel Research, Volume 187, 106950, ISSN 0143-974X

[6] Asan Mahjoob Behrooz, Saeed Erfani (2020), "Parametric study of Stub-Beam Bolted Extended End-Plate connection to box-columns," Journal of Constructional Steel Research, Volume 171, 106155, ISSN 0143-974X

[7] Xue-Chun Liu, Yue Wang, Xiao-Xiong Cui, Cheng Yu, Zheng-Xian Bai (2020)," Seismic performance of bolted beam-to-column connection with rib-stiffened splicing plate," Journal of Constructional Steel Research, Volume 174, 106300, ISSN 0143-974X

[8] Chen, Jingsi Huo, Wensu Chen, Hong Hao, Ahmed Y. Elghazouli,(2020), "Experimental and numerical assessment of welded steel beam-column connections under impact loading," Journal of Constructional Steel Research, Volume 175, 106368, ISSN 0143-974X

[9] Ashraf ElSabbagh, Tarek Sharaf, Salah Nagy, Mohammed ElGhandour, (2019), "Behavior of extended end-plate bolted connections subjected to monotonic and cyclic loads," Engineering Structures, Volume 190, Pages 142-159, ISSN 0141-0296

[10] Jothiarun Dhanapal, Hossein Ghaednia, Sreekanta Das, Jonathan Velocci, (2020)," Behavior of thin-walled beam-column modular connection subject to bending load", Thin-Walled Structures, Volume 149, 106536, ISSN 0263-8231

[11] Hamdolah Behnam, J.S. Kuang, Bijan Samali (2018), "Parametric finite element analysis of RC wide beam-column connections", Computers & Structures, Volume 205, Pages 28-44, ISSN 0045-799

[12] X.C. Liu, X.N. He, H.X. Wang, A.L. Zhang (2018), "Compression-bend-shearing performance of column-to-column bolted-flange connections in prefabricated multi-high-rise steel structures," Engineering Structures, Volume 160, Pages 439-460, ISSN 0141-0296

[13] Machel Morrison, Shahriar Quayyum, Tasnim Hassan (2017), "Performance enhancement of eight bolt extended end-plate moment connections under simulated seismic loading", Engineering Structures, Volume 151, Pages 444-458, ISSN 0141-0296