IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 5 Issue 4, April 2018
ISSN (Online) 2348 – 7968
www.ijiset.com

Prediction of Behaviour of Steel Beam-Column Joint with Pretensioned Bolt Connectors

Aarsha Balan[1], Manju George[2]

[1]Civil Engineering Department, APJ Abdul Kalam Technological University, Mar Baselious Institute of Technology and Science Nellimattom, Ernakulam, India

[2] Civil Engineering Department, APJ Abdul Kalam Technological University ,Mar Baselious Institute of Technology and Science Nellimattom, Ernakulam, India

Abstract

The beam-column joint is one of the most important and crucial part of any structure. Pretensioned bolt connectors are used to improve the strength and stiffness of the joint. The steel beam-column joint is modelled in ANSYS considering different loading conditions with variation of pretension applied to the bolts. This investigation focuses on analyzing the variation of stress, strain, pressure and frictional stress of the bolts under different types of loading conditions. It is observed that there is a decrease in values of stress, strain, pressure and frictional stress in the model with pretensioned bolts and cyclic loading at the end of the beam which decrease the slippage and improve the shear resistance, joint separation, fatigue resistance. Moment rotation response corresponding to cyclic loading is also obtained.

Keywords: *Stiffness, Pretension, Cyclic, Fatigue Resistance, frictional stress, slippage, shear resistance, moment-rotation response.*

1. Introduction

Beam column joint is the part of column where beam intersects. Design of beam column joint is one of the most challenging design in the structures and structural engineers have to be careful in the design of these components as it affect the safety of the structures**.** A thorough knowledge of the different types of load acting should be considered in the design of structures. Mainly the beam-column joint fail by three modes including, inadequate transverse and vertical reinforcement ,anchorage failure and shear failure. High shear stress is induced in the structure due to external forces, which causes diagonal cracks. Strength and stiffness of joint is affected by load reversal leading to shear deformation and extensive cracking.

This proposed study focuses on analyzing the difference in variation of stress, strain, pressure and frictional stress values with and without pretension bolts under four types of loading.

2.Characteristics of pretensioned bolts

In a pretensioned bolt, high tension is introduced above yield strength so that a better load carrying capacity is enabled in the whole structure. Benefits of using pretensioned bolt includes rigidity of joints (no slip in service),no loosening of bolts due to vibrations, better fatigue performance, tolerance for fabrication/erection (because of the use of clearance holes).Familiarity within industry.

3.Procedures

Investigation is conducted on steel beam column joint using pretensioned bolt connectors having end-plates.The thickness of end plate is choosen to avoid prying action.The behaviour of the connection is assessed for the different types of loading :one with load at the tip of the beam without pretensioning of bolts, second with load at the tip of the beam with pretensioning of bolts, third with cyclic rotations at the end of the beam without pretensioning of bolts and last with cyclic rotations at the end of the beam with pretensioning of bolt.The main objective is to study the behaviour of steel beam-column joint with filled rib under following criteria:

1. To study the effect of different parameters
    a. Joint without pretensioned bolts.
    b. Joint with pretensioned bolts
2. To compare various parameters like equivalent stress, equivalent elastic strain, frictional stresses and pressure with the filled rib connection with following conditions:
    a. Loading at the tip of the beam.
    b. Cyclic rotations at the end of the beam.
3. To understand the variation of yield criteria on the filled rib type of connection with cyclic rotations at the end of the beam.

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 5 Issue 2, April 2018
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4.Numerical Stimulation

A three-dimensional model was prepared using ANSYS software. A steel beam-column joint with 16 number of bolts were used for connection. The details and dimensions of connection elements are presented in Fig. 1.

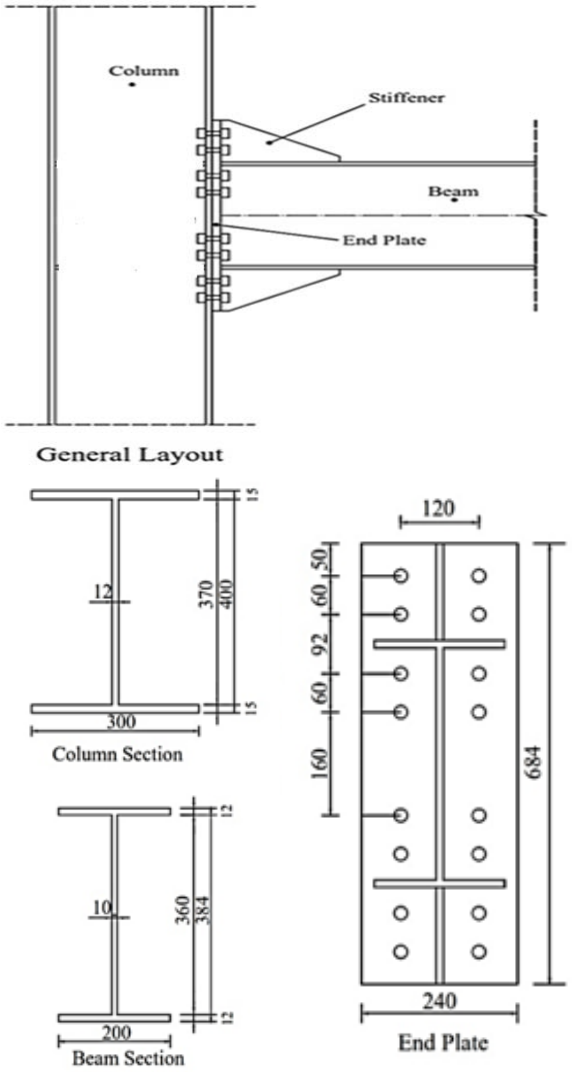

Fig 1 The details and geometrical dimensions of beam column joint

The element type used is SOLID 185 for the model. The column was considered fixed at the top and bottom.The material properties of connection element is shown in Table1.The proposed connection system are connected to each other frictionally with a friction coefficient of 0.2 and dimensions of beam-column joint is tabulated in Table 2 . The model of steel beam column joint with filled rib is shown in Fig 2.

Table 1 Material properties of connection elements

Material	Modulus of elasticity (GPa)	Poisson's ratio	Yielding stress (MPa)	Ultimate stress (MPa)
ST37	200	0.3	240	370
HS 8.8 (ASTM 325)	200	0.3	640	800

Table 2 Dimensions of beam column joint

Length of beam	1.5m
Length of column	3.2m
Diameter of bolt	22mm
Filled steel rib	200mmx200mmx12mm

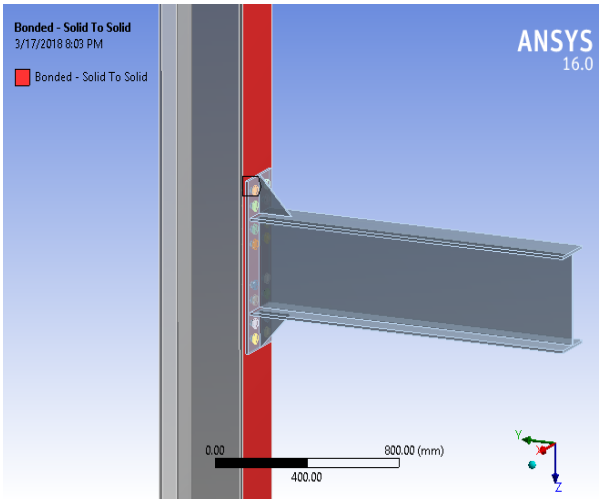

Fig 2 The model of beam column joint with filled rib

5.Finite Element Analysis

Loading is applied to the steel beam-column joint with filled rib in the following .

1. A load of 1000 N is applied at the tip of the beam and without pretensioning of bolts is shown in Fig 3

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2. A load of 1000 N is applied at the tip of the beam and bolts are pretensioned by 100 N load is shown in Fig 4.
3. Cyclic rotations are applied at the end of the beam and without pretensioning of bolts is shown in Fig 5
4. Cyclic rotations are applied at the end of the beam and bolts are pretensioned by 100 N load is shown in Fig 6.

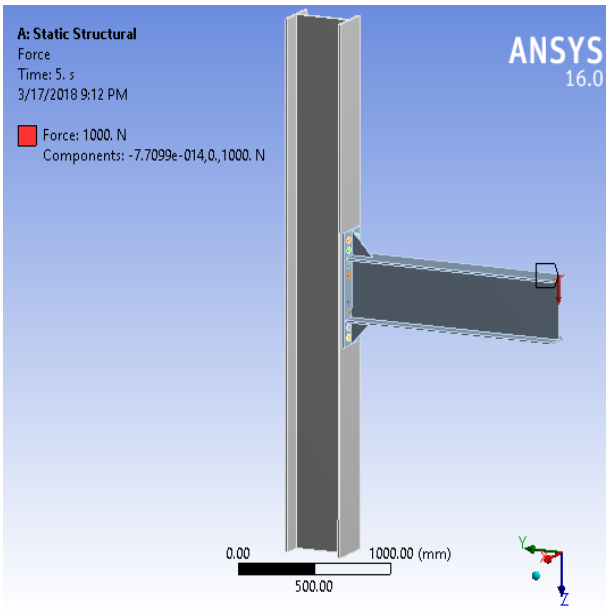

Fig 3 Loading at the tip of the beam and without pretensioning of bolts

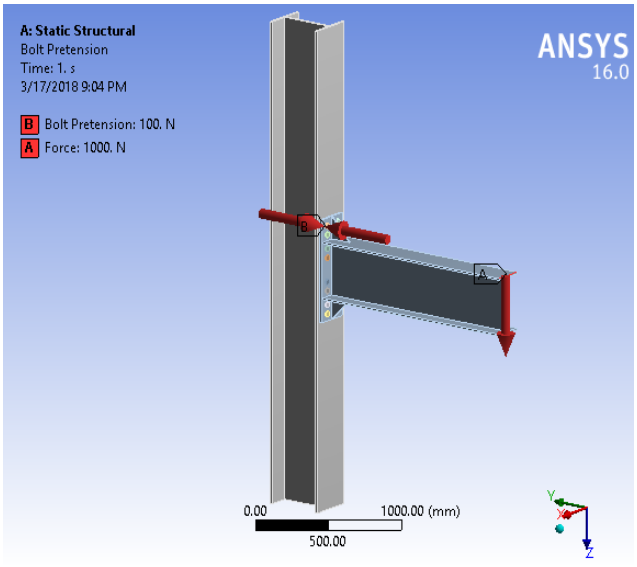

Fig 4 Loading at the tip of the beam and with pretensioning of bolts

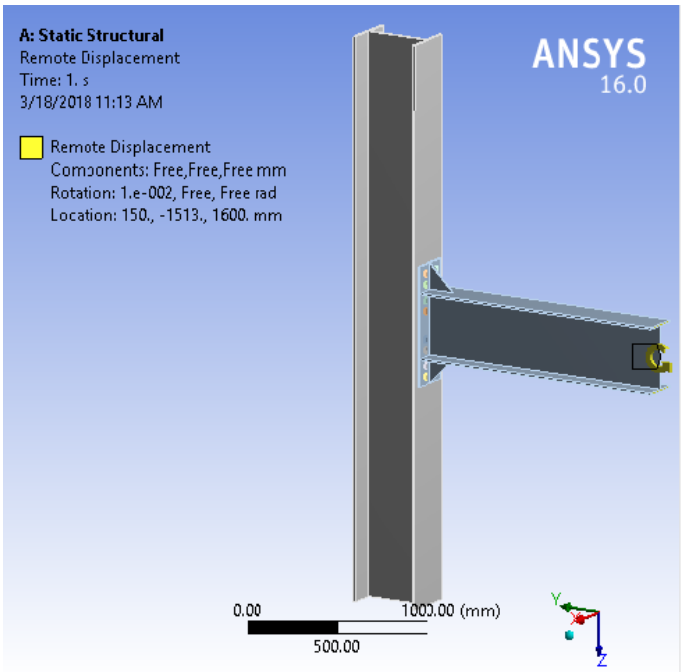

Fig 5 Cyclic rotations are applied at the end of the beam and without pretensioning of bolts

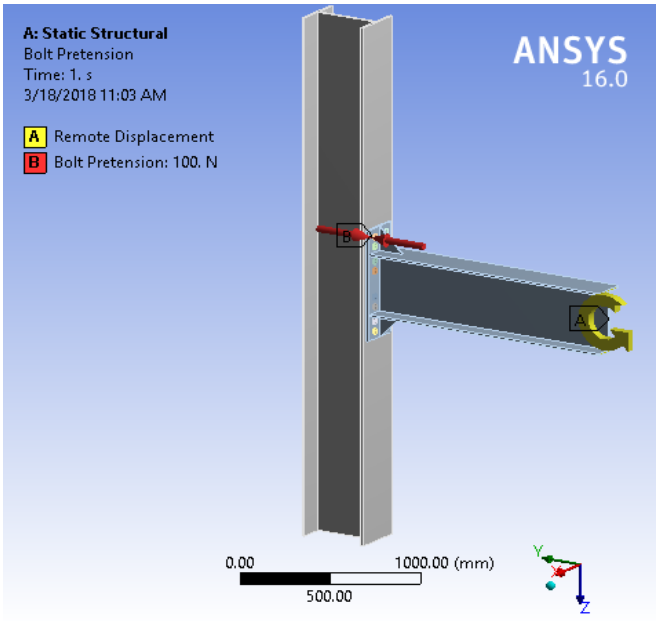

Fig 6 Cyclic rotations are applied at the end of the beam and pretensioning

6. Results and Discussions

The models were statically analysed and the results obtained are discussed below and the notations used for different models is given in Table 3.

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Table 3 Notations used for different models

Description of the model	Notation
Steel beam-column joint with filled rib, without pretensioned bolts and load applied at the tip of the beam.	FWOPL
Steel beam-column joint with filled rib, with pretensioned bolts and load applied at thetip of the beam.	FWPL
Steel beam-column joint with filled rib, without pretensioned bolts and cyclic rotations applied at the end of the beam.	FWOPC
Steel beam-column joint with filled rib, with pretensioned bolts cyclic rotations applied at the end of the beam.	FWPC

The comparison of above results with loading at the tip of the beam tabulated below in Table 4 and the comparison of above results with cyclic rotation at the end of the beam tabulated below in Table 5.

Table 4 Comparison of results with loading at tip of the beam

MODELS	FWOPL	FWPL
Eq.Stress (MPa)	15.497	5.328
Eq.Strain	$7.8e^{-5}$	$2.8e^{-5}$
Frictional Stress(MPa)	2.046	0.124
Pressure(MPa)	5.678	0.584

Table 5 Comparison of results with cyclic rotation at the end of the beam

MODELS	FWOPC	FWPC
Eq.Stress (MPa)	1709.8	280
Eq.Strain	0.0086	0.0014
Frictional Stress(MPa)	632.82	26.772
Pressure(MPa)	865.14	114.19

From the above tabulated datas we can conclude that when pretensioned load is applied the value of equivalent von-Mises stress, strain, pressure and frictional stress is decreased. Hence it can carry more load without any large deformations before reaching its yield point. The frictional stress values for models with pretensioned bolt is less compared to that models without pretensioned bolt. Lesser the frictional value, greater is the shear resistance and improved the fatigue resistance. The yield stress value of steel is 310MPa.When cyclic rotations are provided at the end of the beam without pretensioned bolts, the yield stress value exceeds its maximum and greater stress value is obtained for small strains.In case of model with pretensioned bolts, the yield stress value lies within the limit.

5.1 Comparison of Cyclic Response with and Without Pretensioned Bolts

5.1.1 Moment-rotation response

The moment-rotation plots for different steel beam-column joint models and their comparison which are drawn from analysis are given below..

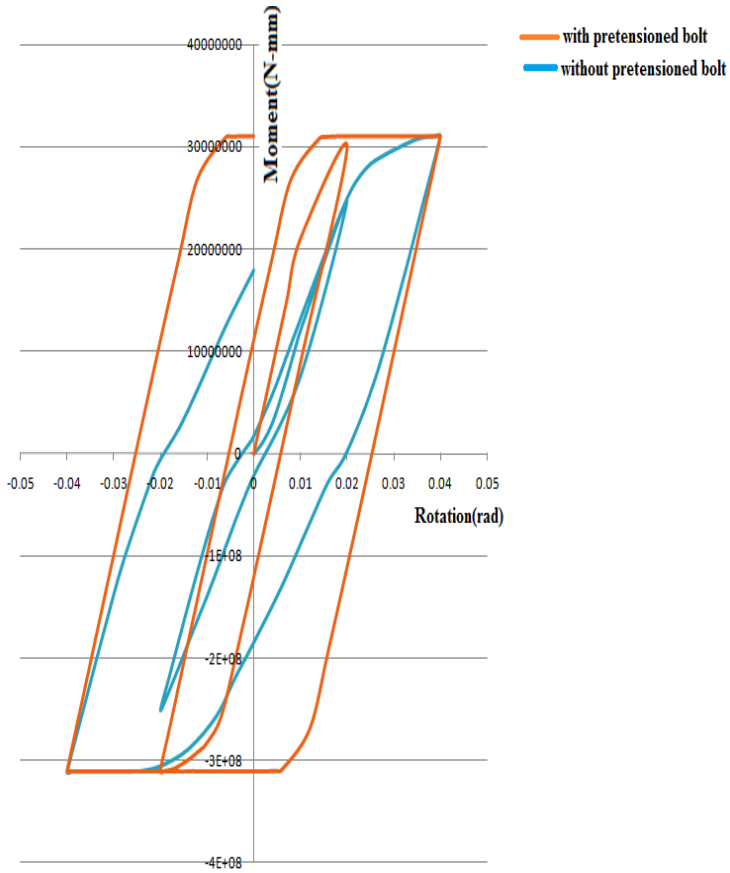

Fig 7 Moment –rotation graph for steel beam-column joint

From Fig 7, we can see that for a steel beam-column joint with filled rib and pretensioned bolt connectors maximum moment of 31kN-m is obtained corresponding to 0.015 rad of rotation and steel beam-column joint with filled rib and without pretensioned bolt connectors maximum moment of 31kN-m is obtained corresponding to 0.04 rad of rotation.Hence in case of joint without pretensioned bolt connectors more rotations are required to obtain the same value of moment compared to that model with pretensioned bolt connectors.

Conclusions

The finite element model was developed by using ANSYS 16 software.For the model, four different types of conditions are applied by varying the pretension in the bolt, cyclic rotations and loading.Support conditions are assumed as fixed on both the ends of the column.Analysis was carried out and result was obtained.

1. By using pretensioned bolt connectors the equivalent stress, equivalent strain, frictional stress and pressure values are decreased to lesser values.
2. Based on the cyclic rotations provided at the end of the beam,moment-rotation graph for models was plotted.The graph pattern shows that,the moment values for the steel beam-column joint with pretensioned bolt connectors is greater for lesser number of rotations.
3. Hence yielding happens only after taking greater moment values with lesser number of rotations as compared to the steel beam-column joint without pretensioned bolt connectors.In overall,the shear resistance, joint separation, fatigue resistance of bolt is improved.

References

[1] Nader Fanaiea and Morteza N. Monfared, Cyclic behavior of extended end-plate connections with shape memory alloy bolts,Structural Engineering and Mechanics, (2016).

[2] Xing-wen Liang , Ying-jun Wang, Yi Tao, Ming-ke Deng ,Seismic performance of fiber-reinforced concrete interior beam-column Joints ,Engineering Structures (2016) .

[3] M.M. ArabnejadKhanouki , N.H. RamliSulong , Mahdi Shariati , M.M TahirInvestigation of through beamconnection to concrete filled circular steeltube (CFCST) column, Journal of Constructional Steel Research (2016).

[4] Xuhong Zhou , Guozhong Cheng , Jiepeng Liu , Dan Gana, Y. Frank Chen ,Behavior of circular tubed-RC column to RC beam connections underaxial compression, Journal of Constructional Steel Research (2017) .

[5] Lewei Tong , Yingzhi Chen, Yiyi Chen, Cheng Fang ,Cyclic behaviour of beam-to-column joints with cast steel connectors ,Journal of Constructional Steel Research (2016).

[6] OzgürYurdakul ,OzgürAvsar, Strengthening of substandard reinforced concrete beam-column joints by external post-tension rods , Engineering Structures(2016)

[7] Tian-Yi Song ,Zhong Tao , Ali Razzazzadeh , Lin-Hai Han , KanZhou,Fire performance of blind bolted composite beam to column joints,Journal of Constructional Steel Research (2017)