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LONG BOLTED END-PLATE MOMENT CONNECTIONS

M. SenthilPandian and M. Helen Santhi
Division of Structural and Geotechnical Engineering,
School of Mechanical and Building Sciences, VIT Chennai, TamilNadu, 600127, India

ABSTRACT

This paper provides the efficient and economical moment connection details of a cold formed tubular beam column end plate joint with different arrangemet of long bolts. Totally nine models are created and analysed using the finite element software ANSYS APDL. The size of the beam and column sections used is 700 mm x 50 mm x 100 mm and 900 mm x 50 mm x 100 mm, respectively. The thickness of the section is 2.0 mm. The end plate size is 100mm x 150mm x 2.5mm and 6 mm diameter long bolts are used to connect the members in the joint. The performance of end plate and long bolts during the loading is investigated. For validation, one of the models is tested to failure and found satisfactory. The results of the analysis show that the end plate deformation in tension zone is reduced by adding more number of bolts and the symmetrical arrangement of long bolts increase the rigidity of the joint and prevent the detachment of end plate from column face. The models HS2.5P-6 and HS2.5P-9 show almost similar behaviour in terms of moment-rotation and therefeore from economic design and fabrication point of view the model HS2.5P-6 may be considered as the best suitable connection.

Keywords: Cold Formed steel, Tubular section, End Plate, Long Bolt, Moment-rotation

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1. INTRODUCTION

The cold formed steel sections are joined by various methods, namely, screwed connections, welded connections and bolted connections [1]. The design of the beam- column joint is important in the overall performance of steel frames [7]. In order to have easy fabrication and transfer of load from beam to column end plates are used. The extended end plate joints are used in the investigation for the moment connection such as beam to column connection and beam to beam connection [2] [13] [14]. In recent days the welded end plate connection are widely used because of its simplicity [3] [12]. In prefabricated steel industries, open steel sections are widely used and the column sections can be modified based on the requirement of moment and shear as specified in the design standards [5] [6] [9]. In the recent past the usage of tubular steel sections is gaining importance in the construction industry.

Tubular sections used in the construction of beams and columns have many advantages than the open sections as for the same cross sectional area the tubes have more moment of inertia compared to open sections, inturn increases their bending and torsional strength [18]. Tubular columns have wider area when compared to open sections so that the short columns may be made which are more stable and buckling can be avoided [19]. Also tubular sections have a larger contact area to transfer the load on adjacent structural elements [8] [16].

In tubular sections, the connections are made up of using either the blind bolt or the long bolt [15]. The specifications of blind bolts have been described in the European standard [4]. The connections between the structural elements using tubular sections with blind bolts may deter the efficiency of the joints. It is felt that the usage of long bolts would overcome this deficiency. Very rarely the long bolts are used in the construction industry and there is no design details available as of now; a very few researches are under progress [20]. Therefore an attempt has been made in this study to investigate the moment-rotation capacity of the tubular beam-column end plate connection with long bolts using the Finite Element Analysis software ANSYS Apdl [10] [11][17]. In addition the influence of the number of bolts and their position on the moment-rotation capacity is studied.

2. OBJECTIVE AND SCOPE

The present research is to study the behavior of the bolted moment joint between two tubular sections via end plate analytically. Totally nine models have been studied by varying the number of bolts in the joint. The thickness of end plate is 2.5 mm and the diameter of bolt is 6 mm. The study focuses on the following:

- To investigate the behavior of the end plate
- To investigate the behavior of the bolts in different position in the joint
- To establish the overall structural performance of the joint in terms of moment rotation.

3. ANALYTICAL INVESTIGATION

3.1. Pre processing

3.1.1. Geometric details

In this study, 2 mm thick cold rolled rectangular tube sections are utilized. The size of the beam and column sections used is 700 mm x 50 mm x 100 mm and 900 mm x 50 mm x 100 mm, respectively. The end plate is welded with the beam and then the beam is connected to the column using 6 mm diameter long bolts. It has been assumed that the failure of the bolted connection occurs first i.e either the failure of the bolt or the end plate and then the failure occurs in the weld. The size of the end plate is fixed as 100mm width 150 mm height and 2.5 mm thickness by taking into consideration of the size of the column, beams, and bolts.

3.1.2. Details of Joints

Totally nine numbers of connections are used with a constant thickness of the end plate with varying number of the bolts in the joint. The schematic view of the connections' details is shown in Figure 1. The various arrangements of bolts in the joint are decided based on the expected failure pattern in the end plate and bolts and also for attaining maximum moment transfer in the joint.

Figure 1 Connections' details

3.1.3. Finite element model

The finite element modeling of the joint is made in the ANSYS apdl. The loading is applied at the end of the beam gradually. The column is assumed to be rigid in all direction at their ends. The solid 185 elements are used in the modeling which has three degrees of freedom at each node and capabilities of large deflection. Bonded contact (i) between bolt washer and end plate and (ii) between washer and column face has been created. Sliding contact between end plate and column face has also been created to get the response. To represent the 3D target surface TARGE170 element is used, which laid over on the solid element. An associated contact surface of CONTA173 is used for bonding and sliding contact to transfer the forces.

The bolts and washers are modeled together assumed to be as a single element. The washer is considered as a contact surface and end plate and column section is considered as a Target surface. Contact status assumed is always bonded. End plate surface is represented as the contact surface and column section as a Target surface. The behavior of the contact surface is considered as sliding.

3.1.4. Meshing

In this finite element analysis, the hexahedra meshing are used to increase the number of elements and this will not increase the size of the global finite element matrices. The size of the element is varying based upon the quality of the meshing. The minimum size of the mesh used is 0.65 mm and maximum size of the meshing is 5mm.

3.1.5. Material Properties

The material properties of the sections (Table 1) are experimentally tested and same have been fed into ANSYS apdl. The friction coefficient used in the section is 0.3and Poisson's ratio IS 0.3.

Table 1 Material properties of the sections

Sl.No	Section	Elastic Modulus (N/mm2)
1	Column and Beam	2.10 x 105
2	Bolt	2.02 x 105
3	End Plate	1.95 x 105

3.2. Post processing

The analysis is done by using geometry and material nonlinearity. The loads are applied in two steps; the first step is the pretension of the bolt and the second is an external load to the structure at the free end of the beam. Newton Rapson method approach is chosen to resolve this nonlinear behaviour to have better convergence.

4. VALIDATION OF ANALYSIS

An experimental study has been carried out on the model, HS2.5P-1 and it has been compared with the simulation model. The results are well comparable and is shown in Figure 2. With the confidence gained from validation, the authors have planned and analyzed the end plate beam-column joint with different possible arrangements of long bolts for the optimum connection details.

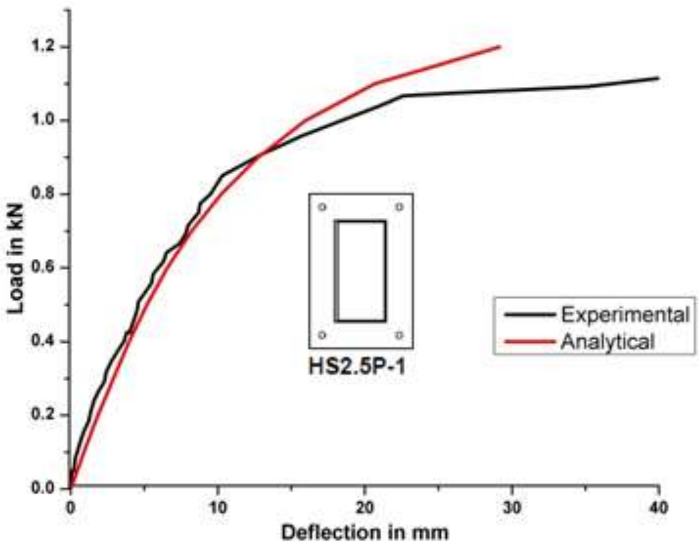

Figure 2 Validation of analysis

5. RESULTS AND DISCUSSION

5.1. End Plate Deformation

The end plate deformation pattern at the ultimate load is indicated in Figure 3 and the plate is subjected to tension and compression due to the external load acting at the beam end. When the force is subjected to act at joint tends to transform the moment i.e joint subject to rotate. In this simulation, the end plate and bolts play a major role to transfer force to the column.

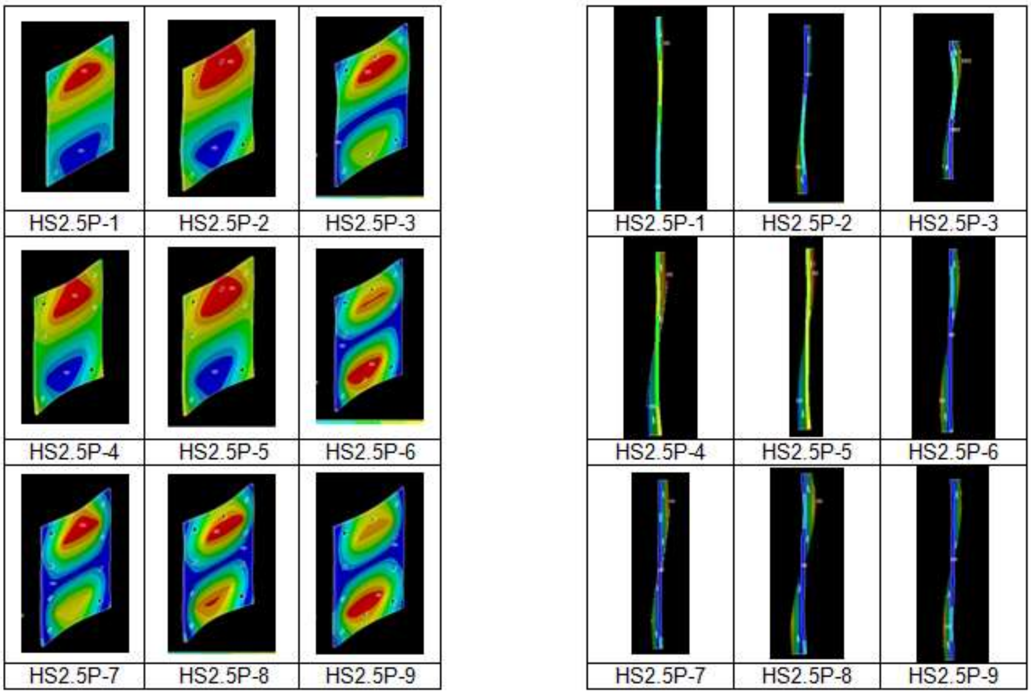

Figure 3 End Plate deformation

The load versus deflection behavior of end plate in all models at the tension zone and compression zone is shown in Figures 4 and 5, respectively. It is observed that the deformation of the end plate is more in the tension zone than the compression zone. It can be seen that the models HS2.5P-6 and HS2.5P-9 show good response in tension i.e good both in stiffness and strength. In the compression zone, the models HS2.5P-3, HS2.5P-6 and HS2.5P-9 show fruitful results due to the additional bolts at the bottom of the end plate.

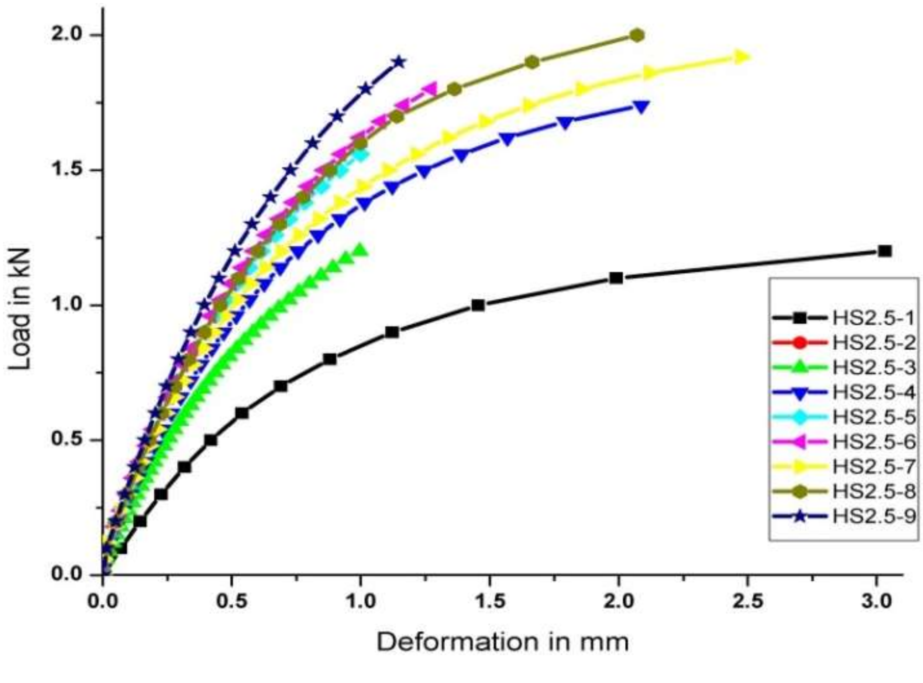

Figure 4 End Plate deformation in Tension

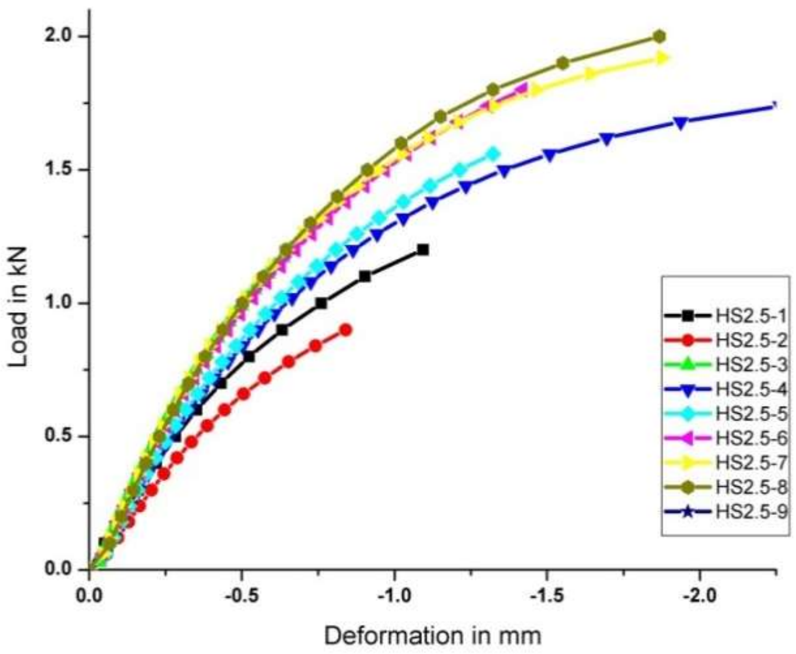

Figure 5 End Plate deformation in Compression

5.2. Bolt Deformation

In general, an increase in the number of bolts decrease deformation; by cleverly arranging the bolts, the joint can be made stiffer with less number of bolts. Figure 6 indicates the deformation in the bolts at the maximum load for different models. In tension and compression zones as shown in Figures 7 and 8, the models HS2.5P-6, HS2.5P-8 and HS2.5P-9 show reasonable results. It is evident that the increase in the number of bolts decreases the deformation. It is also observed that the symmetrical arrangements of bolts reduce the deformation and increase the rigidity of the connection.

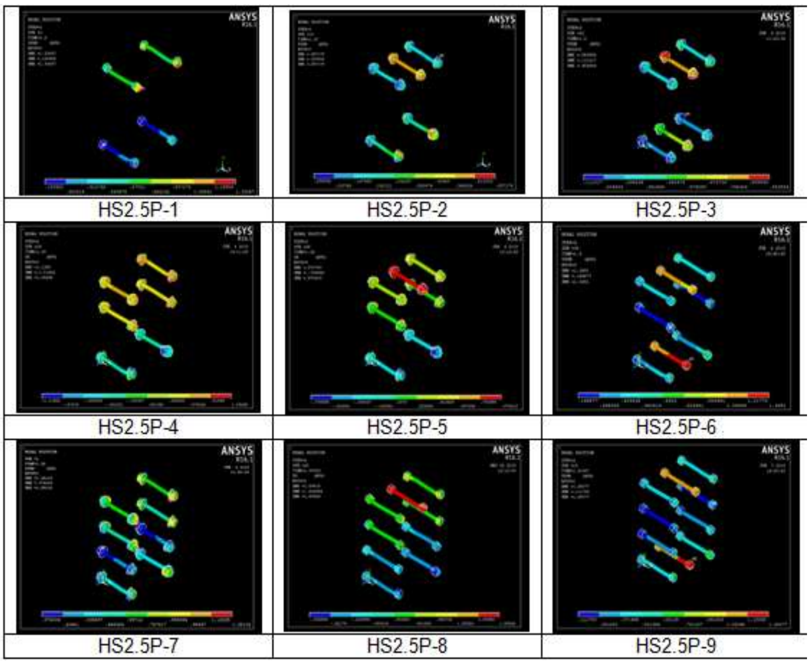

Figure 6 Bolt Deformation

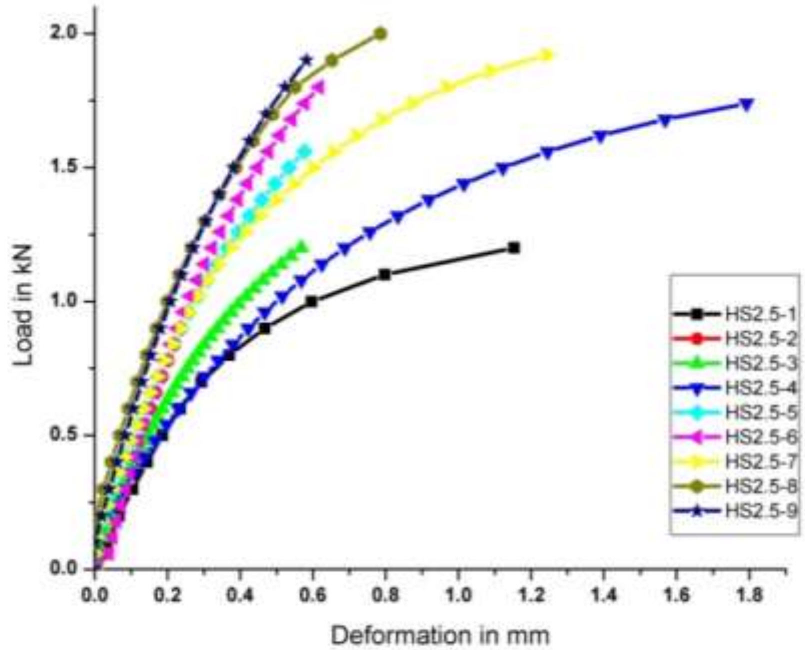

Figure 7 Bolt deformation in Tension

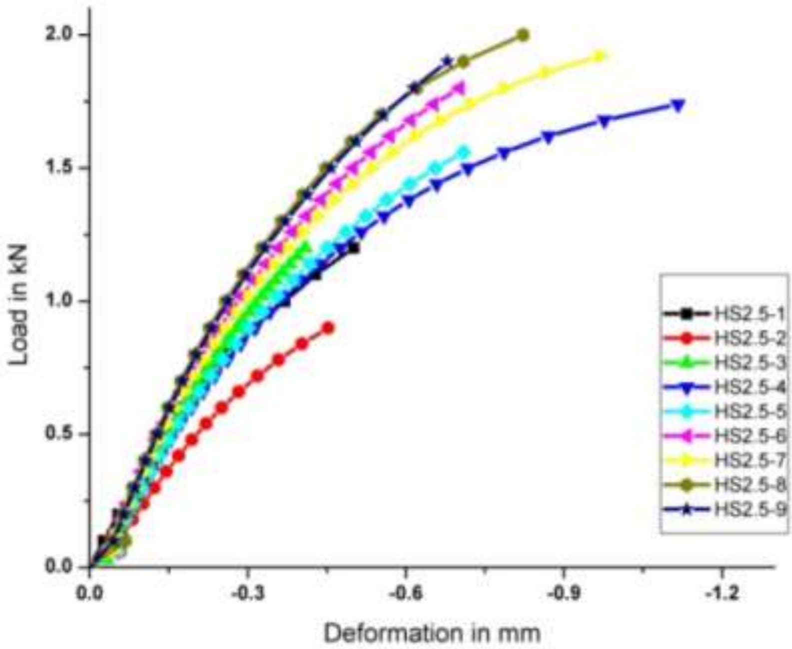

Figure 8 Bolt deformation in Compression

5.3. Contact Sliding of Joint

Figures 9 and 10 show the failure of the joint in different models. As the external load is applied at the end of the beam section the contact between the end plate and column tries to come apart as shown in Figure 9. When the pitch distance is large then there is a buckling in the end plate in tension and compression. The models HS2.5P1, 4 and 7 clearly show that the end plate contact is sliding and move away from the column due to larger pitch distance. Whereas an increase in the number of bolts in the tension side i.e top bolts in HS2.5P2, 5 and

8 prevent the end plate from buckling. Models HS2.5P3, 6 and 9 behave uniformly in both tension and compression zones.

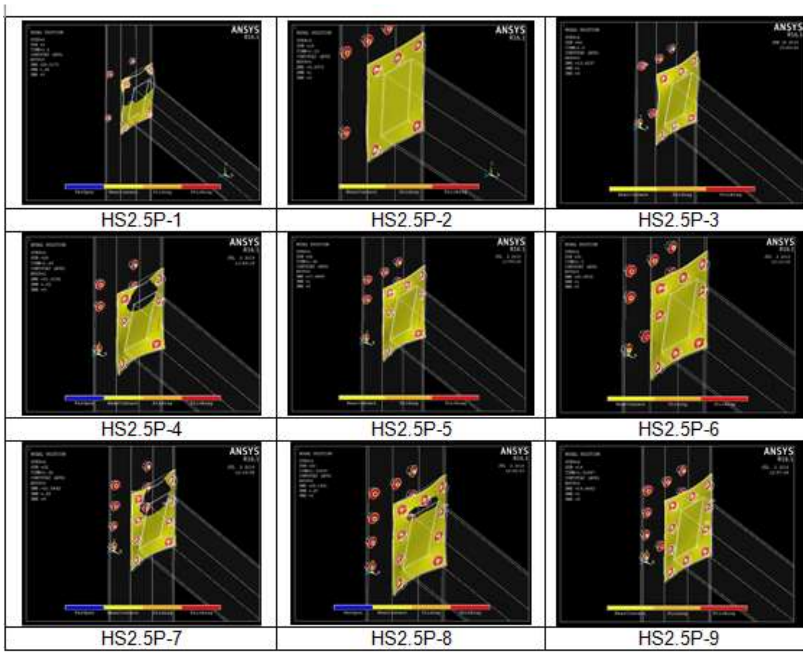

Figure 9 Sliding Contact behaviour

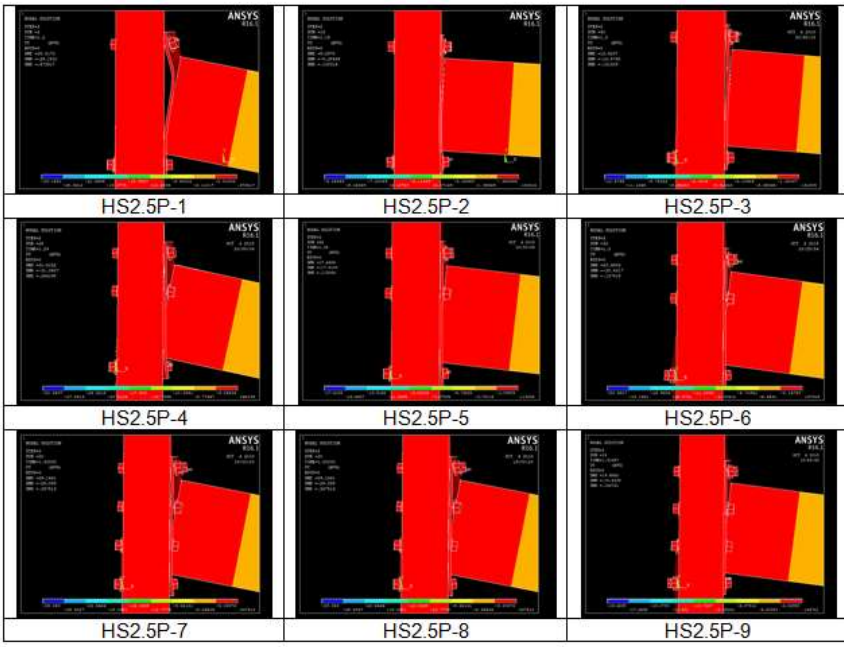

Figure 10 Failure of Connection

5.4. Moment-rotation behaviour of joint

The moment –rotation behaviour of all the models under study is shown in Figure 11. It is observed that the moment transfer capacity of the models increases with the addional number of bolts. The initial stiffness of the models other than HS2.5P-1 is good. However the models, HS2.5P-6 and 9 produce better performance than other models in view of moment-rotation. This may be due to the more number of bolts and their symmetrical arrangement in the joint.

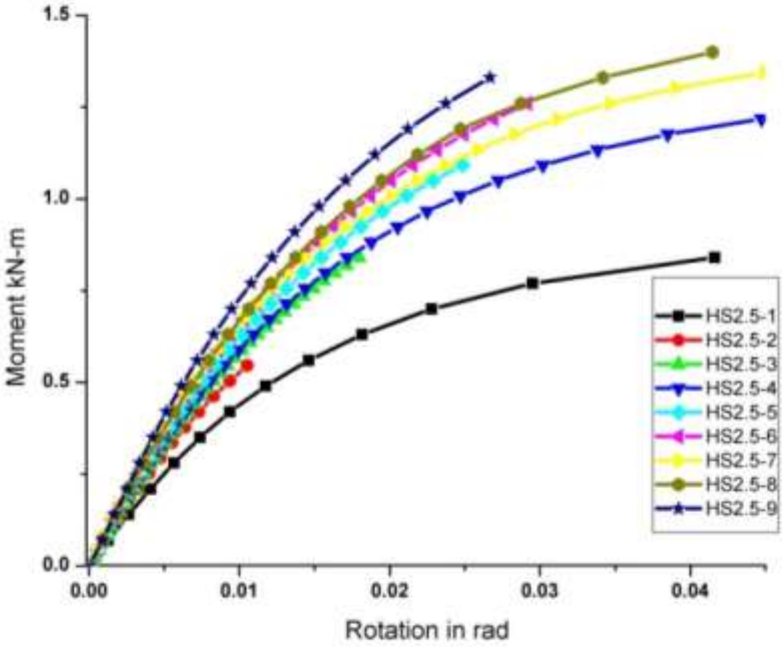

Figure 11 Moment – rotation behavior of joint

6. CONCLUSION

In this study the moment –rotation behaviour of a cold formed tubular beam column end plate joint with different arrangemet of long bolts is investigated and the following conclusions are made.

1. The increase in the number of long bolts make the joint stiffer and stronger
2. The end plate deformation in tension zone is reduced by introducing additional number of bolts
3. The symmetrical arrangement of long bolts increase the rigidity of the joint and prevent the detachment of end plate from column face.
4. Moment-rotation behaviour of the models HS2.5P-6 and 9 is better than other models. The diffenrence in moment-rotation capacity between these models is meager, therefore the model HS2.5P-6 may be considered as the best option for design and fabrication in view of economy.

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