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BEAM TO RECTANGULAR HOLLOW SECTION COLUMN JOINT USING LONG BOLTS

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ملخص البحث

إن وصلة لوح النهاية للكمرة مع العمود المفرغ ذو القطاع المستطيل عادة ما تتم بإستخدام واحدة من الطرق التقليدية مثل المسامير الخاصة أو إستخدام عنصر وسيط وبالرغم من إن تلك الوصلات تتغلب على صعوبة وضع المسامير عندما يكون قطاع العمود مغلق فإن هذه الحلول لها عدة عيوب مثل تكلفتها العالية وصلابتها ومقاومتها المنخفضة. يعد إستخدام المسامير الطويلة لوصل الكمرة إلى العمود المستطيل المفرغ بديل جيد للتغلب على العيوب المذكورة سابقا حيث إن ثمن هذه الوصلة منخفض مقارنة بالوصلات الأخرى كما أن صلابة ومقاومة هذه الوصلات من الممكن أن تكون أفضل كثيرا من مثيلاتها السابقة ولهذا فسوف يتم إجراء دراسة عددية بإستخدام طريقة العناصر المحددة لوصلات الكمرات مع العمود المستطيل المفرغ باستخدام المسامير الطويلة و يتم ذلك من خلال عمل نموذج عددي لاخطي بإستخدام برنامج العناصر المحددة (ABAQUS). يتم التحقق من نتائج نموذج العناصر المحددة و ذلك بمقارنتها بنتائج تجارب معملية وتشمل أيضا هذه الدراسة إستخدام نتائج هذه الدراسة البارامترية دراسة وصلات الكمرات مع العمود المستطيل المفرغ باستخدام المسامير الطويلة و العوامل المؤثرة على تلك الوصلات.

Abstract

In any structural system, beam to column moment connections have always been a matter of interest. Using closed column sections such as RHS or SHS in bolted moment connections may be a problem, since not a lot of alternatives are provided in front of any designer engineer. Unless joint is located at the near opened end of the column, difficulty in accessing the inner closed column face may stand as a barrier for utilizing common moment connections for this joint.

Using long bolts is presented as a good alternative to be used for overcoming all these previously mentioned defects, also column face would not be subjected directly to tensile stresses and so the applied forces will be resisted by the whole column. This would lead to improving the joint rigidity and resistance.

Numerical work was used for simulating this joint, but first the simulation for the moment connections was verified against a previous experimental work for beam to column moment connection.

Finite element models for beam to closed column moment connection through long bolts were modelled via ABAQUS software program to help having a better understanding for the behaviour of such joints.

Parametric study was made to study the effect of some parameters such as end plate and column wall thicknesses, bolt diameter, bolt grades, along with other special cases.

Keywords: Long bolts moment connection, closed steel column, numerical modelling.

INTRODUCTION

Moment connections have always been the concern of engineers in any structural framing, especially beam to column connections. End plate bolted connections are

considered one of the most familiar and important connection in these type of beam to column moment connection.
Although column sections can be executed using a various number of connections, whether these connections are bolted connections or welded connections, closed column sections don't have such various connections available to be used due to the difficulty of accessing the column's inner face and bolts placing unless this joint location is nearby open end of closed hollow section.

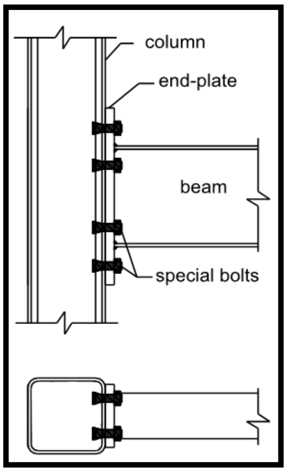

Figure 1 U channel connection

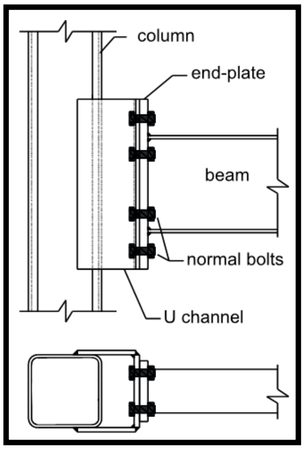

Figure 2 Special bolts connection

Connecting beam end-plates to closed column section columns may need a lot of preparations if it is carried out by cutting a hole access in the hollow column section to be able to tight the bolts from the inside of column or is usually carried out by one of the common ways as using special bolts (blind bolts/flow drill connectors) or using intermediate elements (such as U channels). While such connections can be used to overcome bolt placing difficulty, these joints may have some defects such as high cost, necessity of a high quality control, low rigidity and low resistance.

LITERATURE REVIEW

Studies for moment connections varied between numerical studies using finite element models and experimental works.

Numerical works:

Using numerical method is one of the ways that several engineers use in the different fields of studies in order to help them simulate the behaviour of structural members under different conditions. Example of numerical modelling is E. Mashaly et al. (2010). In Alexandria University, E. Mashaly et al. (2010) has conducted a study using finite element analysis for beam to column joints in steel frames subjected to lateral loads, this study was done under cyclic loading.

Experimental works:

Several experimental works were conducted to beam moment connection to closed steel column section. . Among these are the following works.

In (2010) Bogazici University an experimental study on the behaviour of I-beam to square hollow section column connection under cyclic and monotonic loading was conducted. Studied joint consisted of 2 t-stubs bolted to I beam and connected to a hollow section column using long partially threaded studs.

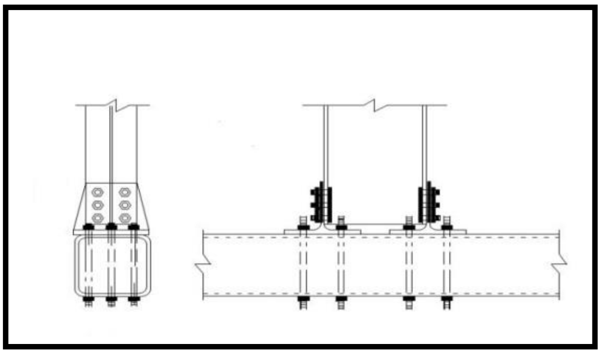

Figure 3 Studied Tee joint in (2010) Bogazici University

In (2015) liege university-Belgium an experimental work was performed in order to study behaviour of extended end plate I- beams connection to concrete-filled columns of rectangular hollow section using long bolts .

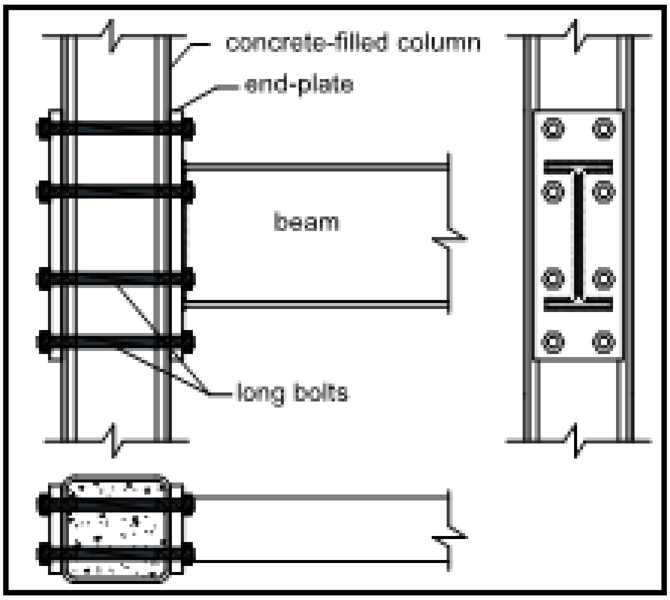

Figure 4 Studied joint configuration in liege university-Belgium

Also in (2013) liege university-Belgium, experimental investigation comparing three different types of connections for connecting beam to a closed column section were investigated.

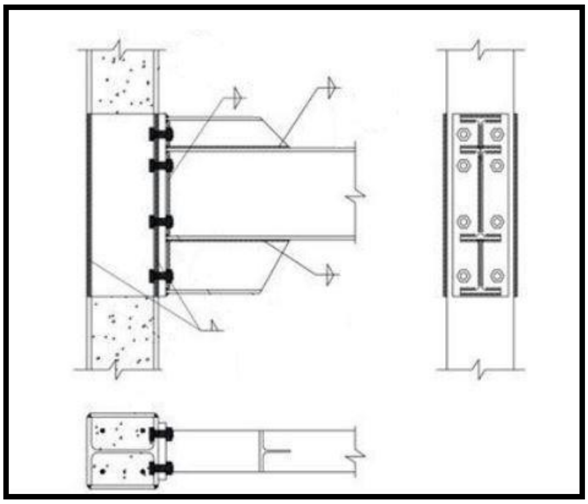

Figure 5 (B-EP-H) connection

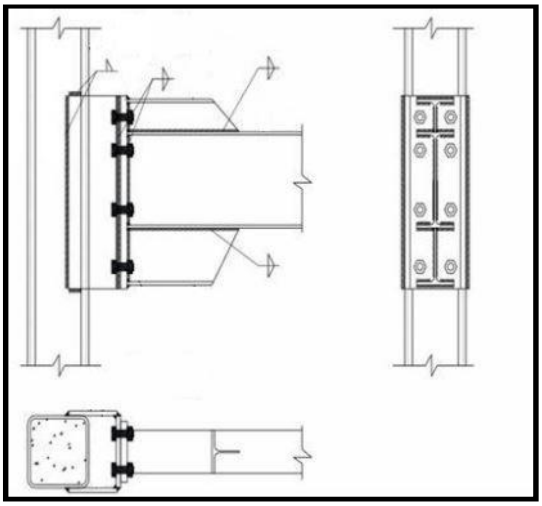

Figure 6 (B-EP-U) connection

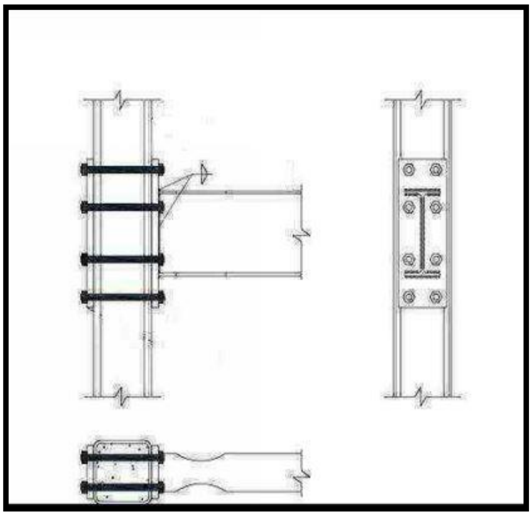

Figure 7 (B-EPL-RBS) connection

It has been concluded that the above three innovative joints for beam to column connection s can be proposed in moment resisting frames.

VERFICATION USING FINTE ELEMENT MODEL

This part of the thesis displays work done in an experimental investigation for extended end plate connections in 2004 by a joint work in Portugal and The Netherlands universities against a verification finite element model modelled using ABAQUS. analyzing program.

General

Experimental work in 2004 was done on 8 specimens. One of the Specimens, which is FS4b**,** was chosen for verification against a finite element model.
Verification finite model connection consists of the following main parts:
the main steel SHS column, the cantilever steel beam, the end plate, stiffeners and bolts.

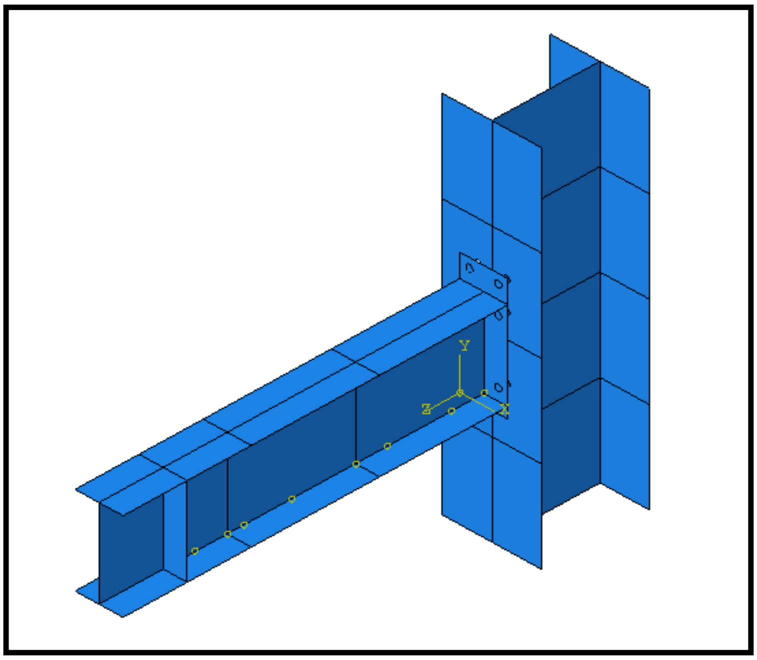

Figure 8 General figure for FE model

Verification for experimental work

- **Verifying FU.**

Experimental work result shows ultimate maximum force reached equals to Fu= 187 KN, verification finite element model shows maximum ultimate force reached equals to 193 KN. By comparing results, it is found that the difference between both results nearly equal to 5%.

- **Verifying moment – rotation curves.**

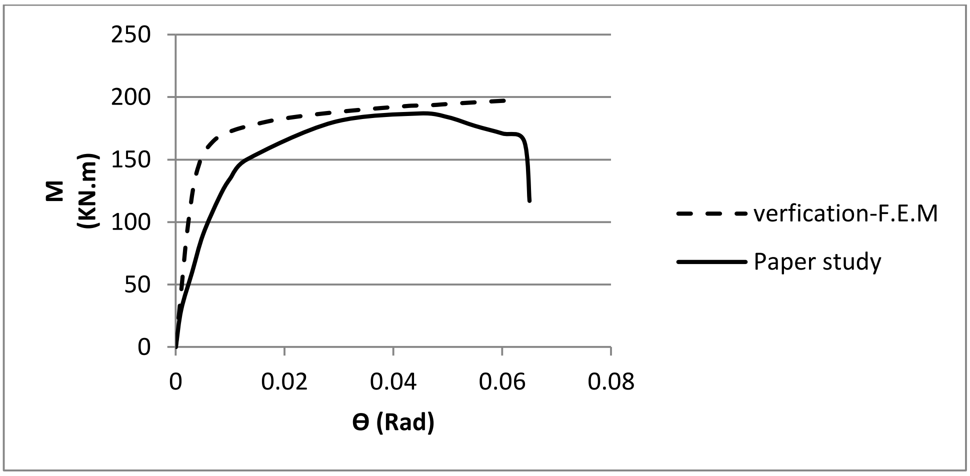

Figure 9 Verification using moment versus rotation curves for studied paper versus verification FEM

By plotting both paper study and verification model as shown in above curve for moment vs. rotation curve, the following was noticed:

Table 2 Table summarizing verification wok

Values	Experimental test	Verification F.E.M	Difference
Maximum moment (KN·m)	187	197.10	5%
Maximum beam rotation (Radian)	0.065	0.061	-7%

NUMERICAL MODELLING OF LONG BOLTS CONNECTION

General description

Analysis and modelling of the discussed connection was performed using FEM to simulate the behaviour of beam to SHS column connection using long bolts.
FEM of the studied connection consists of the following main parts: The main steel SHS column, cantilever steel beams, end plates, bolts.

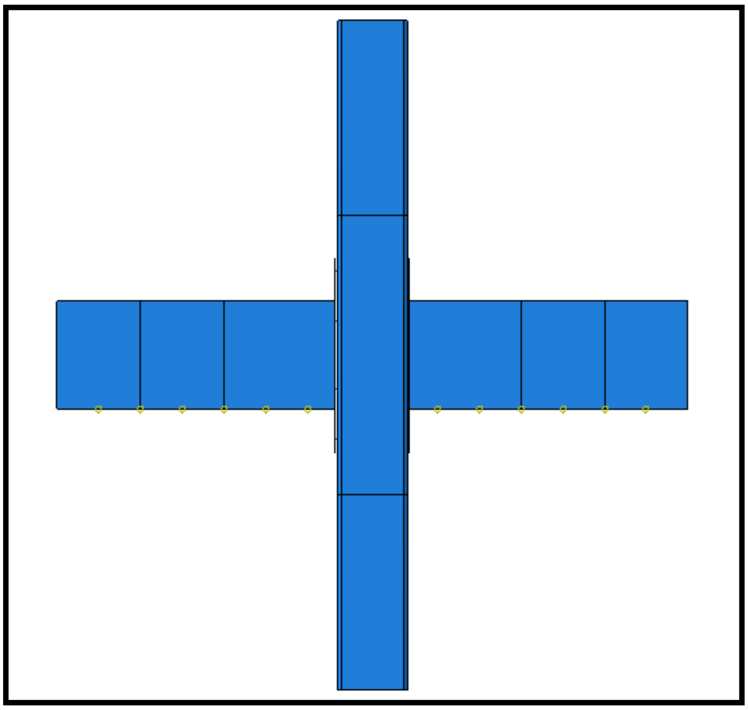

Figure 10 General figure for studied finite element model

Material used

There are two material used, one is for the joint steel structural elements (column, 2 cantilever beams and end plate), and the other is for the joint bolts.
As general properties for all elements:
Density for steel was taken = 7.85E-005 N/mm3
Young's Modulus for steel was taken = 210000 N/mm2

Poisson's ratio for steel was taken = 0.3
The following table shows the characteristic mechanical properties for the different elements used in FE model.
Below table shows structural steel elements grade St.37, St.44 and St52, and bolts grades (8.8 and 10.9) properties.
In some trials bolts grade 10.9 were used, while others bolts grade 8.8 were used.
In some steel structural elements grade St.37 were used, while others steel structural elements grade St.44 and St.52 were used.

Table 3 characteristic values for structural steel elements

Member	Plastic yield stress (Mpa)	Plastic ultimate stress (Mpa)	Ultimate plastic strain (Mpa)
Joint elements (St.37)	240	360	0.198286
Joint elements (St.44)	280	440	0.197905
Joint elements (St 52)	360	520	0.19752
Bolts grade (10.9)	900	1000	0.195
Bolts grade (8.8)	640	800	0.19619

Boundary conditions

The column at the bottom end is totally fixed through encastre fixation. Top of column was assigned boundary conditions to permit only displacement in the vertical direction. Both beams were supported laterally all over their flange length to prevent LTB each 150 mm starting from the end of the cantilever beams.

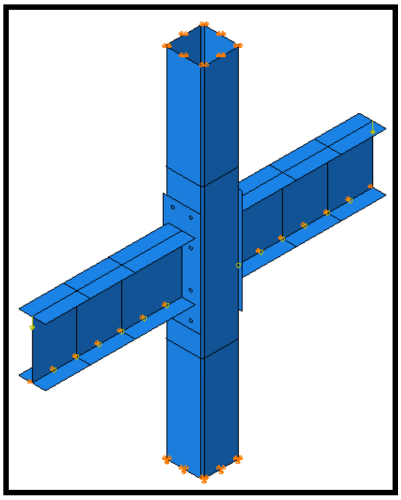

Figure 11 Model boundary conditions

Load application

Two concentrated vertical forces were applied on free ends of the two cantilever beams as shown in the below figure.

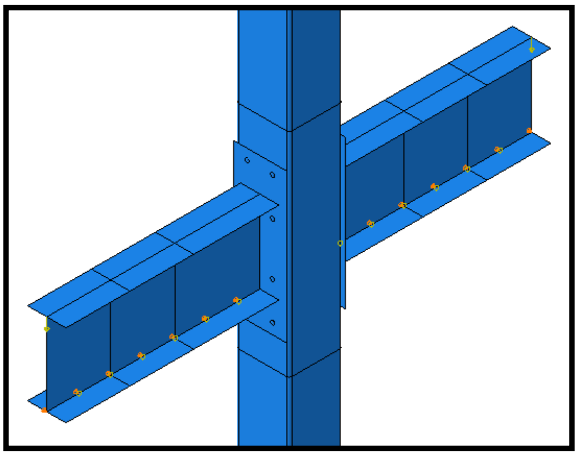

Figure 12 Applied loads to FEM

Load was applied using Riks algorithm method.

PARAMETRIC STUDY

As discussed before, finite element model consists of one column and 2 steel cantilever beams connected to column using moment end plate connection using long through bolts.

In parametric study, the following parameters are studied:

- End plate parameter effect was investigated through studying four end plate thicknesses, which are 10, 16, 20 and 30 mms.
- Column wall thickness parameter effect was investigated through studying three column wall thicknesses, which are 8, 10 and 16 mms.
- Bolt diameter parameter effect was investigated through studying three bolt diameters, which are 12, 20 and 24 mms.
- Bolt grade parameter effect was investigated through studying two bolt grades, which are grades 8.8 and 10.9.
- Effect of single and double cantilevers steel beams was investigated through modeling models for both cases.
- For the main models studied the end plate width was equal to the column wall width, however cases for end plate with smaller width relative to the column wall were studied. Case where end plate width equal to 200 mm and column wall width equal to 250 mm was investigated.
- Steel members grade parameter effect was investigated through studying three grades for steel members, which are steel grades St.37, St.44 and St.52.

RESULTS

The below figure show behaviour of samples of FE models in terms of (Load vs vertical displacement curve) for general case of double cantilever beams and equal column and end plate width through some comparison between results of different models in the performed parametric study.

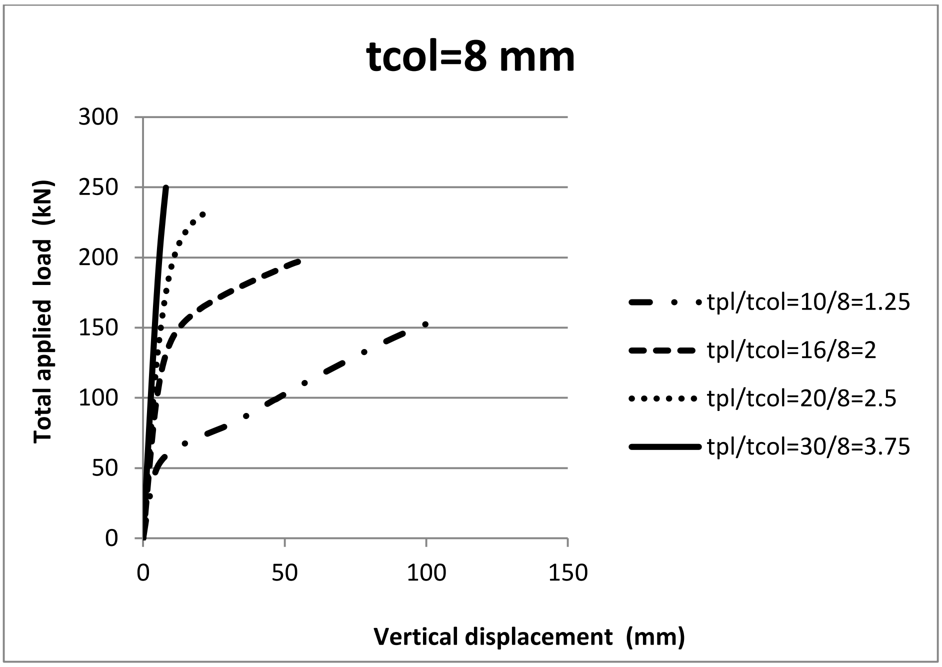

Figure 13 shows total applied load vs. vertical displacement curves for different end plate thicknesses in case of bolt diameter 20mm of grade 10.9, column wall thickness=8 mm, end plate width=250 mm, steel grade 37

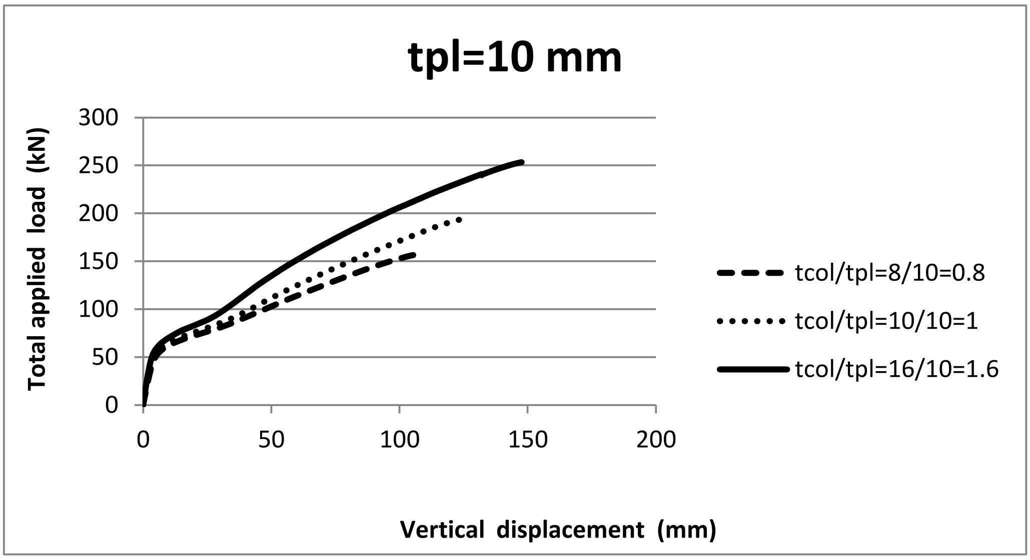

Figure 14 shows total applied load vs. vertical displacement curves for different column wall thicknesses in case of bolt diameter 20mm of grade 10.9, end plate thickness =10 mm, end plate width=250 mm, steel grade 37

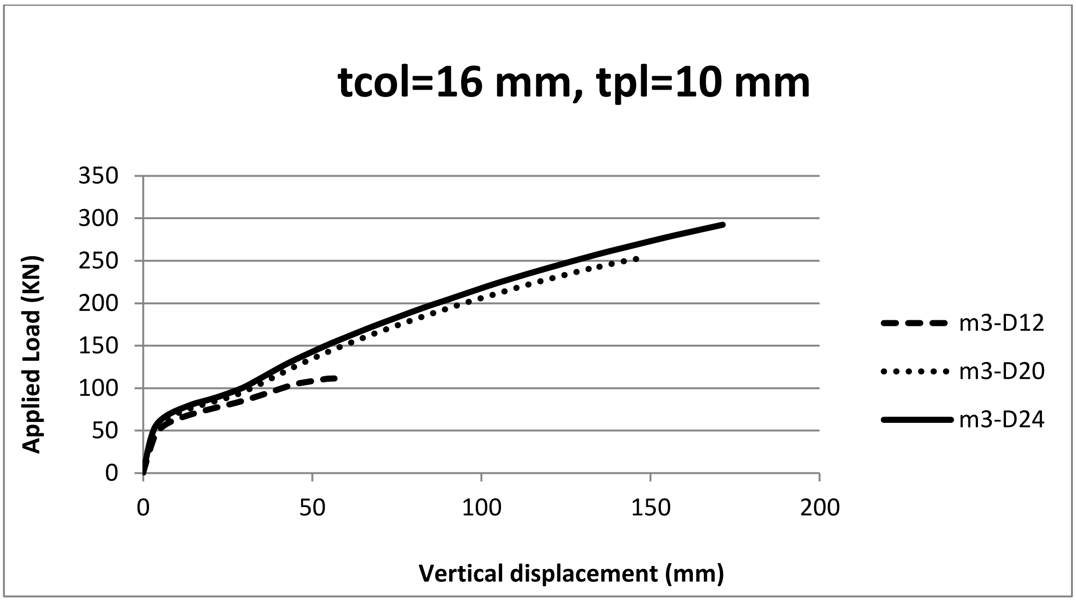

Figure 15 shows total applied load vs. vertical displacement curves for different bolt diameters in case of bolt grade 10.9, end plate thickness =10 mm, column wall thickness=16 mm, end plate width=250 mm, steel grade 37

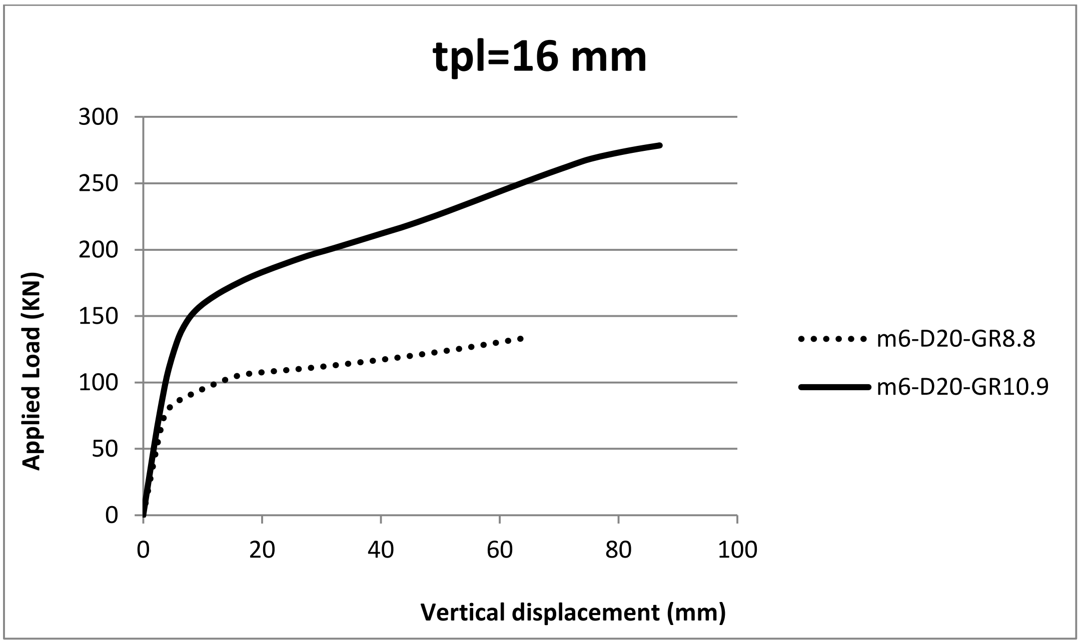

Figure 16 shows total applied load vs. vertical displacement curves for different bolt grades in case of bolt diameter 20mm, end plate thickness =16 mm, column wall thickness=16 mm, end plate width=250 mm, steel grade 37

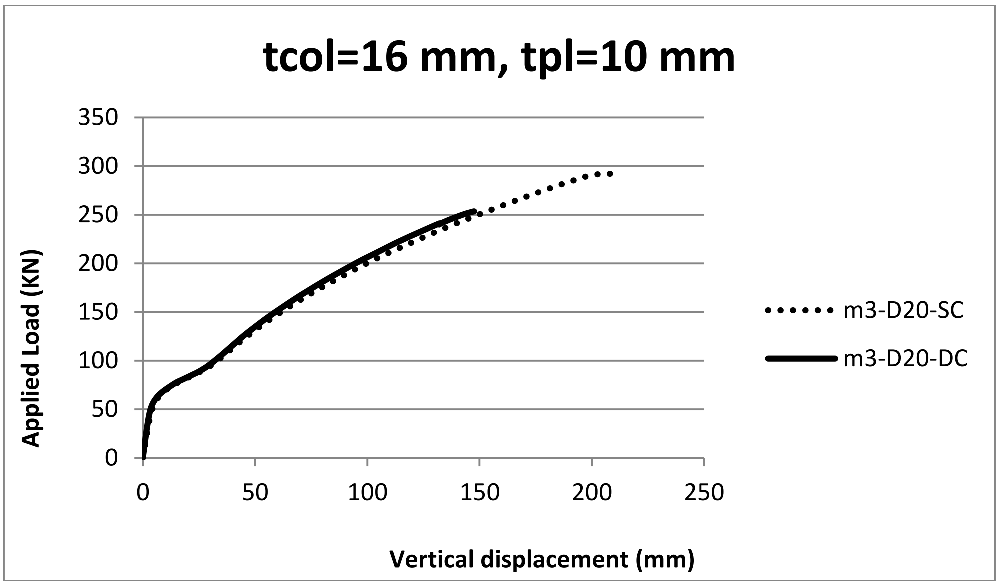

Figure 17 shows total applied load vs. vertical displacement curves for different cantilever status of double cantilevers (DC) and single cantilevers (SC) in case of bolt diameter 20mm of grade 10.9, end plate thickness =10 mm, column wall thickness=16 mm, end plate width=250 mm, steel grade 37

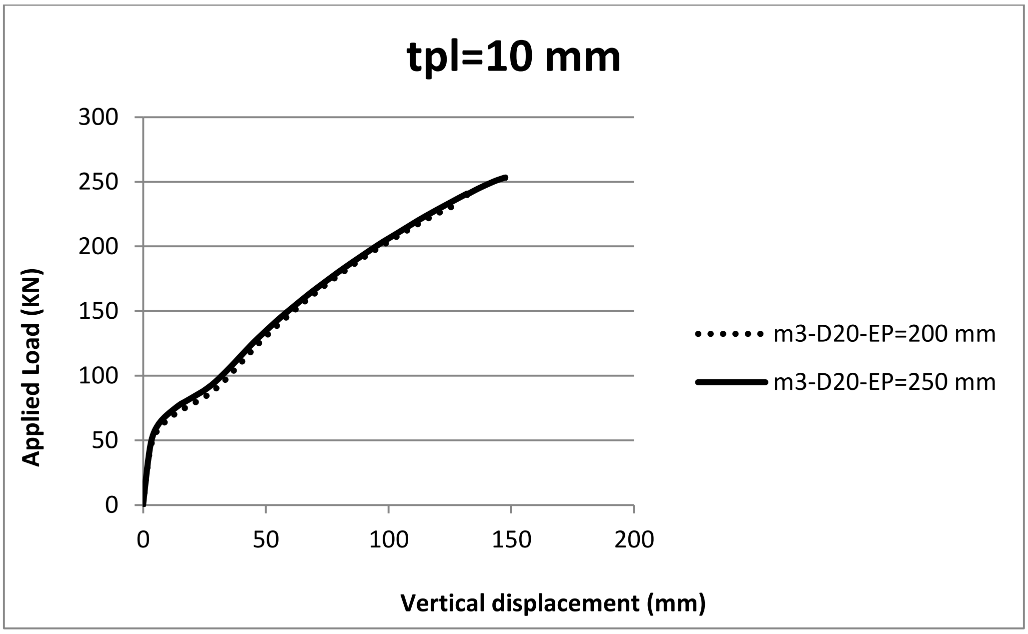

Figure 18 shows total applied load vs. vertical displacement curves for different end plate widths in case of bolt diameter 20mm of grade 10.9, end plate thickness =10 mm, column wall thickness=16 mm, steel grade 37

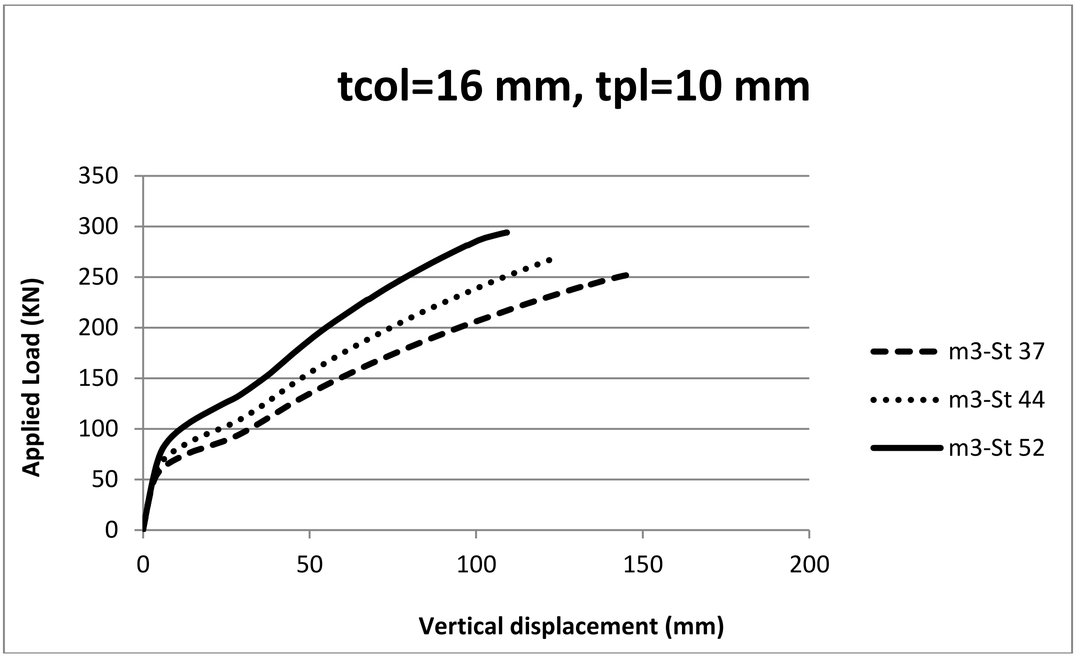

Figure 19 shows total applied load vs. vertical displacement curves for different steel members grades in case of bolt diameter 20mm of grade 10.9, end plate thickness =10 mm, column wall thickness=16 mm, end plate width=250 mm, steel grade 37

CONCLUSION

From the results, it can be concluded that maximum capacity of bolted beam to column joint using long bolts is affected by various parameters such as end plate and column thicknesses, bolt diameter, bolt grades, steel members grade. Other parameters such as status of having double or single cantilever beams and width of end plate relative to column width slightly affect the joint. Effects of different parameters such as the previously mentioned are clearly explained in the content of thesis.

Also prying force effect is studied for different FE models results. It is also observed that prying force effect is underestimated in some cases according to prying force equation in ECP compared to the other equations such as prying force equation in (Limit states design of steel structures book by Dr. Ezzeldin Sayed-Ahmed and Dr. Ahmed Elserwi).

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