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IMPACT OF THE THICKNESS OF THE END PLATE OF THE END PLATE CONNECTIONS WITH HIGH STRENGTH BOLTS SCREWS ON THE CAPACITY OF ROTATION OF THE JOINTS

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ABSTACT: In this paper FE method for obtaining an M-F moment–rotation diagram for the end plate connection with high strength bolt is given. The contact between the coulomb and the end plate is modeling with specific spring elements and the behavior of the high strength bolts is modeling with specific experimental research.
Keywords: end plate connection, high strength bolts, contact problem

INTRODUCTION

As a basic constructive element in the steel buildings, the frames are made of columns and beams connected to each other with joints. Joints, as a part of the construction, in large part define the behavior of the construction. Generally, the distribution of the forces, shifts and deformations in the joints is more complex than their distribution in the elements which they connect.

Joints in the frame systems are most commonly with end plate which is welded to the beam and the connection to the column is made with bolts that are either ordinary or high strength (Figure 1). Despite the load-bearing characteristics, the deformation characteristics are also the basic characteristics of the steel frames.

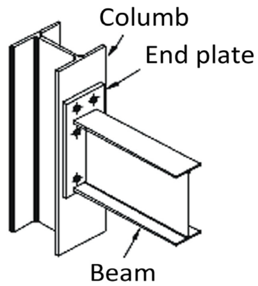

Figure 1. Typical end plate connection

Basic deformation characteristic of the joints on the frames is their capacity for rotation. The capacity of rotation of the joints can be described by the curve which gives the proportion of the rotation of the connection with the moment that is acted to the connection. This curve is called M-F moment-rotation curve of the connection.

For calculation of the deformation characteristics of the frame, previously should be obtained M-F curves of the joints of which they are made.

Below is a method how to get real M-F diagrams for connections of the end plate and the high strength bolts, that takes into consideration all the characteristics of the connection. In this paper attention is paid to the impact of the thickness of the end plate on M-F diagram.

Deformation characteristics of the frames depend on the size of the columns, the dimensions of the beams, dimensions and characteristics of the floor deck, dimensions of the beams and dimensions and characteristics of the joints. Deformation characteristics of the joints with end connection and high strength bolts depend on the material from which is made the structure, the dimensions of the column, the dimensions of the elements of the column, the method of stiffing the column, the dimensions of the beam and the dimensions of the components of the beam, the dimensions of the face plate, the thickness of the face plate and the size and type of bolts.

The dimensions of the column and the elements of the column (height of the column, width of the rib and the thickness of the rib and the belt), also the size of the beam and the beam elements (height of the beam, width of the rib and the thickness of the rib and the belt) is obtained by the static calculation.

The static influences in the joint are the basic elements from which the parameters of the relationship with end panel are selected. But, often, the structural characteristics of the connection and the technical regulations in each country, affects the choice of the dimensions of the elements of the connection. Elements of the connection with the faceplate are its type, its dimensions: height, width, selection of the type and size of the screw and selection of the thickness of the faceplate.

2. NUMEROLOGICAL MODEL

Numerological model of the construction

The numerical model is based on the real model which is given on Fig.2 and which is consisted of column and console loaded with force on the top. Column has dimensions: height 300 mm of which 250 mm height of the rib with thickness of 12mm and two belts with a thickness of 25 mm. Width of the rib is 200 mm. The console has a height of 230 mm, belt which is high 206 mm and metal sheet with thickness 8mm. Belts thickness is 120 mm and thickness of metal sheet is 12 mm. The dimensions of the end plate 120 x 300 mm with schedule of screw holes M16 10.9 as the shown on Figure 2 the end plate thickness is 12, 14 and 16 mm respectively.

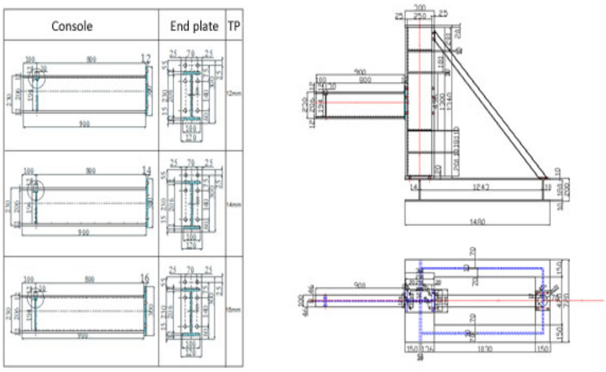

Figure 2. Real model of consisted of column and console loaded with force on the top

Below is mathematical model modeled by FEM Figure 3. The numerical analysis is made with SOFISTIK software package, where the construction is modeled within 3937 QUAD scaly stratified elements with five degrees of freedom in each joint. The model of the construction has a total of 3707 joints. The used element is degenerated scaly element that represents a quadratic finite element with five degrees of freedom per joint with parabolic interpolation of the displacements. Formulation of this element is based on the following assumptions: a) normal of the middle surface remain straight, but not always normal. Norman does not shorten. b) Deformation energy that corresponds to stresses which are perpendicular to the central area is overlooked. Each joint is defined by three shifts and two rotations perpendicular to the middle surface. Displacements and rotations are interpolated independently of each other which allow the shear deformations to be taken into account. Theory of Reissner-Mindlin applied to plates. In the element is implemented layered model that realistically present the state of stresses and deformations along the height of the element. This is of particular importance in non-linear analysis where the state of stresses and deformations along the height of the intersection of the element is different. Stresses are calculated in the middle layer of the element, and in this case each element is divided into 10 layers.

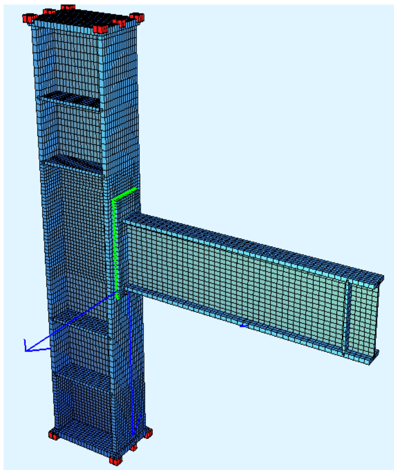

Figure 3. FEM model of the real model

Modeling of the material

The material from which it is made whole structure is steel with yield limit Sn = 240 Mpa. The material in afore mentioned software package is encapsulated by the (σ-ε) diagram in six points with dilation entered in promiles and the stress is in MPa. The picture on the left side of Figure 4 present (σ-ε) diagram obtained by examination of the material obtained from the manufacturer, and on the right side of Figure 4 is shown the diagram approximated 6 points.

Modeling of the contact between the end plate and the column

Special specifics which modeling the connection represent the modeling of contact between the end plate of the connection of the console and belt of the column. The problem is consisted of allowing free deformation of parts of the end plate where shifts of the joints that are normal to the plane of the plate are in a direction which is away from the column, and the remaining joints which shifts are toward the column - the shifts should resist column with its rigid. For modeling of these effects are used special elements types "spring" that which give upon case of tightening Figure 5.

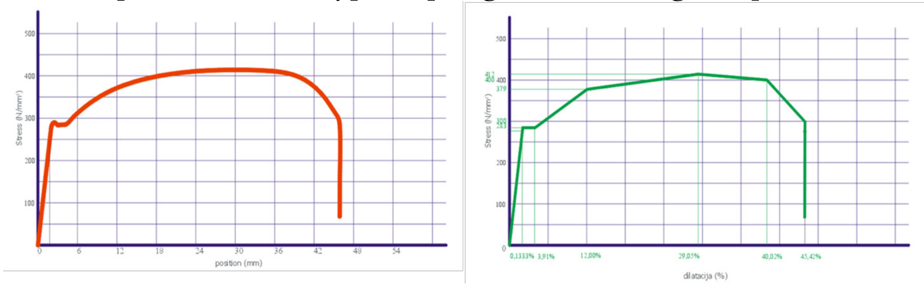

Figure 4. σ−ε diagram of the material of the structure

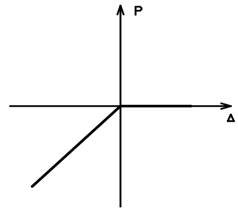

Figure 5. σ−ε diagram of contact spring

Generation of the network of finite elements of the contact column and end plate made 338 joints and used a total of 338 spring elements in each joint by one. Rigidity of these elements is 10x109 kN/m. Since the plate has dimensions of 12x30 cm and has a total of 338 finite element, stiffness of the finite element is 145.883,00 kN and stiffness of secondary elements is 1.633.334 kN.

Modeling of the bolts

Numerical modeling of the bolts in this kind of connections presents specific and requires special attention because the behavior of the bolts the behavior of the end plate define the behavior of the link. Despite this, in the bolts are inserted the power of previous tightening which should somehow be introduced. When modeling the bolts there is no general approach and the various authors in accordance with the possibilities of different software packages make various models. From the literature review may be separated following numerical solutions. In the numerical model used in this research bolts are modeled as springs that are placed in the center of the hole of the screw. Springs which are modeling the bolts, rigidity is not explicitly set as a constant, but rigidity is set implicitly through the force-deformation diagram (F-D). This diagram, obtained by experimental research, fully defines the behavior of "spring" items during the analysis. So the local influence of the screw, ie its impact around the hole should be somehow taken into account. The software package allows in advance to prescribe shifts for certain points of the system or in advance to prescribe the same shifts to group of points (Figure 6). This characteristic of the software package is used to realistically model the physical behavior of the screw in the area of the hole.

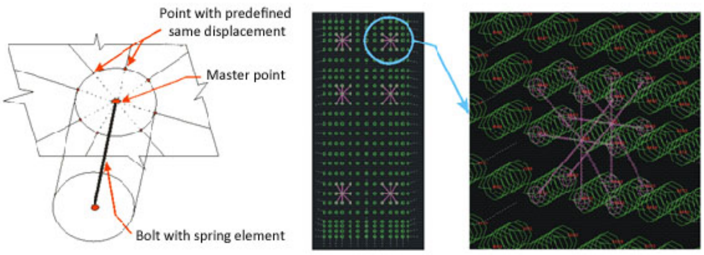

Figure 6. Modeling of the bolt

To all points that are situated in the perimeter of the hole, in advance is prescribed displacement which is same with the displacement of the end of the spring which is used for modeling the screw. This way, all the points from the area of the hole have same deformation like the center of the hole.

3. LOADING OF THE CONSTRUCTION

The construction is load with a concentrated force that is in the direction of the global Z axis of the system (Figure 7). The loading is done this way. The construction is loaded incremental with base load that is taken for size of the increment of 1 kN. The first load of 1x1 = 1kN. For this load are calculated all values: full stress and strength condition in all 3937 elements which discretized the system, forces that modeling springs of the contact and forces in the bolts. If the condition is linear at every point of construction increment of 1 rises to 2. Again, the procedure repeated by increasing the increment for the full amount until then, when any element does not appear in plastic condition. Then the system starts to take the previous permitted situation as a starting and increment begins to increase for the previous plus 0.5. Than the whole procedure is repeated again and on each next step factor before the increment is with lower step of growth until for the previous one and the next step, the situation of stresses and deformations in all the structure is the same, which is the boundary of the system. Force that achieves this condition is the limits force ie the limit

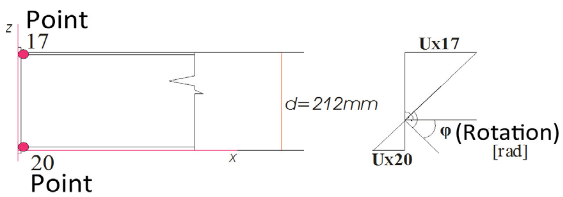

Figure 7. Defining M-F diagram through the displacement of the upper and lower point of the contact of belts with end plate

loads of the construction. The analysis obtain the following border forces: for the console of 12 mm border force is 83.07kN. For the console of 14mm border force is 91.76kN and for console with 16mm border force is 98.93 KH.

4. GETTING THE M-F DIAGRAMS

Obtaining of these curves is indirect from displacements of top and lower point of contact of belts with end plate. (Figure 7) These displacements are obtained from the FEM calculation, separate for each thickness of top plate.

Rotation of the cross section it's obtained from relation if in this relation values of horizontal displacement for corresponding points are replaced, the value of rotation cross section it's obtained. The results (the M-F diagram) are show in diagram for each thickness off the end plates separately. So, ultimate moment Mu = 66.465 KNm is for a connection with end plate thickness of 12 mm. The connection with end plate with thickness of14mm has Mu = 73.908 KNm and the connection with the end plate with thickness of 16 mm has Mu = 78.712 KNm.

5. CONCLUSION

On the diagram in Figure 8, M-F curve for the end plate with thickness of 12 mm is shown in blue, and the end plate with thickness of 14mm in red, and M-F diagram of the console with end plate with thickness of 16mm is shown in green. The curves show that the console with thickest end panel has the highest ultimate moment, and in terms of rotation of the cross section t has the smallest rotation. And opposite console with the thin end plate has bigger rotation for same initiated moment. The diagram also shows that the thickness of the end plate affect the initial stiffness (rigidness). Connections with thicker end plate have greater initial stiffness. From this it follows that in the projection of the structures connections with thicker end panel will have a greater initial stiffness and smaller turning of the joints for the same external influences.

Note: This paper is based on the paper presented at the Vth International Conference Industrial Engineering and Environmental Protection 2015 – IIZS 2015, University of Novi Sad, Technical Faculty „Mihajlo Pupin", Zrenjanin, SERBIA, October 15-16th, 2015, referred here as[9].

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