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Analytical and Experimental Studies on Behavior of Beam to Column Connections with Flange Plate under Monotonic Loading

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Abstract: Behavioral study of connections using moment - rotation curve for analyzing different types of connections and also the concept of strength, ductility and rigidity of steel connections are important. One of the most common connections in bending frames of steel structures is beam to column connections with flange plates. A correct perception about structural behavior of beam to column connections and also appropriate knowledge of their force transmission and their behavior in modeling and analysis of the steel structures are essential. In present study, beam to column steel connection with flange plate under monotonic loading, both analytical and experimental would be investigated. The obtained results showed that moment - rotation curves of experimental sample and finite element (F.E.) model are reasonably close to each other. As a result, F.E. method could be an appropriate tool to investigate the behavior of these connections which would significantly decrease number of trial and error approaches.

Key words: Beam to column connection · Moment- rotation curve · Finite element meth

INTRODUCTION

Behavioral curve for the analysis of the different connections and presenting the concept of rigidity, strength and plasticity of steel connections are important in classification and design of steel structures. The common approach for the determination of moment - rotation curve is performing tests on connections [1, 2]. To plot moment - rotation curves, bending moments are directly measured. The static loading of experimental samples and rotational angles are directly measured by beams displacement. But due to the lack of a precise determination of parameters such as actual yield stress of the connections materials, tightening the screw connection and also the existing differences in size and dimension of each connection, utilization of such curves, necessary cautions should be taken [3]. Due to difficulties in conducting experimental tests on connection sample, use of non-linear finite element method for analysis of connection and the determination of moment - rotation curve are common. Provding the details of each connection, drawing the rotation - moment curve by experiment for all kinds of connections is not possible [4]. Therefore drawing (plotting) moment - rotation curve for connection, mathematical models or computational programs should be utilized. As usual connections in steel structures are composed of various components by different dimensions [5]. In order to perform detail investigation, it is more convenient to apply F.E. method.

This paper analyzes the beam to column connections with flange plate by means of F.E. method and experimental approach. The target sample first was modeled by ABAQUSF.E. software. Then monotonic loading was applied to prepared samples in the laboratory of Babol University of Technology and the obtained results were recorded. The results of experimental tests have been used to confirm the accuracy of F.E. modeling. The main objective of the suggested F.E. model is to simulate the behavior of steel beam to column connections with flange plate under the applied loads.

Finite Element Model

Geometric Properties of Models: The overall shape of used models for numerical and experimental analysis is shown in Figure 1. The proposed sample is composed of beam with IPE200 and column with IPB180. Component design of connection for studied model during monotonic

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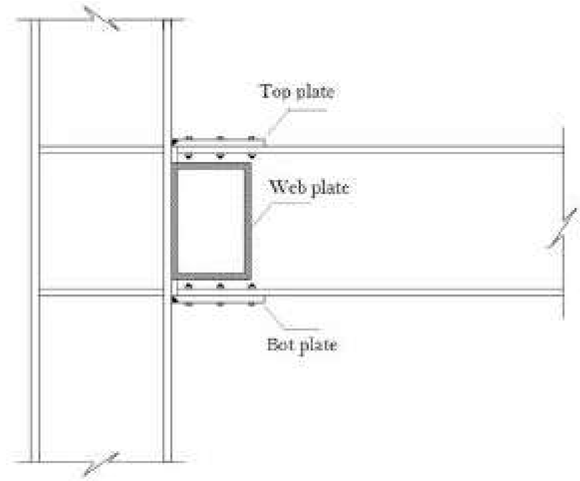

Fig. 1: Schematic of structure

Table 1: Consumed materials and geometric specification of model

Beam Section	IPE200
Column Section	IPB180
Beam Top-Flange Plate	PL160×100×20
Beam Bottom -Flange Plate	PL160×120×15
Doubler Plate	PL190×140×10
Stiffener Plate	170×130×8
Diameter Bolts	16

analysis is performed according to Iran's [6] and AISC [7] regulations. Design details for sample are given in Table 1.

Modeling Approach: For modeling beam to column connections with flange plate, ABAQUS F.E. software was used. For creating component of connection, solid elements were used. In modeling diffusion welding, tie constraint of software was utilized for the integration of welded component such as, stiffeners and flange plate. Relying the body of screw to internal edge of hole was modeled as hard and also with a friction coefficient of 0.6 and by penalty method. For meshing elements of connection, low order hexagonal meshes were used. To determine the exact size of meshing, convergence analysis of elements was performed.

For example, in convergence analysis of such connections, a linear increasing tensile force was applied to the end of beam and the displacement of that end point of beam was measured. The size of mesh was selected according to the comparison of results and also required time for analysis of the model was considered. Figure 2 shows the F.E. model and meshing one of the connections.

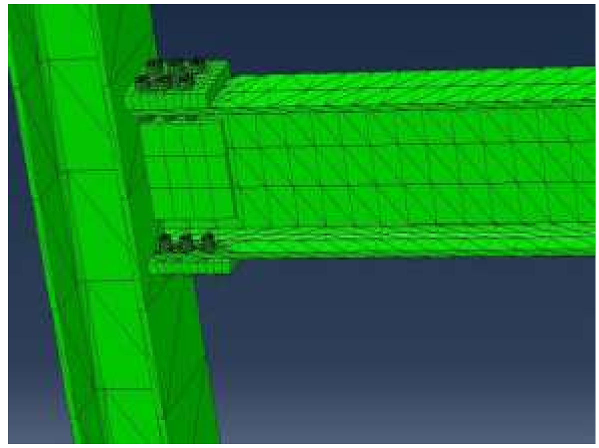

Fig. 2: Finite element model

Numerical modeling of considered connections which was performed according to the following assumptions:

- Consumed steel in all components are ST-37.
- For modeling steel's behavior in software, strain - stress bilinear curve was used.
- Properties of existing materials in model were considered as isotropic.
- In curve model, parameters such as elasticity module, Poisson ration and yield stress are defined. The value of such parameters which are 0.3, 2.1 0E +0.6 kg/cm^2, respectively.
- All of the component of such connection such as beam, column, flange plate, nuts and screw bolts were modeled by deformable solid element.
- This element has the ability of considering the plasticity, large rotation phenomenon and large strains.
- Holes of screws were modeled equal to 18 mm and also 2mm greater than screws diameter.
- End of columns have rotational freedom and act as a joint
- Von - Mises yielding criterion was used to predict time of start yielding. The behavior after yielding is predicted by flow and hardening rules. Flow rule for Von - Mises yielding criterion with hardening steel sections and screws are used to model Bauschinger effect. Kinematics hardening is assumed for modeling steel connection and then the yields level is passed to surrendering and growth does not occurs in the size.

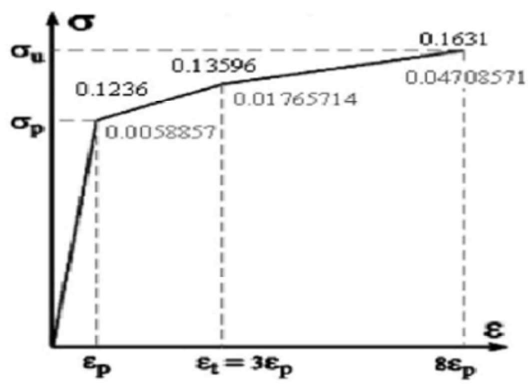

Fig. 3: Strain-stress curve for structural steels

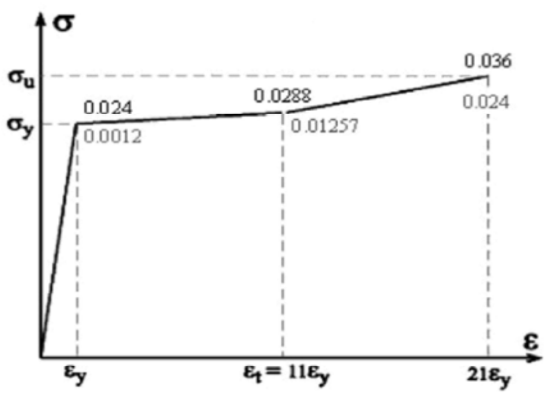

Fig. 4: Strain-stress curve for screw steels

Isotropic hardening rule is utilized for steel dough deformation. In current model, non - linear stress - strain curve is used. First curve is for component made of low carbon steel that are include the web and beam flange and column, flange plate and Lateral column stiffener (Figure 3). Second curve is defined for steel screws which have high resistance [8] (Figure 4).

Loading and Analysis: Models analysis is a non - linear static condition and loading is as monotonic. Non - linear analysis includes physical non - linear analysis, geometrical non - linear analysis and contact non - linear analysis [9, 10]. In loading process of F.E. concentrated load is applied as increasing linear to F.E. model in 20 stages from a distance of 120 cm from the end of beam.

Experimental Studying: According to the obtained results which were from F.E. preliminary model analysis, it was decided to investigate the correctness of analytical results by performing one test. As a result, a model which was numerically analyzed; that was constructed for performing experiments is Babol University of

Fig. 5: Connection experimental model Fig. 6: Moment-rotation curve for experimental sample

Technology with a 1:1 scale. For manufacturing such samples, first, required sections were produced and then drilled and final assemblies were conducted in laboratory. Due to unreliability of welding in laboratory, required welds were done in factory. Flange plates were welded to the column flange by E7018 electrodes and also others were welded by E6013 electrodes. To investigate the moment-to-moment behavior of connection, incremental nodal load was applied in connection. This incremental modal load continues until weld cracked and also failure occurs in connection. Experimental connection model is demonstrated in Figure 5.

RESULT AND DISCUSSION

According to the amount of load which was applied to moment's arm, the amount of bending moment in connection was calculated and based on the derivation of beam than column which is (θ) or rotational deformation due to bending moment (M) is created, M-θ curves of connections were plotted in Figures 6, 7 and 8.

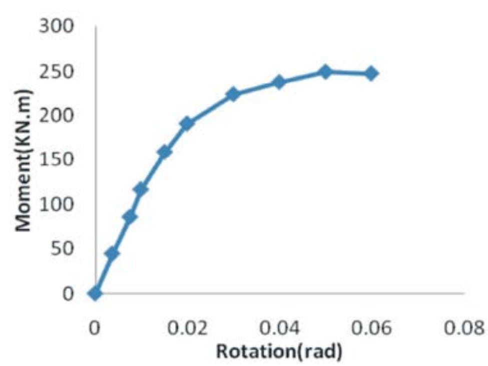

Fig. 6: Moment- rotation curve for experimental sample

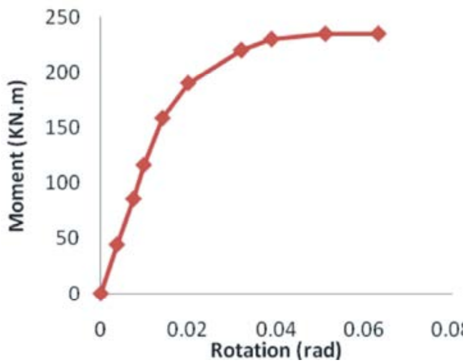

Fig. 7: Moment- rotation curve for finite element method

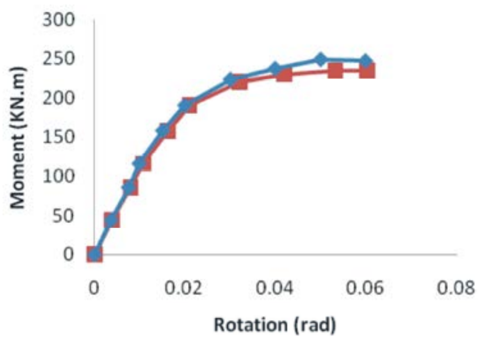

Fig. 8: Comparison of moment-rotation curve for finite element method and experimental sample

CONCLUSIONS

In current study, the behavioral moment-rotation curve (M-θ) of the connection of beam to steel column with upper and lower sheets was studied by ABAQUS software. In addition, the correctness of F.E. results was tested with laboratory samples. The results which were obtained from F.E. method and experimental sample were compared. It was observed that in linear region, results project by F.E. with experimental data were completely matched; but in non-linear region, curves were partially deviating and also the analytical model presented more conservative results than experimental model. The justified reasons are stated as follows:

- Differences exist between the condition of analytical model and experimental model.
- Equipment errors appeared in loading and in recording results.
- The terms of supports.
- Differences between actual conditions of the materials of both beam and column components.
- Behavioral differences of weld's element in actual and analytical models consequently.

It could be concluded that F.E. method has an acceptable accuracy for the parameters such as connections and F.E. method could decrease the experiment's trial and error procedures and also reduce its relevant cost.

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