Tanta University Faculty of Engineering

A Thesis Submitted for the Partial Fulfillment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY
IN CIVIL ENGINEERING
(STRUCTURAL ENGINEERING)

Entitled

STATIC AND DYNAMIC NONLINEAR ANALYSIS OF FRAMES WITH SEMI-RIGID JOINTS

By

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M. Sc. Structural Engineering, Monofia University, 1997
B. Sc. Civil Engineering “Distinction with Honor Degree”, Monofia University, 1991

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ABSTRACT

A three-dimensional finite element model using ANSYS program (Version8) has been developed to study the response of extended endplate bolted connections to static and cyclic loading. Two models (Solid-Element model and shell-Element model) were used to simulate the entire behavior of extended endplate connections, up to the ultimate loads. The models included the individual modeling of bolts and the complex contact surfaces as well as the material nonlinearity. Also, an experimental investigation program of ten endplate joints subjected to static and cyclic loading was described and performed. A comparison between the results of the experimental tests and the results out of the suggested finite element model was performed to verify the present suggested FE model. The finite element models simulated the experimental moment-rotation behavior of the connections well in the cases of both static and cyclic loading, which provide the confidence to use such models in wider-range parameters. A numerical parametric study using the suggested FE model was carried out to investigate the influence of different factors on the mechanical properties of extended endplate bolted connections. Also, a regression analysis to find the analytical expression of the parameters that define the proposed moment-rotation hysteretic mathematical model of the steel joint was presented. Connections represented by the proposed mathematical model (bilinear model) are incorporated in a frame analysis program. The effect of degree of semi-rigidity of frame joint under dynamic loading is demonstrated.

Keywords: Finite element modeling, steel connections, extended endplate, cyclic loading, semi-rigid steel frame, dynamic analysis, hysteretic.

SUMMARY

Steel frames are widely used in practice. This is because they meet the need to cover large spans without intermediate supports. They require small weight of structural material per unit covered area. Steel frames also provide indirect saving in fabrication, construction, and in increasing the service life of the structure. Unlike brittle materials such as concrete, steel has a high ductility and thus a stronger resistance to seismic loads. In construction of steel framed buildings, beam-to-column connections are widely used. In recent years, bolted connections, especially extended end-plate types, have increased in popularity. They have the advantages of requiring less supervision and a shorter assembly time than welded joints. Also, because of poor performance of welded-moment connections in comparison to the performance of bolted-moment connections in the 1994 Northridge earthquake and the 1995 Kobe earthquake, extended end-plate moment connections were under serious consideration as an alternative to welding in seismic regions.

For conventional analysis and design of steel framed structures, the actual response of the beam-to-column connections is simplified to either rigid or pin-connected behavior. Although the adoption of such idealized performance simplifies the analysis and design process, the predicted response of the idealized structure may be quite unrealistic compared to that for the actual structure. This is because most beam-to-column connections used in practical steel framed structures actually exhibit semi-rigid deformation behavior. This behavior can contribute substantially to overall structural deformation and to internal force redistribution in the members of structures subjected to static or dynamic loading. Evidently, then, the neglect of real connection behavior may lead to unrealistic predictions of the stiffness and strength of steel structures. Thus, it is necessary to account for the effect of connection flexibility when designing such structures if realistic and economical designs are to be found.

A three-dimensional finite element model using ANSYS program (Version8) has been developed to study the response of extended endplate bolted connections to static and cyclic loading. Two models (Solid-Element model and shell-Element model) were used to simulate the entire behavior of extended endplate connections, up to the ultimate loads. The models included the individual modeling of bolts and the complex contact surfaces as well as the material nonlinearity. Also, an experimental investigation program of ten endplate joints subjected to static and cyclic loading was described and performed. A comparison between the results of the experimental tests and the results out of the suggested finite element model was performed to verify the present suggested FE model. The finite element models simulated well the experimental moment-rotation behavior of the connections, in the cases of both static and cyclic loading, which provide the confidence to use such models in wider-range parameters. A numerical parametric study using the suggested FE model was carried out to investigate the influence of different factors on the mechanical properties of extended endplate bolted connections. Also, a regression analysis to find the analytical expression of the parameters that define the proposed moment-rotation hysteretic mathematical model of the steel joint was presented. Connections represented by the proposed mathematical model (bilinear model) are incorporated in a frame analysis program. The effect of degree of semi-rigidity of frame joint under dynamic loading is also demonstrated.

Displaying the various chapters of the thesis, the following can be detected:

In chapter (1), an introduction for the thesis was presented. Also the classification and definition of the semi rigid joints were presented. Finally, the goals and description of each chapter of the thesis were presented. In chapter (2), the important researches in semi rigid joints were reviewed to start to form their results and conclusions. In chapter (3), the finite element modeling philosophy employed to analyze extended endplate steel connections subjected to static or cyclic loading was presented. The ANSYS finite element package (version 8.0) is used to simulate the actual behavior of steel joints. Also, comparisons of the numerically predicted ultimate loads and moment rotation responses with those of the corresponding previous tests were presented. In chapter (4), a complete description of the experimental investigation program for ten endplate connections was presented. Five joints were tested under static loading and another five joints were tested under cyclic loading. All joints were tested up to failure. Also, the standard tests of the materials used and their results were detailed. Test setup and test procedure were described. In chapter (5), the experimental results of the tested joints were compared with numerical results of these joints using the suggested FE models described in chapter (3). In chapter (6), a numerical parametric study using ANSYS was carried out to investigate the influence of different geometric variables on the mechanical properties of steel joints. Also, a regression analysis to find a mathematical expression of the parameters that define the considered moment- rotation model of the steel joint was presented. In chapter (7), the results of semi- rigid frame analysis under static and seismic loading were presented. In chapter (8), a summary of the work done, main conclusions from this research and recommendation for the future work are presented.

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