Study of Non-Linear Static Behavior and Equivalent Non-Linear Model of Reinforced Concrete Beam-Column Joints

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Abstract
In reinforced concrete structures, the beam-column joints are the key elements in determining structural behavior against various loads. A quick look at damage caused by past earthquakes indicates that in most cases the destruction of reinforced concrete structures is due to shortcoming in the joint zone while the other structural components have suffered little or no damage. This research is timely because a large number of reinforced beam-column joints with insufficient strength or deformation capacity are in use today in seismic regions, placing many structures and people at risk in the event of a major earthquake. Considering this fact, the need for more accurate assessment of the structural capacity of concrete components in seismic retrofit projects is felt. But to date, behavior evaluation criteria for some of structural components such as reinforced concrete beam-column joints is still based on engineering judgments and no coherent and comprehensive analytical and experimental data exist. The need to do research in this field seems to be proper and is seriously required.

In this thesis, the main purpose is the review and evaluation of nonlinear behavior of interior reinforced concrete beam-column joints in order to more accurately assessing its structural capacity and also providing an analytical model to simulate joint response and its impact on overall structural behavior. For this purpose three basic experimental specimens A-M-Z-4, B01 and D07 tested by different researchers have been selected and then by changing shear demand of the joints ten new analytical specimens were defined. The modeling of joints using ANSYS software is described and to evaluate the accuracy of nonlinear analysis results, they are compared with experimental results, showing good agreement.

The impact of behavior and stiffness of joint panel on overall response of basic joints are also studied. To evaluate the performance of these joints, the impact of various parameters such as column axial load ratio, joint shear demand ratio and transverse reinforcement details are investigated and in each case the relevant are presented. The moment-rotation curves obtained from finite element analysis of joints studied in specific groups are classified and the joint shear strain at the corresponding strength is compared with those mentioned in seismic assessment instructions such as FEMA356(2000) and ASCE/SEI41-06(2006). The finite element analysis results of studied specimens showed that the above guidelines provide a conservative assessment of joint shear strain at the related strength for interior joints with conforming transverse reinforcement details and joint shear ratio less than 1.5 and in contrast provided a non-conservative assessment of this parameter for interior joints with joint shear demand greater than or equal to 1.5. These guidelines provide a conservative or occasionally non-conservative assessment of joint shear strain at the peak strength for joints with nonconforming transverse reinforcement details depending on the hoops spacing within the flexural plastic hinge region and within the joint, axial load ratio and joint shear demand. According to the results and considering the impact of parameters influencing the behavior of joints, suggestions for determining the joint shear strain at the peak strength are presented. Also, stiffness models proposed by these guidelines are evaluated. The results showed that these models provide sometimes a non-conservative assessment of initial stiffness of the joints depending on joint shear demand ratio and column axial load.

In the last part of this thesis, a practical analytical model that is applicable in common commercial softwares to simulate the elastic and inelastic behavior of reinforced concrete beam-column joints is presented. A data set of 20 planar interior beam-column joints is used to evaluate the analytical models. Results of comparative analysis with analytical models show their capability in simulation of linear and nonlinear behavior of reinforced concrete beam-column joints. By comparing the numerical analysis and experimental results, a good conformity between the results was achieved. The main feature of the analytical model is their applicability in reinforced concrete frames for a more accurate assessment of response and behavior of new or existing structures.

Key Words
Seismic Evaluation, Nonlinear Static Analysis, Reinforced Concrete Beam-Column Joint, Finite Element Model (FEM), Analytical Model, Transverse Reinforcement Details, Joint Shear Demand Ratio, Initial Stiffness of Joint.