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Nonlinear Modeling of Reinforced Concrete Beam-Column Joints

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Abstract —*The performance of reinforced concrete moment resisting frame structure under a seismic activity is reflected by the behavior of beam-column joint as revealed by various experimental studies. Beam-column joint plays a vital role in maintaining the structural integrity and the failure of joint often leads to the failure of whole structure. On the other hand, beam-column joints are usually assumed as rigid zones and the nonlinear inelastic behavior is generally not considered which as a consequence leads to underestimation of the story drift and misleading results. This paper presents a beam-column joint panel zone modeling technique for simulating the shear deformation in a reinforced concrete moment resisting frame. A parametric study is conducted and various factors such as cracking shear rigidity, cracking moment, and the opposed respective curvatures is discussed and the response of hysteretic loops to these parameters is evaluated using a finite element software.*

Keywords*-Inelastic Modeling; Reinforced Concrete; Beam-Column Joints; Moment Resisting Frames; Panel Zone Modeling; Shear Deformations.*

I. INTRODUCTION

The seismic performance evaluation study of reinforced concrete moment resisting frame structures has been increasing day by day among the researchers of structural and earthquake engineering. This is due to the vulnerability of deficient reinforced concrete frames which have been exposed by various seismic events as well as experimental and numerical studies [1-7]. Regions such as beam-column joint experiences reversal of stresses when subjected to lateral loads and thus makes it one of the most crucial zone during an earthquake.

Figure 1. Failure of joint during Turkey earthquake, 1999

Several numerical modeling techniques have been proposed in the past decades and this field can be traced back to 1970 when plastic hinges were proposed to model the inelastic response of RC connections by defining the hysteretic behavior using several geometric curves and rules based on experiments [8-10]. Similarly, various numerical modelling techniques [11-13] have been developed over the years based on various analytical formulations and mechanics to simulate the shear and bar slip deformations of RC beam column joint as shown in the figure 2, 3 and 4.

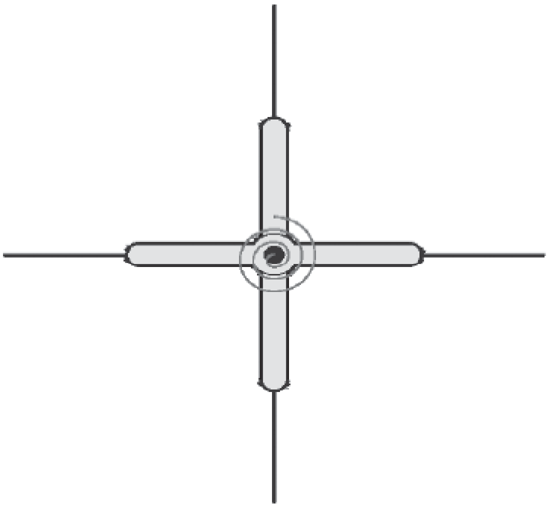

Figure 2. Alath & Kunnath Model [11]

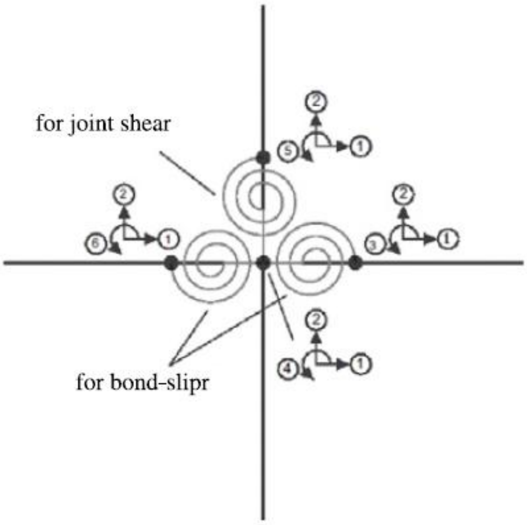

Figure 3. Biddah and Ghobarah [12]

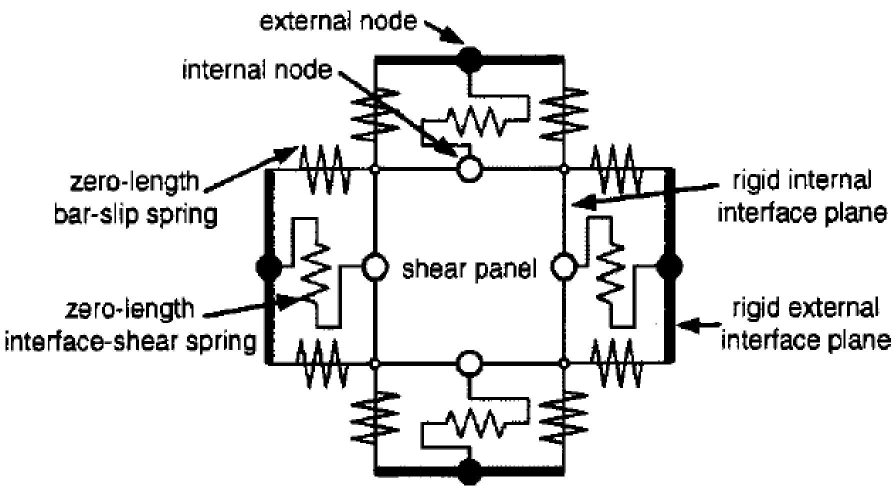

Figure 4. Lowes and Altoontash [13]

The objective of this study is to model the shear deformation of RC beam-column joint panel zone using a hysteretic constitutive relationship and to discuss the effect of various parameters in simulating the shear distortion of connections.

II. MODEL DESCRIPTION

In this study, a single story, single bay, RC frame with bay width of 18 feet and story height of 12 feet is considered in the analysis with material properties for concrete and steel chosen as 2000 psi and 60,000 psi respectively. The beam-column joint panel zone is modelled using a zero length link element at the centerline of beam and column element and a constitutive hysteretic relationship developed by [14] is adopted for the define link element.

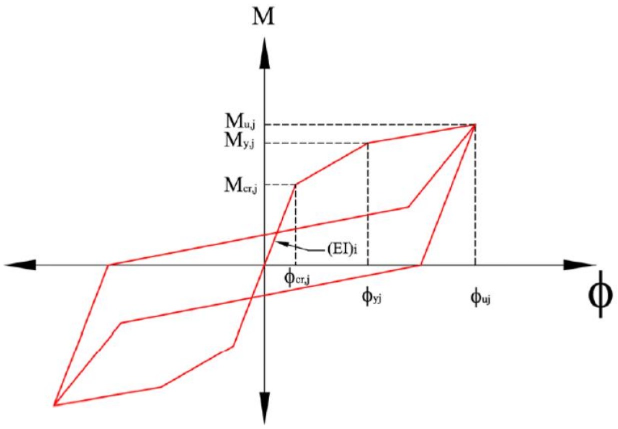

Figure 5. Sivaselvan and Reinhorn Hysteresis [14]

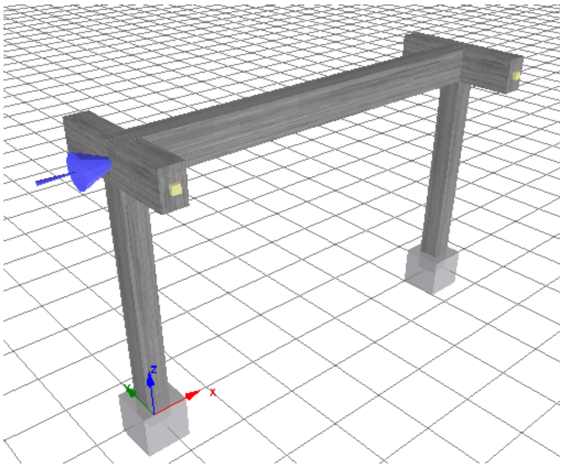

Figure 6. Considered Frame for Analysis

The various parameters of the tri-linear curve such as initial shear rigidity, cracking moment and the curvatures etc. are evaluated. These various parameters significantly affect the structure behavior and is discussed in the next section.

III. ANALYSIS RESULTS AND DISCUSSION

In this study a finite element software SeismoStruct, capable of modeling the geometric and material nonlinearity is used for simulation and a static time history analysis have been performed with an increasing drift loading time history protocol as shown in the figure 7.

Among the various input parameters of the joint panel zone constitutive relationship, the initial shear rigidity significantly affects the capacity of the structure and by decreasing the initial shear rigidity, the deformations of the link element increases as opposed to other parameters. The values of various parameters such as shear rigidity depends on the accuracy of shear strength analytical models and equations. The comparison of numerical models can be more realistic and accurate with experimental data by deriving such analytical equations which can accurately predict the behavior of beam-column joints. The initial shear rigidity is a function of cracking moment of the joint panel and the cracking curvature, and the moment that can be transferred to the joint link element contributes in a great extent to the shear deformations of the joint as observed after a series of analysis. The capacity curve of the frame with and without panel zone modeling is shown in the figure 8 and 9.

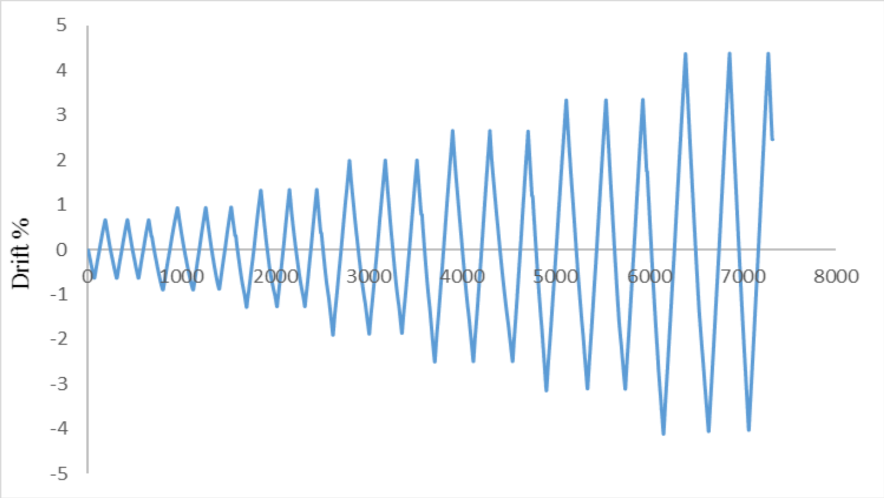

Figure 7. Loading Protocol

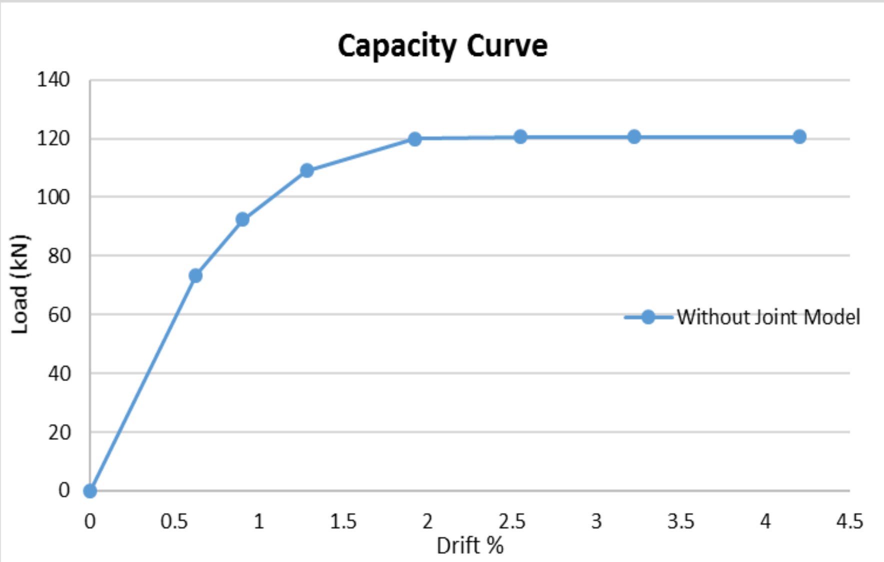

Figure 8. Capacity Curve without link element

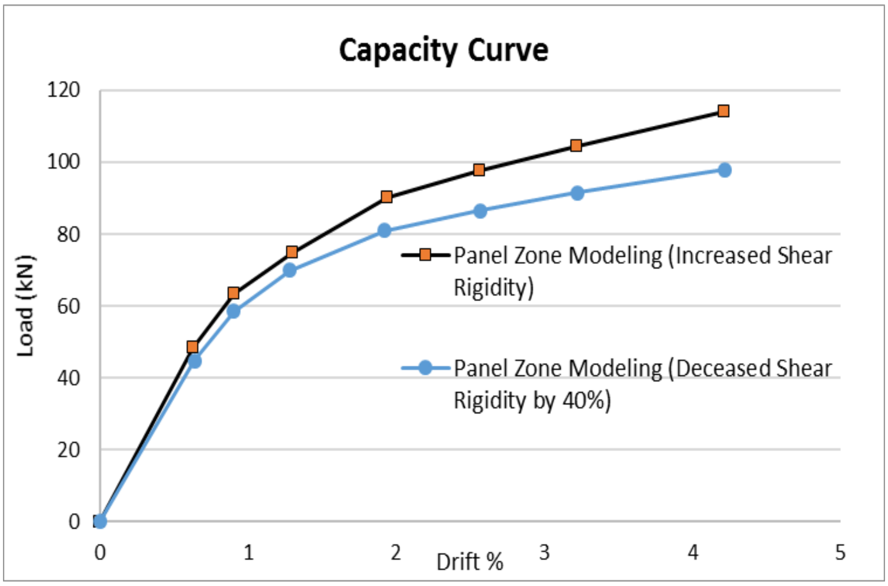

Figure 9. Capacity Curve Comparison Using Joint Link Element

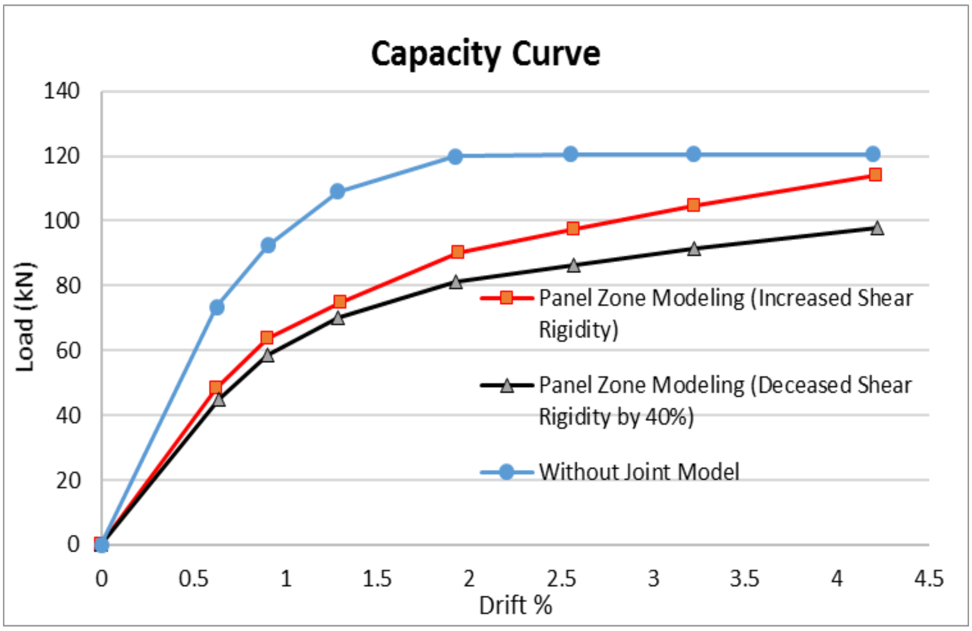

Figure 10. Capacity Curve Comparison With and Without Modeling Technique

A comparison of capacity curve of the frame with and without modeling technique is shown in the figure 10. Results show significant difference for the beam-column joint being treated as an elastic panel zone and being modeled with a link element by assigning different shear rigidity values to the panel zone hysteresis. The decrease in capacity of structure is due to the link element which considers the deformation occurring at the joint during an earthquake event. While the capacity of the frame is high in the case of beam-column joint being model as a rigid zone (elastic). This is due to the fact that joints are considered as rigid zones and as result can lead to misleading results as it not capable to simulate the deformations occurring in reality. The final comparison of the hysteresis of the RC frame for all three cases is shown the figure 11.

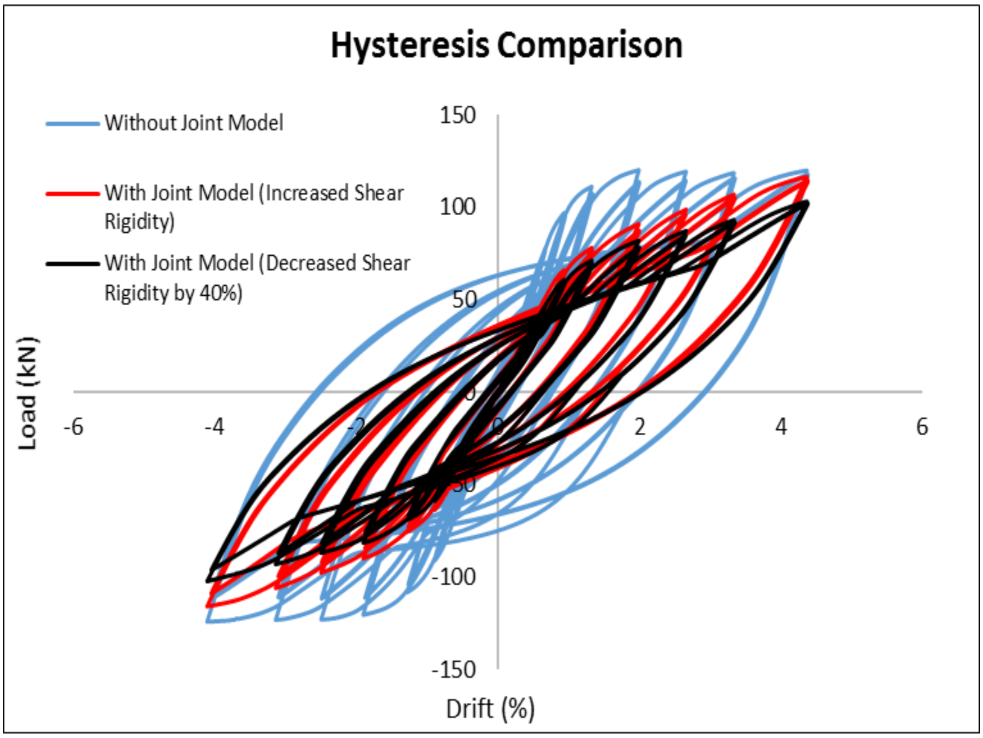

Figure 11. Load Vs Drift Comparison

Various factors such as loading stiffness, unloading stiffness and pinching effect etc. of the hysteretic curves are controlled by the panel zone link element and its input parameters as it can be seen in the above figures. The numerical modeling of joint depends on the analytical equations and the shear stress-strain envelopes which can be adopted further for accurate modeling and development of force deformation constitutive relationships.

IV. CONCLUSION

This paper presented a numerical study of reinforced concrete beam-column joints using a finite element software, capable of considering material and geometric nonlinearity. A simplified tri-linear hysteretic relationship for the joint panel zone is followed and a parametric study is conducted by assigning various values to the proposed link element. Different input parameters significantly affect the overall performance of the RC frame, however, it is found that the initial shear rigidity significantly alters the response of the model and effecting the overall performance of the structure. The assumptions to consider beam-column joint as rigid zone may lead to misleading results as in reality various deformations occur at the joint resulting in reducing the capacity of the structure. However, to accurately model beam-column joint simplified analytical models and simplified hysteretic rules is necessary in order to define backbone and hysteretic constitutive laws.

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