A Simplified Numerical Model for Reinforced Concrete Beam-Column Joints

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Abstract- Reinforced Concrete Beam Column joints are most critical regions of any reinforced concrete structures. The performance of RC joints determines the performance of whole building during seismic loading. Many researchers have focused on the experimental study of RC joints to determine the seismic performance of RC structures. However, experimental tests are expensive and time consuming. Therefore, the alternative approach of numerical modeling is preferred to study a wide range of parameters affecting the behavior of beam-column joints. This study presents the result of macro modeling of RC beam-column joints using finite element based software SeismoStruct. The results of the numerical model are compared with the experimental results and found to be in excellent agreement. The peak strength of the numerical model was found to be 75.2 kN, which is 8% higher than that of experimental model and drift ratio at which peak strength of the numerical model was obtained is 4.33%, which is higher than that of experimental model by 2%. This shows good agreement of numerical results with the experimental results. It is also observed that the initial stiffness of numerical model is higher than that of the experimental model. The numerical model may be used for more comprehensive parametric study of the beam-column joints.

Keywords- calibrated, modeling, macro model, stiffness

1 Introduction

In the past beam-column joint region was assumed to be rigid during analysis, but this lead to overestimated results. Beam-column joints mostly have brittle failure, which may not contribute significantly to the ductility performance of the structures [1]. In the past earthquakes, most of buildings collapsed due to the failure of RC joints as shown in Figure 1 [2]. In RC frames the beam-column joint are important region to resist the seismic forces and determine response of the building during earthquakes [3]. Therefore, RC beam-column joint need to be studied comprehensively in order to ensure a safe design of RC structures.

Figure 1: Building collapses due to beam-column joint failure [4]

Extensive experimental studies have been conducted in order to study the response of the beam-column joints, based on which several codes have been improved [5]. Present joint design and detailing using ACI provides the adequate provision in joint against the gravity and seismic forces [6].
Sufficient development length and confinement is provided in the joint to resist the reversed cyclic loading. However, to satisfy these requirements, the joint region become very congested and the execution become a challenge on site. Therefore, this study aims to develop a numerical model to study various parameters contributing to the strength of the joint and which determines the governing failure type (shear failure of joint core, bar slippage etc.).
Failure mechanisms including Bar Slip Failure and Shear Panel Failure which are the two primary mechanisms determining the inelastic behavior of RC beam column joint can be studied using this model, to investigate whether the failure will occurs due to Bar Slip Failure or due to Shear Panel Failure of particular RC beam column joint.

2 Research Methodology

2.1 Numerical Modelling

Reinforced concrete structures can be modelled using both micro and macro approaches, both having pros and cons. This paper presents the results obtained using macro modelling of RC beam-column joints. The numerical model is first verified and calibrated with the experimental results and then a comprehensive parametric study is conducted to determine the contributing parameters in various failure scenarios.
Manders [7] model will be used for the modelling concrete (20.68 MPa) and Manegotto Pinto [6] model for modelling steel (413.5 MPa). A finite element based software package SeismoStruct is utilized for the numerical modelling of RC joints.

2.2 Simplified Joint Model

One of the simplified beam-column joint model was presented by Lowes et al [8]. This model is able to capture the mechanisms responsible for the nonlinear behavior of RC beam-column joints [8]. It is used in the two dimensional analysis of the RC frame and has the following characteristics: (1) it has 12 degree of freedom at the four exterior nodes (2) 4 interior degrees of freedom (3) It has eight anchorage failure components which are used to model the bar slip mechanism. The model also consists of joint core component which are used to capture the shear failure of joint core, and interface shear component to capture the shear at the interface as shown in Figure 2. Every component of this model needs an independent action-deformation response curve [9].

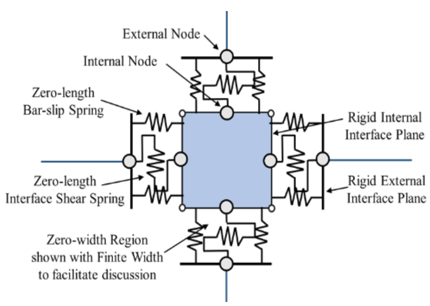

Figure 2: Beam Column Joint Spring Model by Lowes et al [8]

Table 1 Tekeda Curve Parameters

Parameters		**Bar Slip Component (Beam)**	**Bar Slip Component (Column)**	**Shear Panel Rotation**
Yielding strength	Fy	9.64E+07	8.43E+07	1.73E+08
Initial stiffness	Ky	1.66E+11	1.29E+11	1.42E+12
Post-yielding to initial stiffness ratio	α	0.1	0.1	0.1
Outer loop stiffness degradation factor	β0	0.4	0.4	0.4
Inner loop stiffness degradation factor	β1	0.9	0.9	0.9

In the SeismoStruct, all these components are modeled using the "Joint Element" available in SeismoStruct [10]. The joint element is a three dimensional element with six degrees of freedom. As mentioned above, action deformation curve needs to be provided for every degree of freedom. There are 12 response curves available in SeismoStruct, and modified Tekeda curve will be used to model the response of the model. The parameters required to define the Tekeda curve are given in the Table 1.

2.3 Description of Test Specimen

The numerical model was developed for a typical RC beam-column joint which was tested at Civil Engineering Department, University of Engineering and Technology, Peshawar. The numerical model and experimental test specimen are given in Figure 3. The specimen employed concrete with compressive strength of 20.68 MPa and steel had a yield strength of 413.5 MPa.

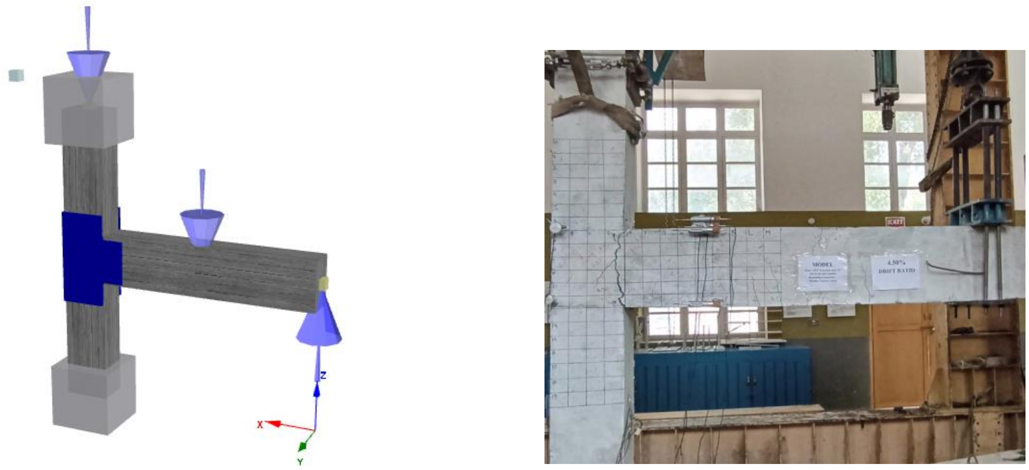

Figure 3: SeismoStruct Model (Left Figure) and Experimental Test Specimen (Right Figure)

3 Results

Figure 4 compare the numerical and experimental action deformation response. The strength and hysteristic reponse of numerical study agrees well with the expeimental results. For the Normal Concrete Model, the maximum load capacities of the test specimen were 75.2 kN. This capacity was higher than the experimental test by about 8.0% as shown in Table 22. Numerical results show high value for initail stiffness due to assumptions made during modeling.

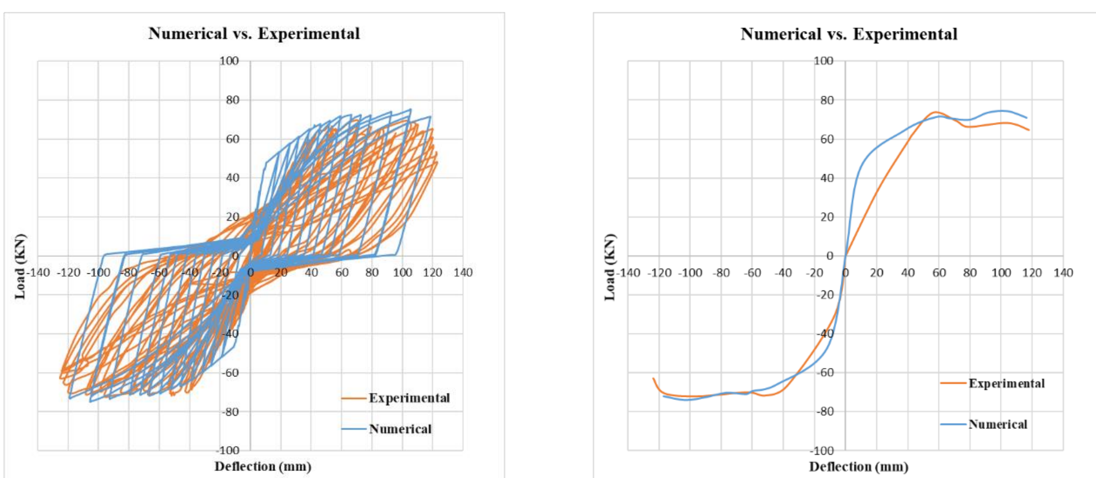

Figure 4: Numerical vs. Experimental Hysteretic Curves (Left Figure) and Envelope Curves (Right Figure)

Table 2: Comparison of Numerical and Experimental Results

Model	**Loading Direction**	**Load max (KN)**		**Rmax**
		Analytical	Experimental	
		Pmax (kN)	Pmax (kN)	
RC Model	Positive	75.2	69.6	1.08

4 Practical Implementation

Failure mechanisms including Bar Slip Failure and Shear Panel Failure which are the two primary mechanisms determining the inelastic behavior of RC beam column joint can be studied using this model, to investigate whether the failure will occurs due to Bar Slip Failure or due to Shear Panel Failure of particular RC beam column joint

5 Conclusion

Based on the above numerical results it can be concluded that :

1) The peak strength of the numerical model was found to be 75.2 kN, which is 8% higher than that of experimental model and drift ratio at which peak strength of the numerical model was obtained is 4.33%, which is higher than that of experimental model by 2%. This shows good agreement of numerical results with the experimental results.
2) The non linear response of the beam-column joint can be accuratetely modelled and simulated using the above mentioned simplified modeling technique using Seismostruct software.
3) The mechanisms like anchorage failure and joint core shear failure mechanisms responsible for the non linear response of the beam-column joint can be modeled and incorporated in the numerical analysis.
4) It is also observed that the initial stiffness of numerical model is higher than that of the experimental model because of the simplified approaches used in the numerical model.

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