A Simplified Numerical Model for Seismic Analysis of Reinforced Concrete Beam-Column Joints

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Abstract

Reinforced Concrete Beam Column joints are most vulnerable regions of any reinforced concrete (RC) structures. The performance of reinforced concrete 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 numerous factors that affects the response of beam-column junctions. This paper reports on the macro modeling of RC beam-column junctions with a finite element (FE) software, SeismoStruct. The outcomes of experimental and finite element (FE) model outcomes are compared and found to be in excellent agreement. For the FE model, ultimate load capacity was 75.2 KN. This numerical load capacity was higher than the experimental test by about 8%, and the corresponding drift ratio at which the numerical load capacity was achieved was 4.33%. The drift ratio value of numerical model was found to be 2% higher than that of experimental model. The mechanisms responsible for the nonlinear behavior of RC joints, including bar slip and shear panel failure can be incorporated and studied using this simplified numerical macro model.

Keywords: Modeling, Calibrated, Macro Model, Bar Slip, Shear Panel, Non Linear

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 given in the Figure 2 [2]. In RC frames the beam column connections 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 Collapsed due to connections failures [4]

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Figure 2. Collapse of structures due to failure of connections [4]

The behavior of the connections has been extensively studied experimentally, as a result of which various code have been improved [5]. Present joint design and detailing using ACI provides the adequate provision in joint against the gravity and seismic forces [5]. Sufficient development length and confinement is provided on 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 [6]. Therefore, the goal of this investigation is the development of a FE model to study various parameters contributing to the strength of the joint and which determine the governing type of failure (shear failure of joint core, bar slippage, etc.).

2 Numerical Modeling

Reinforced concrete structures can be modelled using both micro and macro approaches, both having their pros and cons [7]. The findings of macro modeling of RC junction are presented in this research study. The FE model is first verified and then calibrated with the experimentally tested specimen outputs and then a comprehensive parametric study is conducted to determine the contributing parameters in various failure scenarios. Manders [8] model will be used for the modeling concrete (3ksi) and Manegotto Pinto [9] model for modeling steel (60ksi). A FE based software, SeismoStruct is utilized for the numerical modeling of RC joints.

2.1 Simplified Joint Model

Lowes et al. introduced a simplified joint model for the RC junctions [10]. The mechanisms responsible for the response of reinforced concrete junctions in nonlinear range can be captured using this joint model [9]. It is used in the two dimensional analysis of RC frame system 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 for the modeling mechanism of the bar slip [7].The model consists of joint core components which are used to get the joint core shear failure mechanism, and shear component at the interface to simulate the shear as given in Figure 3 and Figure 4. Every component of this model needs an independent action-deformation response curve [11].

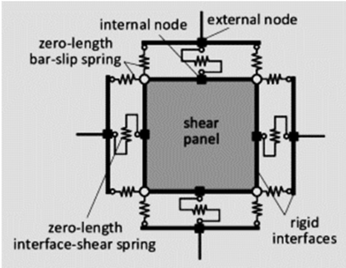

Figure 3. Spring Model for Beam-Column Junction by Lowes et al [10]

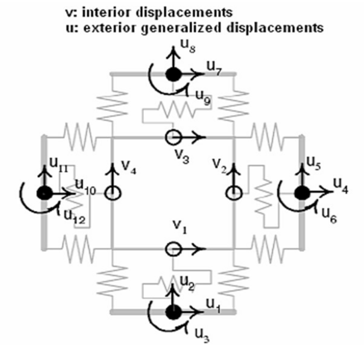

Figure 4. Degree of Freedoms in joint model [12]

In the SeismoStruct, all these components are modeled using the "Joint Element" available in SeismoStruct [9]. The joint element is a three dimensional element with six degrees of freedom. As mentioned above, we need to provide the action deformation curve for every degree of freedom [13]. There are 12 response curves available in SeismoStruct, and to simulate the model's response, a modified Tekeda curve will be employed as given in the Figure 5 [14].

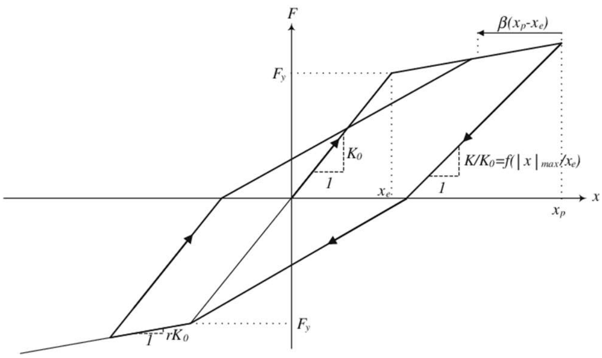

Figure 5. Takeda et al. Model [15]

2.2 Description of Test Specimen

For a standard RC beam column connection, a numerical model was created which was previously experimentally tested by a Ph.D. Scholar at UET Peshawar. The detail of reinforcement used and applied loading of the specimen are provided in Figure 6 and Figure 8. The loading (cyclic) was assigned at the tip of the beam, and pre-compression at the top of column. Bottom and top of beam was reinforced with three bars of diameter 12.7 mm respectively and eight (8) bars of 12.7 mm was used in the column as given in Figure 8. The specimen employed concrete with compressive capacity of 20.68 MPa and steel had a yield capacity of 413.5 MPa.

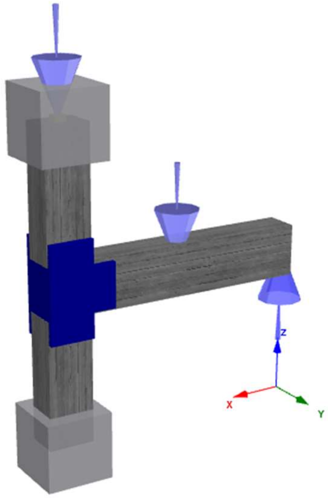

Figure 6. SeismoStruct Model

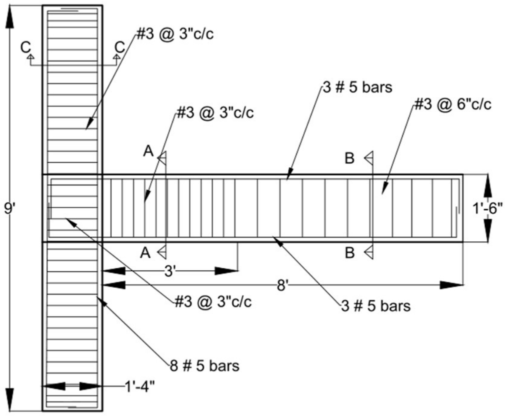

Figure 7. Description of Experimental Model

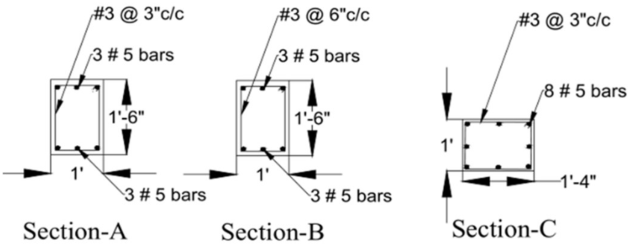

Figure 8. Description of Test Specimen Cross Sections

3 Results

Figure 9 and Figure 10 compare the numerical and experimental action deformation response. The strength and hysteretic response of numerical study agrees well with the experimental results. Numerical results show high value for initial stiffness due to assumptions of the models used during the numerical analysis.

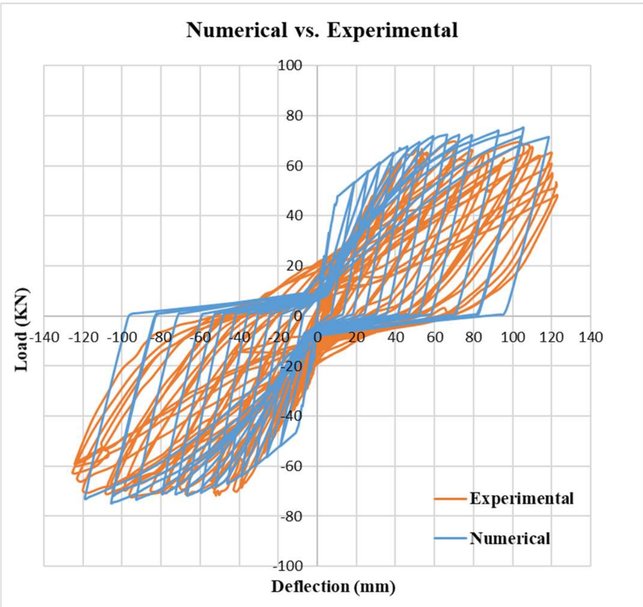

Figure 9. Numerical vs. Experimental Hysteretic Curves

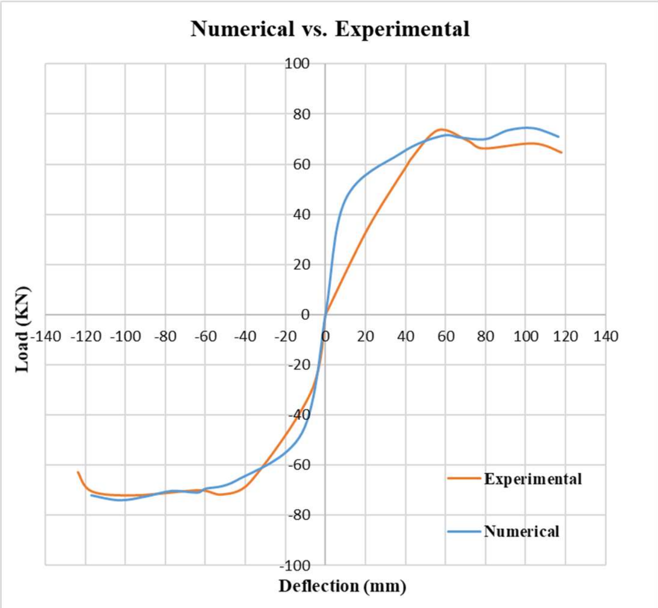

Figure 10. Numerical vs. Experimental Backbone Curves

4 Conclusions

Comparison among the both numerical and experimental results was made and conclusions are presented below:

- The beam-column junction can be accurately modelled and nonlinear response can be simulated using the above mention simplified modeling technique using SeismoStruct software.
- The mechanisms like anchorage failure and joint core shear failure mechanisms in the beam column junction can be modeled and incorporated in the numerical analysis.
- 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.

Disclosure of Interests

Regarding the subject matter of this article, the writers have declared no competing interests.

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