MODELING THE NON-LINEAR BEHAVIOR OF A REINFORCED CONCRETE CORNER BEAM-COLUMN JOINT

Bryce A. Lloyd[1], blloyd11@gmail.com, San Jose State University, 2009 PEER Undergraduate Summer Internship Program

Victor M. Sanchez[2], Wael M. Hassan[3], Beyhan Bayhan[4] and Dr. Jack P. Moehle[5]

University of California, Berkeley

[1] Undergraduate Student of Civil Engineering, San Jose State University ; [2] Undergraduate Student of Civil Engineering, Cal Poly San Luis Obispo, PEER Intern

[3] Graduate Student of Structural Engineering, University of California Berkeley ; [4] Graduate Student of Structural Engineering, University of California Berkeley

[5] Professor of Structural Engineering, University of California Berkeley

A. PURPOSE OF RESEARCH

The purpose of this research project is to develop several analytical models using computational software of the inelastic behavior of a non-ductile reinforced concrete beam-column joint specimen. Comparisons of the different analytical models used were performed to determine how accurately they predicted the experimental results. The analytical models generated included a conventional rigid joint model, an adjusted flexural rigidity model based on the ASCE 41 supplement, and a theoretical model that utilizes slip and moment rotational springs to characterize the stiffness of the joint.

B. Background

Figure 1: Non-ductile Beam Column Joint Failure.
Photo taken from PEER archives

Beam-Column joints found on structures built before the 1970s are vulnerable to collapse under seismic loading. Figure 1 shows an example of joint failure. Reasons for their deficiencies according to work performed by Beres *et al.* (1996) are as follows:

1) The reinforcement ratio of longitudinal steel in the columns is less than 2.
2) Widely-spaced column ties provide little or no confinement to the joint region.
3) Little or no transverse reinforcement within the beam-column joint.
4) Discontinuous positive beam reinforcement with a short embedment length into the column.
5) Columns with bending moment capacity less than that of the beams (weak column- strong beam case).

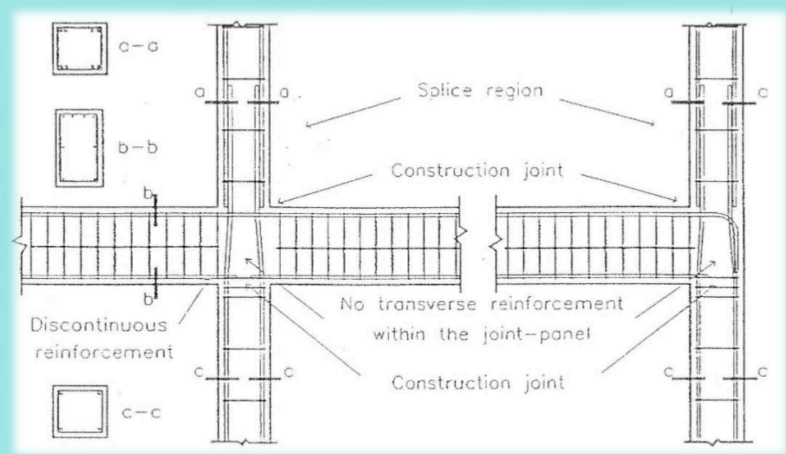


Figure 2: Insufficient Detailing.
Photo taken from Dr. Jack Moehle's powerpoint

An example of improper detailing is shown in figure 2. In order to efficiently retro fit these structures, accurate computer models must be developed.

C. TEST SPECIMEN CONSTRUCTION AND SET UP

Figure 3: Test Specimen.
Photo taken by Victor Sanchez[2]

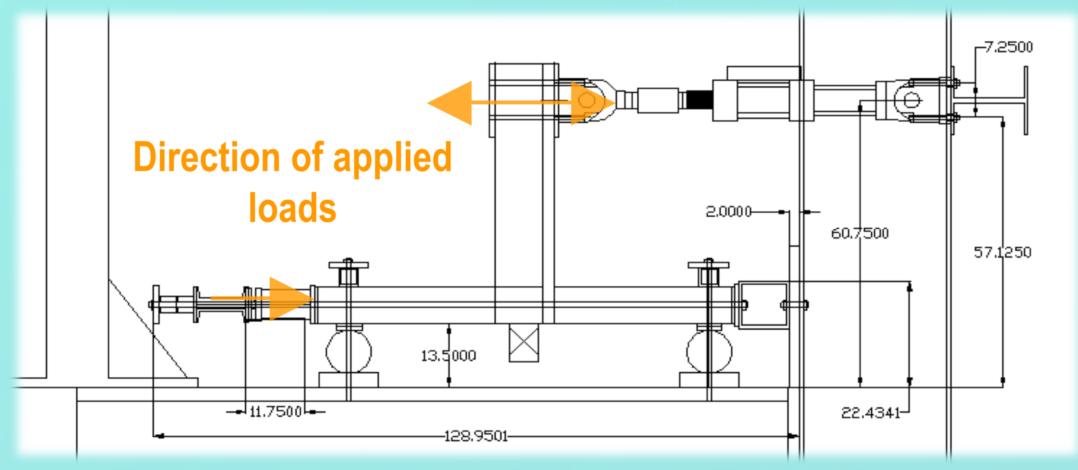


Figure 4: Experiment Set Up & Loading.
Photo taken from Barnes Report

The specimen tested and analyzed was a concrete reinforced corner beam-column joint. The joint had a transverse beam stub, half the length of a column above and below the joint, and half the length of a longitudinal beam and slab. The specimen was 1/2.25 scale and was reinforced with # 4 bars in the column and # 5 bars in the beams. A picture of the specimen's reinforcement and outer shape are shown in figure 3. The detailing matched that of conventional pre-1970s code guidelines. The specimen was loaded axially with a compressive force equal to 0.2fc'Ag on the column throughout the test. The specimen was loaded at the beam in a displacement controlled quasi static cyclic loading pattern up to 10% drift as shown in figure 4.

D. COMPUTATIONAL SOFTWARE

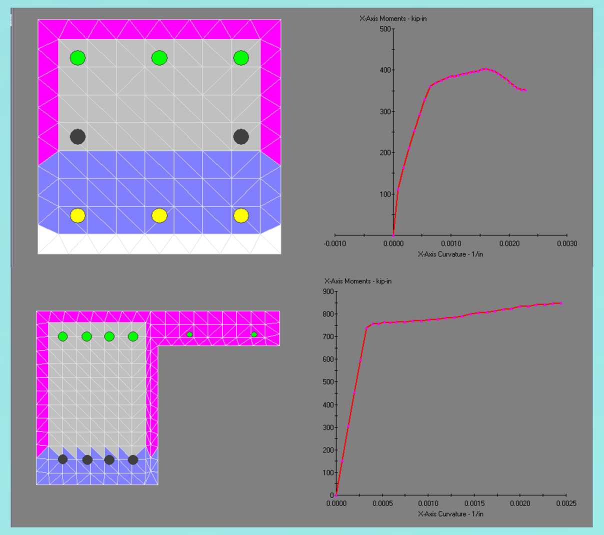


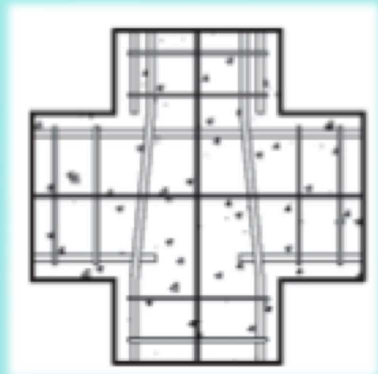
Figure 5: XTRCACT.
Photo taken from XTRACT

The software used to generate the analytical models was XTRACT and OpenSees. XTRACT was used to analyze the flexural capacities of the beam and column sections. XTRACT was used because of its user friendly interface and graphical representation of the analysis. A screen shot of XTRACT moment-curvature diagrams are shown in figure 5.

OpenSees was used to develop the node-member model of the specimen. The graphs shown representing the analytical data were generated with OpenSees. OpenSees was used due to its open source code, which enables users full customization of their model.

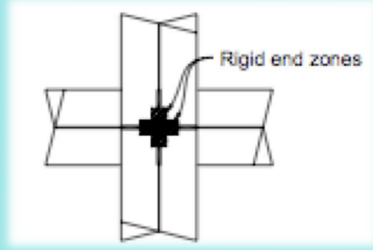
E. MODELS GENERATED FOR ANALYSIS

1) Conventional Model



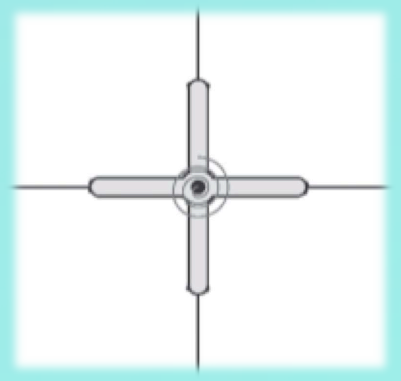
The conventional or pre-1970s model simplifies the joint area by assuming a high level of rigidity for the member's end zones inside the joint. As shown in figure 5, this assumption gives a higher flexural shear capacity in analysis than the experimental results. The model also does not accurately represent the strength degradation associated with bond slip failure and joint shear.

2) ASCE 41 Supplement Model



The ASCE 41 Supplement model is similar to the conventional model as it does not use spring coefficients to model the strength degradation of the joint. The estimated shear capacity is closer to the joints actual capacity because the supplement model determines which members of the joint are more critical in flexure and assigns a level of rigidity to the end zones accordingly.

3) Slip & Moment Spring Model

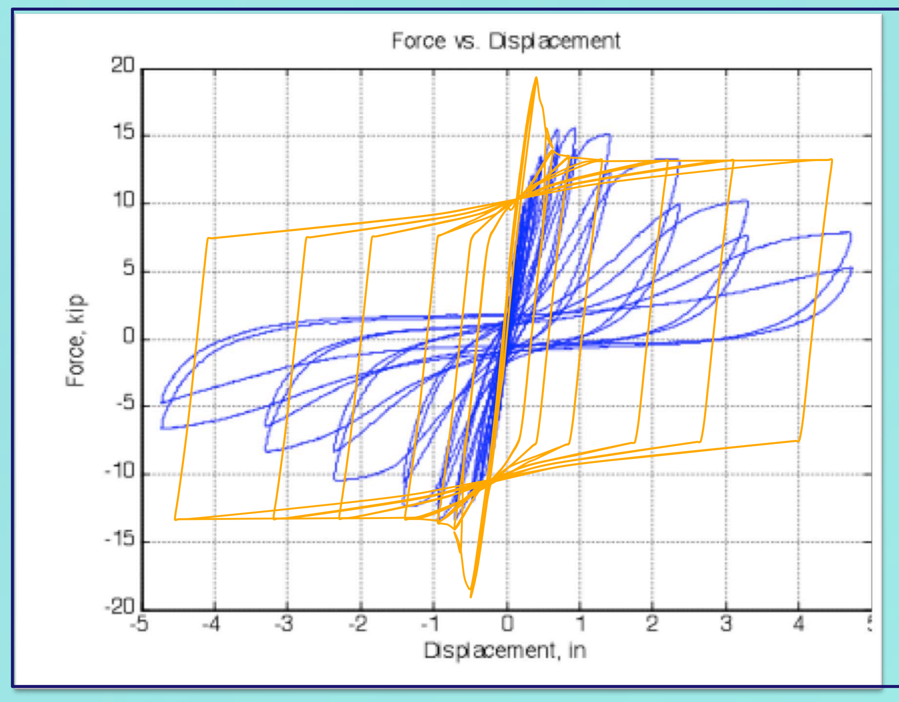


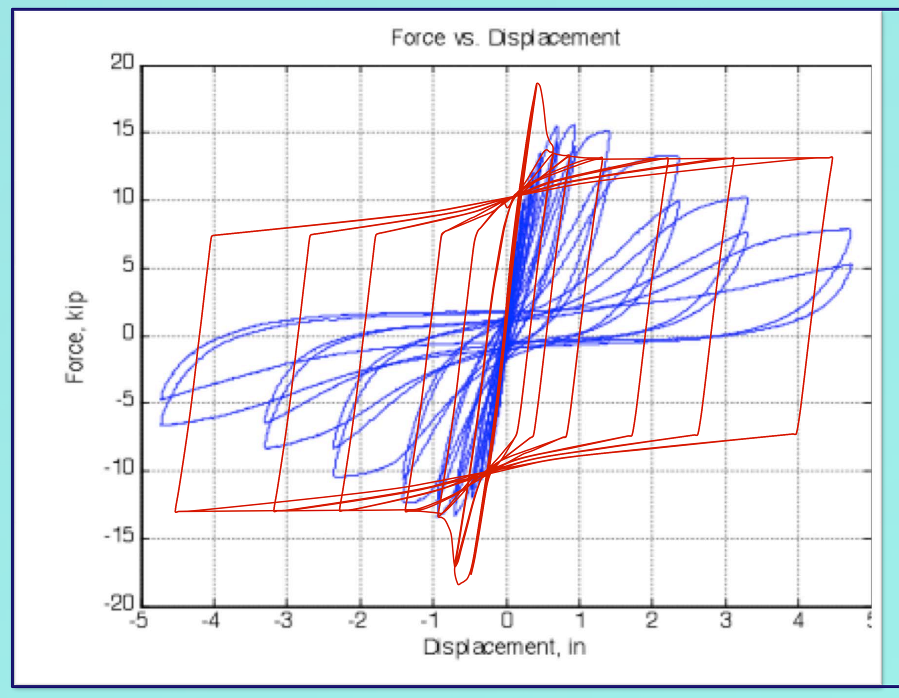
The Slip and moment spring model assumes a rigid joint area but assigns slip springs were bond failure is likely to occur and a moment rotational spring that exhibits emplicitly determined hysteresis behavior to model the strength degradation associated with joint shear. The stiffness of the slip springs is based on similar parameters used to determine the bond strength between the reinforcement and the concrete. The stiffness in the moment rotational spring determined by the shear capacity parameters of the joint. This includes lateral confinement and joint geometry.

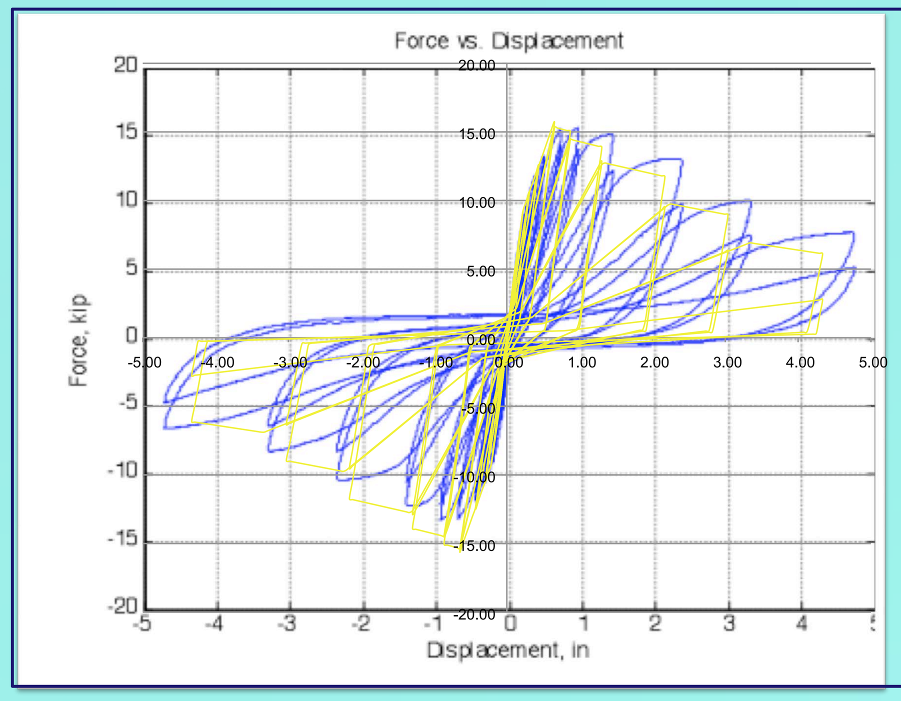
F. CONCLUSION

The slip and moment spring model closely matches the strength degradation and shear capacity shown in the experimental results. This model also predicts a shear capacity more accurately than the conventional and ASCE 41 supplement models. To develop this type of model is rather tedious and not likely worth the time for a design firm to consider using. More research should be conducted on how the slip and moment spring model could be simplified for practical use.

G. MODEL COMPARISONS WITH TEST RESULTS







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