Practical Linear and Nonlinear Models of Reinforced Concrete Beam-Column Joints in Existing Structures

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Beam-column joint damage can significantly impact the performance of reinforced concrete moment frame structures subject to earthquake loading, and, in extreme cases, can contribute to frame collapse. To assess the seismic performance of existing concrete frames, engineers require models that can accurately predict the behavior of joints for a wide range of designs and that are easily implemented in commercial software. In this study, a database of 45 planar interior beam-column joints is used to evaluate two types of joint models. First, models acceptable for linear analyses are considered. The rigid offset models recommended in the ASCE/SEI Standard 41-06 are evaluated, and a modified approach to determining the rigid offset length is proposed to provide improved prediction of the displacement at which beams yield. Second, nonlinear models are considered to support nonlinear modeling of frames and enable simulation of progressing joint stiffness and strength loss. A number of nonlinear joint models can be found in the literature, but few are easily implemented in commercial design/analysis software or verified for a range of joint designs. In this study, a simple nonlinear model is proposed in which lumped-plasticity beam elements are modified to account for joint flexibility and potential strength loss. Specifically, the beam-element plastic hinge is assumed to represent two nonlinear hinges in series. The first hinge represents the flexural response of the beam, and the second represents the nonlinear response of the joint. The beam flexural hinge is defined by the traditional moment-curvature response of the beam section and a newly developed rotation limit at which strength loss is predicted. The joint hinge is bilinear, with stiffnesses calibrated to accurately predict measured response, and includes a rotation limit at which strength loss initiates due to joint failure. The proposed model accurately predicts the load-displacement response of frame sub-assemblages including accurately predicting the mechanism that determines response: beam flexure or joint failure.