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Improved analytical model for special concentrically braced frames

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ABSTRACT

Special Concentrically Braced Frames are commonly used as the seismic resisting system in buildings. Their inherent strength and stiffness assure serviceable performance during smaller, more frequent earthquakes. Inelastic tensile yield and post-buckling compressive deformations of the brace dominate performance during large seismic events. However, inelastic deformations of the brace place secondary yet significant inelastic deformation demands on beams, columns, and connections, which significantly affect the seismic performance. These response modes must be included in an analytical model of the system to capture the response. However, conventional practice uses beam–column elements for the brace, to simulate brace buckling, with pin-ended or rigid end connections; these computer models cannot capture the full range of SCBF behaviors. The research presented in this paper was undertaken to develop a modeling approach for SCBFs to more accurately predict their seismic performance. Beam–column elements are used for the braces, beams and columns and these elements include nonlinear geometric effects to simulate brace buckling. A new connection model is proposed to simulate the behavior of the gusset plate. The model parameters are based upon the member sizes, properties and connection designs. Simulated results are compared with experimental results and predictions from approaches more commonly used in practice. Although a step beyond models currently used in design practice, the proposed model remains simple in its implementation and is suitable for a wide range of practical applications. The proposed model provides accurate simulation of global behavior, while retaining simplicity and providing reasonable predictions for many local behaviors.

1. Introduction

Special concentrically braced frames (SCBFs) are widely used in seismic design. Their strength and stiffness result in an economical system that easily meets serviceability limit states for performance based seismic design (PBSD). During large, infrequent earthquakes, SCBFs must assure life safety and collapse prevention performance states, and this requires simulate of the nonlinear behavior. As a result, theoretical models for PBSD must reliably predict both elastic and inelastic performance. However, modeling approaches used in practice seldom accurately predict the yield mechanisms and failure modes, and therefore fall short of the requirements of PBSD.

The inelastic seismic response of SCBFs is dominated by compressive buckling, tensile yielding and post-buckling behavior of the braces [1]. The braces are typically connected to beams and columns through gusset plate connections, which must tolerate large inelastic deformations and end rotations associated with brace buckling, while sustaining the full axial resistance of the brace. Gusset plate connections and beam and column framing members provide boundary conditions to the brace, and therefore influence its resistance and deformation capacity. Proper design of the connections may significantly improve the response and deformation capacity of the frames [2]. However, in many analyses for structural design, the gusset plate connection is simulated as pinned or rigid joints. In a well-designed system that includes inelastic action beyond the brace, these approximations limit the accuracy of the stiffness and resistance predicted by the computer simulation and they lead to erroneous predictions of the deformation capacity of the system.

Since the seismic behavior of SCBFs is quite complex, some very detailed computer models have been developed to accurately predict their performance (e.g., [3–8]). These models have invariability employed a relatively fine mesh of nonlinear shell or 3-dimensional brick elements. Continuum modeling approaches are computationally expensive, and therefore full building simulation is rare. Some have modeled only braces or their connections [3,4], while others evaluated individual braced bays or multi-story single-bay CBFs [5–8].

Accurate models must include large deformation theory for simulation of both local and global buckling, and some studies extended the models to include consideration of initiation of cracking and fracture based upon the strains, components of strains, or stress–strain history computed in the analyses [3,4,6,7]. The effort required to develop these models is substantial, since some had more than 20,000 shell elements and a much larger number of degrees of freedom. Nonlinear analyses of these complex models required considerable computing time with the analyses required several days to complete a

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