SEISMIC DESIGN AND ANALYTICAL STUDIES OF COMPOSITE STEEL-CONCRETE MOMENT FRAME SYSTEMS

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Composite frame systems were developed in the United States about twenty-five years ago as an alternative to conventional all-steel and all-concrete moment frames in low seismic zones. The primary motivation behind their development is that the system optimizes the usage of the steel and concrete materials. Reinforced concrete columns offer a significant cost-advantage over structural steel for resisting compressive column loads, while composite steel beams and composite slab-deck provides an efficient floor framing system for long spans desired in commercial buildings. Perhaps the most significant advantage of this system is the design and performance of the beam-column connection. A typical connection allows the steel beam to pass continuous through the joint, thereby avoiding interruption of the beam at the column face and eliminating the need for welding or bolting the beam at the point of maximum moment. This type of connection detail avoids the fracture problems of conventional steel moment frames that were encountered during the 1994 Northridge earthquake. Extensive testing over the last fifteen years has demonstrated that composite connections, when properly detailed, can provide reliable hysteretic behavior and sufficient strength to develop the beam plastic moment. Despite these advantages and previous analytical studies that show excellent seismic performance of these composite frames, engineers are still hesitant to utilize this system in highly seismic areas.

The focus of this research program is to (1) develop and calibrate the tools used to model these structural systems within the framework of the OpenSees simulation platform currently being developed by PEER Universities, (2) collaborate with researchers at the NCREE laboratory in Taipei to conduct a benchmark experimental program on a full-scale composite moment frame (Fig. 1), and (3) use the performance of the test frame and the corresponding analytical studies to resolve the seismic design of these systems. In a general sense, the primary goal of this study is to ultimately push forth this composite frame concept in the industry as a viable alternative to traditional moment frames.

Figure 1 –Photo of full-scale composite test frame.

A big part of this push for validation lies within the three-story, three-bay composite moment frame, which was tested in October of 2002 at the NCREE laboratory. Measuring 12 meters tall and 21 meters long, it is among the largest specimens of its type ever tested. Designed to just meet the minimum requirements of current US building code standards, the full-scale frame performed very well under four earthquake loading scenarios and a final static push out to an interstory drift ratio of 10%. In addition to verifying the overall performance of the system, this test has provided valuable data to evaluate and validate design provisions for composite moment frames. The analytical simulations of this test have proven to mimic the overall frame behavior fairly well, but it has also brought up several issues that need to be improved and/or incorporated in the model, such as RC column stiffness degradation and steel beam local buckling.