ABSTRACT

Agarwal, Anil. Ph.D., Purdue University, December 2011. Stability Behavior of Steel Building Structures in Fire Conditions. Major Professor: Dr. Amit Varma.

Steel building structures are known for their susceptibility under fire conditions. This research focuses on the fire behavior of mid-rise steel buildings with composite floor systems. The objective of this research is to identify *weak links* in the building performance in fire. A 10 story steel building is design according to the American design practices. A numerical technique is developed to model and simulate the behavior of this building in fire conditions. The fire conditions are simulated by assigning structural components the temperature values corresponding to the *design fire event*. The numerical technique involves Finite Element (FE) based *macro-models* for connections. The connections in the building models are capable of modeling temperature dependent coupled multi-axial force-displacement response along with a coupled failure criterion. Beam elements and a combination of beam and shell elements are used for modeling columns, and composite slab systems, respectively. Explicit dynamic analysis technique is employed to simulate the structural response.

The results from the simulations identify gravity columns as the most critical elements from fire safety point of view. In the event of a column failure, presence of steel reinforcement was found to be very effective in arresting progressive collapse of the structure. Analysis results also emphasized the role of shear connections in building fire safety. Shear connections can help develop significant negative moments at the beam ends, which can help improve the flexural behavior of the floor system. It was observed that a more detailed investigation into the behavior of steel columns in fire conditions was required.

Detailed parametric study was conducted on wide-flanged column behavior at elevated temperatures. Detailed finite element models of steel columns were analyzed using implicit dynamic analysis. The analysis scheme accounted for the effects of column slenderness, boundary conditions, uniform and non-uniform temperature distributions, residual stresses, and local and global geometric imperfections. New set of design equations were proposed for designing steel columns at elevated temperatures. A simple modification factor was proposed to account for the continuity of a heated column into the cooler stories above and below the story in fire.

All of the current column design equations assume a uniform temperature distribution across the column cross-section. The effects of thermal gradients across the column cross-section were also studied in detail as a part of this research. The parametric study on columns with thermal gradient was used to understand different failure modes of columns with thermal gradient. It was established that the behavior of a column with thermal gradient can be compared with the behavior of a beam-column. AISC ambient temperature beam-column equations were used as the basis for developing a new set of column design equations for columns with thermal gradient.