ABSTRACT

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The overall goal of this research is to develop knowledge of structural mechanics and behavior of steel load-bearing members (columns and beam-columns) under fire conditions. A total of fifteen full-scale steel members were tested under combined mechanical and thermal loading. Five A992 steel beam-columns (W10x68) were tested to determine their fundamental moment-curvature responses at elevated temperatures and different axial load levels. The experimental approach involved the use of radiant heating and control equipment to apply the thermal loading and close-range photogrammetry combined with digital image processing techniques to measure the deformations in the heated zone. Ten A992 steel wide-flange (W8x35 and W14x53) columns were then tested to determine the inelastic buckling behavior at elevated temperatures that developed either uniform or non-uniform temperature distribution through the cross-section. A self-reacting test frame was specially designed to subject the column specimens to axial loading with simply supported end conditions, and thermal loading was applied using the same type of radiant heating and control equipment as the beam-column specimens. The measured behaviors (and strengths) of the tested beam-column and columns specimens were compared with those obtained from detailed 3D finite element analyses.

The experimental results indicated that the fundamental behavior and strength of steel members is governed mostly by the maximum steel surface temperature, and the strength and stiffness of steel columns decreases significantly with increasing temperatures, particularly in the range of 500 ^{o}C to 600 ^{o}C. Also, thermal gradients decrease the load carrying capacity of steel columns and the average temperatures across the section at the onset of buckling. Non-uniform temperature distribution not only makes the column cross-section asymmetric because of the temperature dependent elastic modulus of steel, but it also introduces lateral deformations due to uneven expansion of steel. As part of the research, the existing analytical models and column design equations were verified against the experimental test data. Eurocode-3 mechanical and thermal properties for steel were included in the detailed analyses. The results indicate that the elevated temperature behavior of steel members can be predicted reasonably using detailed 3D finite element models and computationally efficient fiber-based models.

The versatile experimental approach developed in this research can be extended to other structural members and loading conditions. The verified models and fundamental experimental data can be used to conduct further parametric studies, and develop structural performance-based design guidelines for building structures subjected to fire loading.