ABSTRACT
RESPONSE OF STEEL AND COMPOSITE BEAMS SUBJECTED TO COMBINED SHEAR AND FIRE LOADING

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Civil infrastructures are built to last for several decades and hence, they are subjected to various types of loading during their service lives, including fire hazard. Thus, provision of fire safety measures to structural members is one of the primary considerations in the design of civil infrastructure. Since structural members, made of steel, exhibit lower fire resistance due to high thermal conductivity and rapid degradation of strength and stiffness properties of steel, they are vulnerable to fire-induced damage or collapse. Therefore, the behavior of steel and composite beams, under fire conditions, is of critical concern from fire safety point of view.

In contrast to current design philosophy at room temperature, where steel and composite beams are to be designed for flexural limit state and then checked for shear resistance, fire design of such beams is carried out based on flexural limit state only. This design philosophy for fire resistance evaluation may not be conservative or realistic under certain scenarios where shear forces are dominant or shear capacity degrades at a rapid pace under fire. Further, there is limited data and understanding in literature on the mechanism of shear failure in steel and composite beams under combined effects of shear and fire loading.

To overcome some of the limitations in current design philosophy with respect to shear limit state, a research program involving experimental and numerical studies on the fire response of steel and composite beams/girders is undertaken. Four composite beams were tested under simultaneous loading and fire exposure to study their flexural and shear behavior. Each of these composite beams is made of uninsulated standard hot-rolled steel section, compositely attached to
a concrete slab through shear studs. The main test variables included; level of composite action, type, and magnitude of loading. Results from fire tests indicate that composite beams can experience failure under standard fire conditions in about 30-50 minutes and their response is highly influenced by type of loading and development of sectional instability.

As part of numerical studies, a finite element model was developed in ANSYS for tracing thermal and structural response of beams under combined effects of structural loading and fire conditions. The developed model specifically accounts for geometric and material nonlinearities, temperature-dependent material properties, shear effect, sectional and global instability, composite action, and various failure limit states. This model was calibrated utilizing test data generated from fire experiments. The validated model was applied to carry out detailed parametric studies to quantify critical factors influencing response of steel and composite beams under dominant shear and fire loading such as, sectional instability; web slenderness; load level; fire severity; loading configuration (type); level of composite action; shear stud stiffness; and thickness of concrete slab.

Results from experimental and parametric studies are utilized to derive an approach for evaluating degrading shear capacity in fire-exposed steel and composite beams. This methodology accounts for temperature-induced degradation in materials, as well as sectional instability and level of composite action offered by concrete slab in evaluating shear capacity in beams. This methodology is combined with flexural capacity calculations, available in literature, to propose a unified approach for design (and analysis) of fire-exposed steel and composite beams. The proposed unified approach can be applied to fire design of steel and composite beams or girders subjected to wide ranging scenarios including dominant shear and fire loading.