Coffee Break Training - Fire Protection Series

Building Construction: Fire Effects on Steel Structures

No. FP-2012-50 December 11, 2012

Learning Objective: *The student shall be able to describe two potential failure modes from fire of unprotected steel construction.*

Steel is a formidable material for building construction. Given its relative light weight and load-carrying capacities, it can be a good value for building designers. Modern high-rise and noncombustible buildings could not exist without steel.

However, when steel is not protected by fire-resisting materials, one of steel's weaknesses is its performance under fire. (See Coffee Break Training FP-2010-1 for an illustration of spray-on fire resistant materials.) Steel's strength remains essentially unchanged until about 600 F (316 C). The steel retains about 50 percent of its strength at 1,100 F (593 C) and loses all of its capacity when it melts at about 2,700 F (1,482 C). However, for design purposes, it is usually assumed that all load-carrying capacity is lost at about 2,200 F (1,204 C).

This pile of twisted steel is all that remains of a noncombustible building that was destroyed by a fire.

Apart from losing practically all of its load-bearing capacity, unprotected steel framing can undergo considerable expansion when it is sufficiently heated. This is described by a **coefficient of thermal expansion,** typically represented by the symbol "α" and varies with the chemical composition of the steel. It is a measure of the change in length of a material in response to a change in its temperature. Materials expand as temperatures increase and contract with decreasing temperatures. The creep rate of steel is sensitive to higher temperatures and becomes significant for mild steel above 840 F (450 C). The thermal expansion can result in steel beams pushing supporting columns or walls out of alignment, increasing the risk of structural collapse.

Steel framing connections — where two steel elements are joined to form different geometry, such as the intersection of a column and floor beam — are the subject of additional consideration. The connections usually contain more material (additional plates, bolts, etc.) than the connected members (beams and columns). Connections often have less exposure to heat and possess higher capacity for heat dissipation because of their proximity to other members. Therefore, temperatures are likely to develop faster in beams and columns than in connections, making connections less critical for fire-protection design.

In the building codes, structures erected of noncombustible construction often are permitted larger "allowable areas"* than similar occupancies in combustible buildings. Generally, this is because the noncombustible character of the structural elements does not add any fuel to a fire. However, noncombustible construction — especially if it is not protected by fire-resistant membranes, spray-on material or automatic sprinklers — is highly susceptible to catastrophic failure when exposed to heat from a fire in combustible contents.

*Review your locally adopted building code for an understanding of allowable areas and how they may be modified based on occupancy, fire resistance, fire protection features and setbacks from property lines or other structures.