

A.3.1.5 Fire Protection Techniques for Steel

Given the significant reduction in the mechanical properties of steel at temperatures on the order of 540 °C (1,000 °F), isolated and unprotected steel members subjected to the standard test heating environment are only able to maintain their structural integrity for 10 to 20 minutes, depending on the mass and size of the structural member. Unprotected open web steel joists supporting concrete floors in the ASTM E119 fire test have been tested and collapse in 7 minutes (Wang and Kodur 2000).

Isolated and unprotected steel box columns 8 inches x 6 1/2 inches formed using 1/4-inch plate and channels in an ASTM E119 fire test collapse in about 14 minutes (Kodur and Lie 1995). Consequently, measures are taken to protect loadbearing, steel structural members where the members are part of fire resistant assemblies. A variety of methods are available to limit the temperature rise of steel structural members, including the insulation method and the capacitive method.

Insulation Method: The insulation method consists of attaching insulating spray-applied materials, board materials, or blankets to the external surface of the steel member. A variety of insulating materials have been used following this method of protection, including mineral-fiber or cementitious spray-applied materials, gypsum wallboard, asbestos, intumescent coatings, Portland cement concrete, Portland cement plaster, ceramic tiles, and masonry materials. The insulation may be sprayed directly onto the member being protected, such as is commonly done for steel columns, beams, or open web steel joists. The spray-applied mineral fiber, fire resistive coating is a factory mixed product consisting of manufactured inorganic fibers, proprietary cement-type binders, and other additives in low concentrations to promote wetting, set, and dust control. Air setting, hydraulic setting, and ceramic setting binders can be used in varying quantities and combinations or singly, depending on the particular application.

Alternatively, the insulation may be used to form a “membrane” around the structural member, in which case a fire resistive barrier is placed between a potential fire source and the steel member. An example of membrane protection is a suspended ceiling positioned below open web steel joists. (In order for a suspended ceiling assembly to perform effectively as a membrane form of protection, it must remain in place despite the fire exposure. Only some suspended ceiling assemblies have this capability.)

In most of the WTC complex buildings and tall buildings built over the last 50 years, the preferred method has been spray-applied mineral fiber or cementitious materials. Of these 50 years, for the first 20 years the product contained asbestos and for the last 30 years it has been asbestos free. The WTC 1, 2, and 7 incidents are the first known collapses of fire resisting steel frame buildings protected with this type of fireproofing material. Occasionally, a portion of the steel is protected with a spray or trowel applied plaster or Portland cement (e.g., Gunitite or shotcrete).

Capacitive Method: The capacitive heat sink method is based on the principle of using the heat capacity of a protective material to absorb heat. In this case, the supplementing material absorbs the heat as it enters the steel and acts as a heat sink. Common examples include concrete filled hollow steel columns and water filled hollow steel columns (Kodur and Lie 1995). In addition, a concrete floor slab may act as a heat sink to reduce the temperature of a supporting beam or open web steel joist.

A.3.1.6 Temperature Rise in Steel

In building materials such as steel, a critical temperature is often referenced at which the integrity of fully-loaded structural members becomes questionable. The critical temperature for steel members varies with the type of steel structural member (e.g., beams, columns, bar joists, or reinforcing steel). North American Test Standards (e.g., ASTM E119) assume a critical temperature of 538 °C (1,000 °F) for structural steel columns. The critical temperatures for columns and other steel structural elements are given in Table A.3. The critical temperature is defined as approximately the temperature where the steel has lost