Fire Protection Basics

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A variety of good options are available.

MINIMIZING THE POTENTIAL FOR A fire to occur, and protecting life and minimizing the extent of destruction if one does, are important goals for the design of any building. Fire loss mitigation in buildings can be achieved through a number of measures, such as fire prevention strategies, control of combustible and hazardous contents, provision of alarm systems, means of safe evacuation, fire-fighting access routes, adequate water supplies, active fire-fighting systems, building separations, compartmentation of premises, and structural fire resistance. The specific combination of fire mitigation measures in a building depends on the size and severity of associated risks and hazards. Structural fire resistance requirements often are prescribed in the applicable building code based on building occupancies, height, area, and other building characteristics. When fire resistance is prescribed for the structure, the associated objective can be described as a succinct inequality: Fire Resistance ≥ Fire Severity. To achieve this condition, the structure must resist collapse or failure during a fire of a specified severity.

Fire resistant materials and systems are designed to prevent or delay the temperature rise in structural steel so that the steel members can maintain adequate strength for the required duration. Ideally, this time allows for safe evacuation of the affected areas and fire-fighting operations, including search and rescue.

Many technologies are available for protecting structural steel during a fire, and they use a variety of methods to achieve specified fire resistance ratings. This article provides a brief overview of different fire protection systems. For a more detailed look at this topic, see AISC Design Guide No. 19 *Fire Resistance of Structural Steel Framing*. That publication also provides references to common assemblies used in fire-resistant designs, such as the Underwriters Laboratories Inc. (UL) Fire Resistance Directory (**www.ul.com**).

Figure 1: Steel framing with SFRM in place at Children's Memorial Hospital under construction in Chicago. Inset shows the hospital's signature handprint rendered in SFRM.

Sprayed-On Protection

Spray-applied fire-resistant materials (SFRM) are most commonly used to protect structural steel. SFRM products are commonly classified by their in-place density as standard-density (13-18 psf), medium-density (22-30 psf), and high-density (40 psf and over).

Most SFRMs are of the "wet-mix" product type (often referred to as "cementitious fire protection"). The proprietary dry factory-premixed combination of gypsum or portland cement binders and lightweight mineral or synthetic aggregates is mixed with water on-site to form a slurry that is pumped and sprayed on the steel substrate. Some SFRM products are "dry-mix" products (often referred to as "fiber fire protection"). The proprietary dry factory-premixed combination of portland cement and inorganic binders combined with mineral wool is pneumatically pumped in a dry state on-site and mixed with water at the spray nozzle immediately before the application of the resulting slurry on the steel substrate.

Because SFRMs have proprietary formulations, it is imperative to closely follow the manufacturer's recommendations for mixing and application. Thicknesses required to achieve various ratings are typically provided by the manufacturer as well.

The biggest advantages of using SFRM are speed, efficiency, and cost-effectiveness. Surface preparation time is minimal for steel that

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is to receive a field-applied contact-type SFRM—the steel need only be shop cleaned of dirt, oil, grease, and loose mill scale. The application of SFRM is relatively easy and fast; however, because it is a wet process, it can impact other trades. Also, protecting on-site areas from overspray is typically required.

It is important to avoid accidental or intentional removal of SFRM as other trades perform their work on or near the steel structure subsequent to the application of SFRM. It is ideal for attachments to be in place before the application of the SFRM. However, if SFRM does need to be removed for attachment purposes, the removed material needs to be replaced. Quality control for the SFRM should be a designated responsibility assigned to a member of the construction team.

Gypsum Board

Gypsum-based board products protect the steel by absorbing energy. Gypsum is a naturally-occurring mineral that consists of calcium sulfate chemically combined with water. When exposed to fire, gypsum-based materials undergo "calcination"—they release the entrapped water in the form of steam, providing a thermal barrier. After calcination, gypsum-based materials retain a relatively dense core, providing a physical barrier to fire in addition to the thermal barrier.

Gypsum board typically is provided with "regular" or "Type X" designations. The "Type X" sheets are special fire-resistant products that ensure the required fire-resistance ratings for specified benchmark wall assemblies. Some manufacturers also produce a "Type C" or "Improved Type X" board that exhibits superior fire performance. Most fire resistant gypsum board includes glass fibers and other additives that reduce shrinkage and cracking under fire exposure.

Gypsum board enclosures are relatively cost-effective when compared with other fire resistant products. Gypsum board walls and ceilings are commonly used in building projects for interior finishes; thus, upgrading to a fire-resistive gypsum assembly achieves two goals simultaneously—interior finish and fire protection.

Several considerations in the design and construction of gypsum board wall and floor assemblies should be addressed to achieve the desired fire ratings in the field.

- Gypsum board enclosures should be designed and specified as an assembly, based upon a tested system. Fire-resistance testing is conducted on assemblies made up of specific materials put together in a specified manner. For example, the mixed selection of individual products each with appropriate fire ratings will not compensate for deficiencies in the size of studs or number of fasteners when compared to a tested assembly.
- The assembly built in the field must be representative of the one tested because construction detail variations from the tested assembly can impact performance. If a product substitution occurs, for example, the designer should be notified and should verify the new assembly. The size and spacing of framing and fasteners should be the same as, or more conservative than, the enclosure assembly test. The intersection of the partition wall with the ceiling or floor should correspond to the tested assembly as well, which typically requires extra attention in the field.

Intumescent Paint Systems

Intumescent paints are multi-layer coating systems that char and expand rapidly in a fire to insulate the steel, as shown in Figure 2. Proprietary intumescent paint formulas typically include a mixture of resin binders and chemicals that react under high temperatures to expand to a thickness up to about 100 times the original thickness of the film, creating a thick char that insulates the steel from fire. Intumescent paints are commonly spray-applied at thicknesses less than 100 mils (1/10 of an inch). The appropriate paint thickness is dependent on the size of the structural element to which it is applied and the fire resistance rating required.

Intumescent paints provide many benefits, including reduced weight per surface area protected, durability, aesthetic appeal, and good adhesion. Aesthetics is typically the main driver for selecting this system—steel members protected with intumescent paint often are used in architecturally exposed structural steel (AESS) applications with a colored finish if desired. Intumescent paints can be applied off-site to save valuable construction time on-site. Maintenance of intumescent paint systems—cleaning the protected members and post installation repairs—is relatively easy.

With these advantages comes a relatively high cost compared to other systems, particularly for higher fire ratings. One way to bring down that cost is to up-size the steel and thus decrease the required thickness of intumescent paint, which not only reduces intumescent paint material costs but also decreases the workmanship and the lengthy drying times involved with the application process. Additionally, suitable environments are required for the application of these paints. Adjacent areas must be protected from overspray. If off-site application is used, areas with mechanical damage to the paint during transport and erection will need to be repainted. Quality control is very important with intumescent paints—the steel surface should be appropriately prepared according to the paint manufacturer's recommendations and proper thicknesses should be applied and verified. Additionally, there should be enough room around the steel member for the intumescent paint to expand, should a fire make that necessary.

Concrete-filled HSS and Pipe

Round, rectangular and square hollow structural sections (HSS) and pipe can be filled with concrete to increase their fire resistance. The HSS serves as permanent formwork for the concrete, which can be reinforced by standard bars, or by adding steel fibers to the wet concrete mix. The HSS can be filled off-site or erected and filled on-site. During a fire, heat passes through the steel to the concrete, which serves as a heat sink. As the yield strength of the

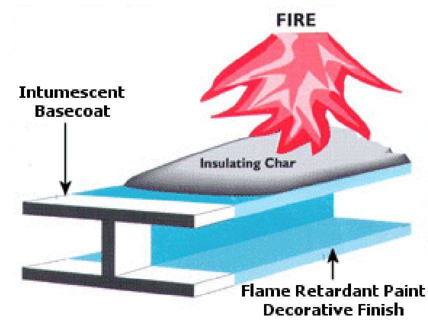

Figure 2: How intumescent paints perform. Courtesy of **www.astroflame.com**.

steel decreases, the load is transferred to the concrete. The steel encasement and reinforcement helps limit the heat effects on the concrete, such as spalling and strength degradation. Ventilation holes in the steel encasement allow for steam to release when the concrete is heated, relieving pressure. This method is frequently used in exposed steel applications because the steel can be easily painted.

Fire-Trol System

Fire-Trol columns are prefabricated members that consist of a load-bearing steel column (labeled A in Figure 3) encased in a special proprietary insulating material (B). An outer non-load-bearing steel shell (C) permanently encloses and protects the insulating material. Fire-Trol columns are shipped to the job site ready to erect and can be specified to achieve up to a four-hour fire rating.

Other Systems

There are a variety of other fire protection systems and products on the market, such as:

- Mineral fiber board enclosures, which can be cut and placed to form a tight seal around structural steel members.
- Ceramic wool wraps that insulate steel.
- Gypsum-based plaster applied directly to steel surface or to metal lathe fixed around the member.
- Plaster, clay tile, concrete, and masonry enclosures.

Improving Economics

Regardless of the fire protection system chosen, there is likely an opportunity to improve the economics of the design. Because the rate of temperature change in a body is a function of its mass and the area of its surface exposed to the temperature difference, the amount of fire protection required is dependent on the steel section selected. The *W/D* ratio (weight per unit length over heated perimeter of the steel member) is critical for the selection of wide flange shapes, and the *A/P* ratio (steel section area over heated perimeter) is used for HSS selection. The larger the *W/D* or *A/P* ratio, the slower the rate of temperature change. Thus, a steel beam with a large heavy cross section may require less fire protection than its lightweight counterpart. Design Guide No. 19 provides tables of *W/D* and *A/P* values for respective wide-flange sections and HSS, as well as design examples for determining thicknesses required for various fire protection systems.

Further References

For more information, please refer to:

- AISC *Facts for Steel Buildings: Fire Facts* (free download at **www.aisc.org/freepubs**).
- AISC Steel Design Guide 19, *Fire Resistance of Structural Steel Framing* (download at **www.aisc.org/epubs**—free for AISC members; fee for non-members).

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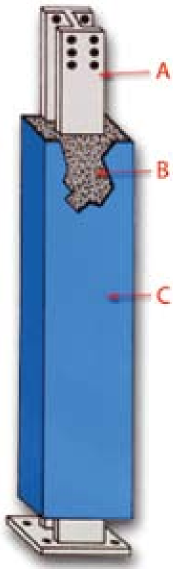

Figure 3: Fire-Trol column elements. Courtesy of Dean Lally, L.P. **www.dean-lally.com**.