

STEEL CONSTRUCTION FACT SHEET

Fire



Steel is the most comprehensively fire-tested of all structural framing materials. Extensive research, including large-scale fire tests, has demonstrated the behaviour of steel in real buildings. The response of steel structures to fire is well understood, and extensive best-practice guidance is available. Where fire protection is needed, a range of cost effective measures is available.

Determining the fire protection requirements for the structural steelwork of a building is a simple and straightforward process, consistent across all common buildings types.

Much is made about steel's supposed vulnerability to fire although, there has been no recorded structural failure of a protected high-rise steel-framed building solely due to fire.

The steel sector has invested decades of research into understanding the behaviour of structural steel components in fire, giving designers the confidence to engineer buildings safely in steel.

Fire protection

The primary goal of fire protection in buildings is to preserve life. A secondary goal is to protect property and safeguard the environment. These goals are achieved by:

- Providing safe means of escape, or safe refuge, for the occupants in the event of a fire.
- Designing the building to limit the progress and spread of fire and smoke, and to minimize structural damage.

Smoke is by far the greatest direct cause of casualties and injuries during building fires.

Fire resistance

Fire resistance is the duration, in terms of time to failure, of a structural assembly or element, against one or more of the following performance criteria:

- Load-bearing capacity, i.e. the ability to support the applied load and to resist collapse
- Integrity, i.e. the ability to resist the passage of flames and hot gases
- Insulation, i.e. the ability to restrict the temperature rise on the unexposed face.

Fire resistance requirements are usually as specified by a given standard test method. Different (standard) testing protocols are used to evaluate the performance of beams, columns, walls, floors, and roofs.

Some building elements require that all three criteria are met, others two and some only one. Structural columns are required to meet only the load-bearing capacity criterion. Structural floors between two fire compartments, must meet all three criteria and it is usually insulation, rather than the structural criteria, which dictates the thickness of the floor slab.

Fire resistance is expressed in units of time so one of the contributory factors to fire resistance is the heating rate of the member; this governs the time taken to reach its failure (or limiting) temperature and varies according to the dimensions of the section, i.e. the beam or column. Clearly, a heavy, massive section will heat up more slowly (and thus have a higher fire resistance) than will a light, slender section.

As with all materials, the strength of structural steel sections decreases with temperature. Following an extensive series of standard fire tests, that strength reduction has been quantified. Recent international research has also shown that the limiting (failure) temperature of a structural steel member is not fixed but varies according to two factors, the temperature profile and the load.

All structural steel sections have some inherent fire resistance and this is a function of the size of the section, its degree of exposure to the fire and the load that it carries.

For unprotected hot rolled steel beams and columns the inherent fire resistance varies between 10 and 45 minutes.

Where the inherent fire resistance of the steel is less than that necessary to meet the requirements for structural stability for the building, additional precautions must be taken. This usually takes the form of applied fire protection which insulates the steel from the increasing temperatures.

Types of fire protection

Fire protection for structural steel includes both passive and active measures.

Passive fire protection

Passive fire protection materials insulate steel structures from the effects of the high temperatures that may be generated in fire. They can be divided into two types, non-reactive, of which the most common types are boards and sprays, and reactive, of which thin film intumescent coatings are the best example.

Boards are widely used both where the protection system is in full view and an aesthetic appearance is required, and where it is hidden. Boards can be divided into two families. Those which are suitable for the application of decorative finishes are generally quite heavy, and more expensive, than the non-aesthetic, lighter materials.



Figure 1. Fire protection boards – decorative (white) boards on the columns and non-aesthetic (silver) boards on the beams

Spray protection systems have decreased in popularity over recent years, despite being one of the cheapest forms of fire protection in terms of application costs. This is mainly due to problems with overspray and impacts on the construction programme.

Flexible, or blanket, fire protection systems have also been developed and fill a niche where complex shapes require protection but where a dry trade is preferred.

Active fire protection

Active fire protection systems are those that use automatic devices or human action to initiate countermeasures, such as to suppress the fire and/or alert occupants to the emergency for the purposes of building evacuation. Examples include:

- Automatic sprinkler systems.
- Smoke and fire detector and alarm systems.

- Water supply systems, hose cabinets, fire extinguishers.
- Systems and personnel involved in fire department response.

Intumescent fire protection

Thin film intumescent coatings are paint-like substances which are inert at low temperatures but which provide insulation by swelling to provide a charred layer of low conductivity material when heated. This char is an excellent insulator. Typical expansion ratios are about 50:1, i.e. a 1mm thick coating will expand to about 50mm when affected by fire. This reaction occurs at temperatures of approximately 200-250°C, a threshold temperature at which the properties of steel are still unaffected.

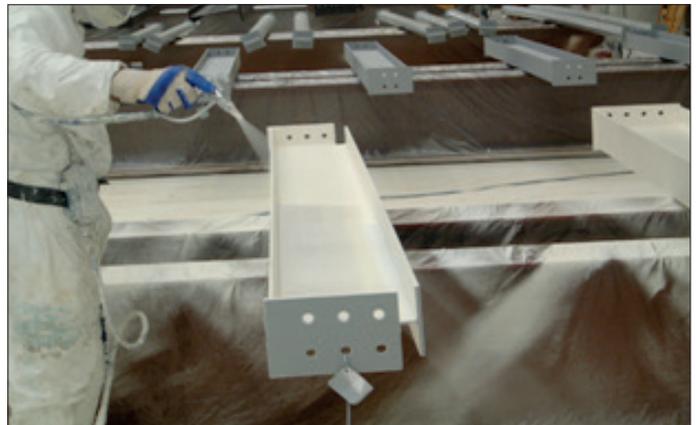


Figure 2. Off-site application of thin film intumescent fire protection

Thin film intumescent coatings are predominantly used in buildings where the fire resistance requirements are up to 90 minutes.

Over recent years, thin film intumescent coatings have come to dominate the passive structural fire protection market. The coatings can be applied on or off-site. Off-site application offers considerable benefits, including:

- Reduced construction times
- Improved site safety
- Speedier access for follow-on trades on site
- Improved quality control
- Reduced weather sensitivity.

Most long span and cellular structural solutions now use the off-site application process.

Design procedure

Determining the fire protection requirements for the structural steelwork of a building is a simple and straightforward process, consistent across all types of common building types.

The first step is to determine the fire resistance period that the structure is required to withstand in order to ensure adequate time for the building to be evacuated in the event of a fire. The fire resistance period is determined by use of the relevant regulations applicable to the building type and location.

The second step is to determine the section factor of the structural steelwork specified. The section factor (A/V or H_p/A) is used to describe the heating rate of a member, with lower numbers indicating stockier sections that are slower to heat than slender members which have higher section factors. Section factors can be calculated but would normally be selected from design data provided by the manufacturer. The value varies dependent on the profile of the protected member (boarded or intumescent) and its exposure to the fire (3 or 4 sided).

The final step is to derive the fire protection requirement based on the required fire resistance period and section factor. For example, specifying the type and thickness of protection.

Partial protection

Partial protection generally refers to the arrangement of either a beam cast into the depth of the floor slab that it supports, or a column built into a cavity wall.

Rather than providing protection to the required fire resistance period, designers can take advantage of the benefit of the heat sink effect of the concrete slab to reduce the fire protection or eliminate it altogether. The most common application of this approach is the use of slim floor construction in which the steel beams are integrated within the floor slab to give up to 60 minutes fire resistance without additional protection.

Concrete-filled hollow steel sections and concrete encased open steel section columns can also provide 60 minutes fire resistance without additional protection.

Fire safety engineering

Recognition of how real buildings react in fire and of how real fires behave, has led many authorities to acknowledge that fire safety may now be achieved by an analytical fire engineered approach. This change has proved beneficial to the construction industry as a whole, but particularly to the steel construction sector, which has carried out most of the research and whose structures consequently offer the greatest potential for improved solutions using fire engineering.

Fire safety engineering can be seen as an integrated package of measures designed to achieve the maximum benefit from the available methods of preventing, controlling or limiting the consequences of fire.

Fire safety engineering is a specialist discipline which can combine a risk based approach to determining the fire period with detailed finite element modelling used to predict actual performance of the structure and fire protection measures in a fire. It is most commonly used on buildings where the prescriptive provisions given in the regulations, can be shown to be more demanding than are really necessary. Many tall and complex steel buildings are now fire-engineered.

Further information

A good introduction to the behaviour and performance of structural steel in fire is available at www.steelconstruction.info/Fire_and_steel_construction *Steel Designers' Manual 7th Edition*, Editors B. Davison and G.W. Owens. The Steel Construction Institute, 2012. Chapter 35, Fire protection and fire engineering. Fire regulations and precautions are building and country specific and therefore local expert advice should be sought.

More detailed technical information includes the following SCI guidance and tools: SCI P124 *The fire resistance of web-infilled steel columns*

SCI P375 *Fire resistant design of steel framed buildings*

Fire resistance of beams at elevated temperatures see <http://bcsatools.steel-sci.org/HotBeamDesigner>

Fire resistance of columns at elevated temperatures see <http://bcsatools.steel-sci.org/HotColumnDesigner>

Composite beam checking tool <http://bcsatools.steel-sci.org/CompositeBeam>

A number downloadable software tools to help designers address fire resistance in steel buildings are available from ArcelorMittal at <http://sections.arcelormittal.com/download-center/design-software/fire-calculations.html>

Notes to editors

Globally, construction is the most important sector for steel industry consuming, by weight, around 50% of global output.

The range of steel construction products is vast and includes:

- Hot-rolled sections and steel plate are used in building structures
- Galvanised steel coil is used for steel studs, cladding and floor decking, etc.
- Rebar used to provide tensile strength in reinforced concrete.

In some markets, the use of structural steel is commonplace but in others it is seen as a new and relatively unproven technology. Often designers and decision-makers are not convinced about the suitability of steel structures in their market due to their limited knowledge of the material's performance, the wealth of experience and guidance available on steel construction and the wider benefits that steel construction brings. This series of factsheets aims to change this by providing facts (and dispelling myths) about the properties and benefits of structural steel.

This factsheet is one of a series of five focussing on multi-storey buildings.