1.0 सामान्य/ General

Fire protection is the use of materials which have thermal insulation properties and bond with steel members (columns, beams, etc.) so as to reduce the thermal energy to which the member is exposed for a standard fire test.



Steel is the most reliable and widely used material in construction industry. In general, it is assumed that the steel does not support combustion and retains significant strength at elevated temperatures, but it is also true that the fully stressed steel members will fail when they reach a temperature of approximately 550ºC.

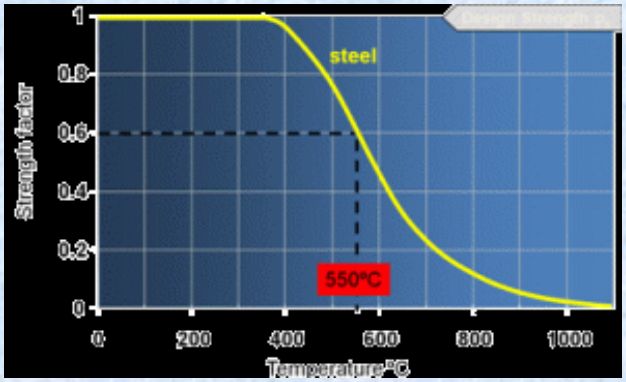
Unprotected steel components are sensitive to the effects of fire. Hence, it is necessary to provide some type of passive fire protection to the steel members if they are unable to withstand the fire loads. Fire protection techniques/ or systems have to be based on the fire behaviour characteristics of different materials and structural elements of structures.

1.1 स्टील का अग्नि व्यवहार/ Fire behaviour of Steel

The performance of structural steel in fires is characterized by its thermal properties and mechanical properties. The thermal and mechanical properties of most materials change substantially within the temperature range up to 1200 ºC.

During a fire, the structural steel begins to lose its strength and stiffness at temperatures above 300 ^{0}C and eventually melts at about 1500 ^{0}C.

The elastic modulus of steel is similarly reduced with increasing temperatures, but at a higher rate. Steel, therefore, needs to be designed to withstand the effects of a fire in order to ensure the safety of people and property.



1.2 अग्नि भार और अग्नि प्रतिरोध/ Fire Loads and Fire Resistance

Fire Loads: As per IS 1641: 1988, the fire load is the amount of heat in kilocalories which is liberated per square metre of floor area of a compartment by the combustion of the contents of the building and any combustible parts of the building itself.

The fire load is determined by multiplying the weight of all combustible materials by their calorific values and dividing the figure by the floor area under consideration.

Fire Resistance: Fire resistance is a measure of the ability of the structure to resist collapse, fire spread, or other failure during exposure to a fire of specified severity.

It is expressed as the ability of an element of building construction, component for structure to fulfill, for a stated period of time, the required stability, fire integrity and/or thermal insulation and/or other expected duty in a standard fire resistance test (Refer IS 3809: 1979 & IS 1642: 1989).

Fire-resistance ratings are assigned to construction components and systems, not materials. These ratings are used in many fire-resistant building components and systems, where load-bearing structural steel members are insulated from the thermal effects of a fire.

For steel structures, these are expressed in units of time ½, 1, 2, 3 and 4 hours. The time parameters are basically a convenient way of comparative grading of buildings with respect to fire safety.

It is important to note that *the rate of heating of the unprotected steel is obviously quite high as compared to the fire-protected steel.*

IS 1642 : 1989 may be referred for fire ratings of different types of constructions.

1.3 अग्नि संरक्षण सामग्री/ Fire Protection Materials

The resisting material should have the following characteristics:

(a) It should not disintegrate under the effect of heat.
(b) It should not expand under heat so as to introduce unnecessary stresses in the building.
(c) The material should not catch fire easily.
(d) It should not lose its strength when subjected to fire.

Fire protection materials and systems are designed to delay the temperature rise in structural steel, usually through one or more of the following mechanisms:

- Low thermal conductivity
- High effective heat capacity

- Heat-absorbing physical reactions (e.g., transpiration, evaporation, sublimation, ablation) or chemical reactions (e.g., endothermic decomposition, pyrolysis)
- Intumescence, i.e., formation of a thicker insulating foam upon heating

The common fire protection materials that provide one or more of these mechanisms function generally in one of three ways are listed as under:

1. **Mostly insulating –** These are low-conductivity, lightweight, spray-applied fire resistive materials; mineral fiberboard products; and ceramic wool wraps.
2. **Energy absorbing** – These are most commonly gypsum-based or concrete-based products, each of which releases water of crystallization when exposed to high temperatures.
3. **Intumescent** – Applied as multi-layer paint, these coating systems expand upon exposure to high temperatures, forming an insulating layer.

1.4 अग्नि संरक्षण के तरीके/ Methods of Fire Protection

Current fire protection strategy for a building or structure incorporates a combination of active and passive fire protection measures.

- ***Active measures*:** Active measures are (i) Fire alarm (ii) detection systems (iii) sprinklers, which require either human intervention or automatic activation. They help to control fire spread and its effect as needed at the time of the fire.
- ***Passive measures*:** Relatively high thermal conductivity and generally thin proportions of steel components make unprotected steel structures susceptible to rapid heating when exposed to fires. *For this reason, steel components in structures usually require passive fire protection.*

1.4.1 स्टील घटकों के लिए निष्क्रिय अग्नि सुरक्षा/ Passive Fire Protection for Steel Components

Passive fire protection materials insulate steel structures from the effects of the high temperatures. They can be divided into two types:

(i) Non-reactive – most common examples are boards and sprays
(ii) Reactive – most common examples are thin film intumescent coatings

1.4.2 अग्नि के प्रभाव से स्टील घटकों की रक्षा के आम तरीके/ Common methods to protect steel components from the effects of fire

They include

1. Spray of fire resistive materials
2. Intumescent coatings
3. Enclosures of
   (i) gypsum board
   (ii) mineral fiberboard
   (iii) concrete, masonry, or similar materials

1.4.2.1 अग्नि प्रतिरोधक सामग्री का छिड़काव/ Spray of fire resistive materials

(i) Sprays containing asbestos-free materials (e.g., vermiculate or mineral fiber) in a cement or gypsum binder are applied on the structural member as a coating for a prescribed thickness. They are relatively low cost and can be applied at the site rapidly, even to cover complicated shapes. They do not suffer from the problems faced in using rigid boarding around the complex structural details. Spray applied products are typically used more to protect beams than columns.

(ii) Mineral fiber fireproofing is generally spread with specially designed equipment. The equipment feeds the dry mixture of mineral fibres and various binding agents to a sprayer nozzle, where water is added to the mixture as it is sprayed on to the steel surface. The other important aspect of this insulation is the 'stick ability' of the material.

Note: In the past, the mineral fiber asbestos was used with a cementitious binder and sprayed onto structural elements to provide fire protection. Due to health hazards associated with construction and occupancy periods, asbestos has been banned.

Advantages of spray of fire resistive materials:

- easy to protect detailed features including connections, bolts, etc
- quick to apply
- may be used for exterior application, but most of them are used for interiors
- can be applied to unpainted steel

Disadvantages of spray of fire resistive materials:

- The process is wet and often can be messy, which can impact the construction schedule and potentially the overall cost.
- Steel typically needs to be prepared.
- Protecting on-site areas from overspray is typically required.
- It produces a rough surface finish and cannot be easily finished to meet aesthetic requirements.
- The material is relatively soft and should be protected when in a vulnerable area where contact could damage the product.

- Sometimes difficult to control quality in the field as process is labour intensive and time consuming.

1.4.2.2 इंट्युंसेंट कोटिंग्स (पेंट)/ Intumescent coatings (paints)

Various binders and additives are mixed in to provide specific physical properties of the total system. The system often is made of several coats with different functions. For example, a topcoat will provide a durable finish surface, while the base coat will provide a strong bond to substrate.

Thin film intumescent coatings are paint-like materials, which are inert at low temperatures but they provide insulation as a result of a complex chemical reaction at temperatures of approximately 200-250°C (a threshold temperature) at which the properties of steel are still unaffected.



As the coating reacts, it swells to provide an expanded layer of low conductivity char that insulates the steel section. Typical expansion ratios are about 50:1, i.e. a 1mm thick coating will expand to about 50mm when affected by fire. Thin film intumescent coatings are predominantly used in buildings where the fire resistance requirements are up to 90 minutes.

Intumescent paints can be divided into three broad categories:

- *Single part solvent-based paints* – typically used for exterior applications, and are tested against weather, temperature variations, etc. They are also used for interior applications.
- *Single part water-based paints* - are available in liquid form and are typically applied via airless spray equipment. Smaller areas may be rolled or brushed, however this often does not leave as smooth of a finish.
- *Two-part epoxy solvent free or solvent-based* - typically used in more harsh environments, including the chemical industry and offshore operations, in areas that may be difficult to access for maintenance, or where high levels of impact damage may occur, and they are more expensive than the other intumescent paints.

Advantages of intumescent coatings:

- do not require a significant thickness relative to other materials.
- typically quite durable, and do not readily flake off when struck.
- relatively quick to apply and good at covering complex structural details.
- being applied off site can lead to decreased construction time.
- often aesthetically acceptable and can be left exposed to show the shape of the structure, and also can be given a colored finish.
- relatively easy to clean.

Disadvantages of intumescent coatings:

- High relative cost when compared to spray on systems, particularly for higher fire ratings.
- Goes on wet and hence suitable environment is needed. Also, protection of adjacent areas from overspray is necessary. Solvent-based paints need to be applied in well ventilated areas.
- Mechanical damage during installation of off-site prepared materials will need to be made.
- can be difficult to verify the existence of intumescents at later dates.
- Regular inspections needed. It is difficult to assess applied thickness without damaging material.
- Coatings typically provide 30 to 120 minutes of protection.
- Important that steel surfaces be appropriately prepared, paint properly applied, etc. and that proper thicknesses are applied.

1.4.2.3 इंस्यूलेटिंग सामग्री का घेराव/ Enclosure of Insulating Materials

Application of insulating materials is one of the most common means of protecting structural members from fire. Steel itself is an effective fire-protective material when used in sheet form to provide a protective and reflective shield for other materials. Steel can also be used in the form of meshes or wraps to help other materials maintain their integrity under heat exposure.

Some of the more popular technologies for using enclosure of insulating material to protect structural elements are:

(i) Gypsum and Mineral Fibre Board: Insulating board systems are typically slab-type materials made from calcium silicate, gypsum plaster or mineral fiberboard with resin or gypsum, and may contain lightweight fillers including vermiculite. They are typically attached to metal or wood framing, which is then attached to the structural member. They can achieve fire ratings of up to four hours.

Gypsum board is less expensive and its insulating properties are better than calcium silicate



because it contains more water and requires more time to heat up.

Insulating board products are more typically applied to columns than beams due to aesthetic reasons and the fact that beams are not always visible in the finished building environment. They are also used for other applications including protecting ducts and fire rated barriers.

Advantages of insulating board systems:

- provide a clean appearance and can be finished/ decorated as appropriate.
- can be attached directly to bare steel elements with little or no preparation.
- relatively easy to install, and easy to finish off once applied.
- manufactured off-site where thickness, composition, etc. can be monitored.

Disadvantages of insulating board systems:

- often slower to install as compared to other types of systems.
- more expensive, particularly where a 'decorative' finish is needed.
- difficult to install around elements and complex details.

(ii) Concrete Encasement: Concrete is a good thermal insulator and can be used as encasement to delay heat transmission to adjacent structural elements. Increasing the thickness of the concrete increases the time required for heat to transfer to the steel.



When reinforced, the concrete may also at times be used to carry part of the load. One of the most important advantages of this method is its durability. Concrete encasement performs very well in environments where resistance to impact, abrasion, weather exposure, and corrosive agents is important. Applications can include interior or exterior components.

Concrete encasement has some notable disadvantages, which can frequently limit the application of concrete encasement for protective purposes.

- poor aesthetic quality of concrete.
- required thickness of concrete may take up valuable space around structural elements.
- time consuming to install on-site.
- can increase the overall weight of the building.
- relatively expensive.
- susceptible to spalling during fire.

1.5 IS 15103:2002

The IS 15103:2002 on 'Fire Resistant Steel – Specification' may also be referred for fire resistant steel plates, strips, sections and bars, etc. for use in structural work up to a maximum temperature of 600 ^{0}C for maximum duration of 3 hours.

1.6 केवल हमारे बहुमूल्य पाठकों के लिए/ For our valuable readers only

There is no specific chapter regarding Fire Resistant mentioned in Unified SOR. Therefore, to make steel structures fire resistant, there is a need for introducing NS items. Field units are requested to communicate their suggestions on this issue. Your valuable suggestions will reflect in the final print of this pamphlet and in subsequent revisions to come.

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स्टील की अग्नि सुरक्षा

FIRE PROTECTION OF STEEL



कैमटेक/सि/2016/एफपीएस/1.0

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यदि आप इस सन्दर्भ में कोई विचार और सुझाव देना चाहते हों तो कृपया हमें इस पते पर लिखें।

If you have any suggestion & comments on contents of the pamphlet, please write to: ***Joint Director (Civil), CAMTECH, Maharajpur, Gwalior (M.P) – 474 005***

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