Behavour of Structural Members with Partial Fire Protection

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During a fire, as structural materials (concrete, steel, etc.) heat up, they lose strength and stiffness which can eventually lead to collapse; with subsequent injury or loss of life and damage to property. Structural members (structural steel in particular) must therefore be protected from fire. This is done through the use of protective coatings or insulation. The preferred method of choice for protection of structural steelwork is by intumescent coatings.

It is normally assumed during analysis that the fire protection applied to structural members is fully effective. In practice however some local damage is likely, either during construction or during use. As a result, it is possible that structural members may be heated locally in a manner that is not considered during the design process.

How Intumescents Work:

Thin film intumescents, or TFI’s, are paint systems which contain active ingredients which break down under the action of heat to release gases which cause the binder to foam up into an insulating char.

A TFI system usually comprises of:

• A primer • An intumescent basecoat • A decorative top coat

The primer protects the steel from corrosion.

A TFI typically expands 30-50 times its initial thickness in a fire, forming an insulating charred exterior, thus increasing in volume and decreasing in density with a low thermal conductivity.

Analysis:

Four types of protection methods were analysed in order to investigate and validate the temperature profile of structural members, with varying degrees of partial protection using finite element analysis. They are shown below:

![Figure 1: A TFI typically expands 30-50 times its initial thickness in a fire, forming an insulating charred exterior, thus increasing in volume and decreasing in density with a low thermal conductivity.](image)

Results:

The heat increment will occur at locations A, and continue until the intumescent coating has fully charred. At this point, when the intumescent can no longer resist the heat energy, conduction will transfer the heat increment throughout the steel's section resulting in a loss of load bearing capacity.

Conclusions:

• The increase in steel temperatures depends on the severity of the fire, the section factor (area of exposed steel) and the amount and type of applied fire protection materials.
• In general, unprotected steel structures perform poorly in fires relative to other structural materials such as concrete, gypsum, and timber. This partly attributed to the high thermal conductivity and thermal expansion of steel.
• The analysis of the heat transfer within the damaged intumescent coating is an important assessment in terms of the beams deflection, as it is the heat increment within the steel member that reduce the steel beam's load bearing capability.
• Normally an object will fail because of stresses induced by uneven heating, fast temperature transformation or dissimilarity in thermal properties.