INTRODUCTION TO
MAKING THE
RIGHT CHOICE:
A GUIDE TO INFORMED SPECIFICATION OF STRUCTURAL STEEL FIRE PROTECTION

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Modern buildings are becoming increasingly more complex as architects and specifiers push the boundaries of functionality, aesthetics, innovation and value. By doing so, continued challenges around building and occupier safety and protection remain vitally important.

A critical area is the assessment of appropriate and fit-for-purpose fire protection solutions for steel structures. When in the unfortunate event of a fire, steps should be taken to ensure maximum fire protection performance for the steel frame.

Significant advances in the knowledge of steel behaviour in fire have been made in recent years, however, issues around fire and steel frame fire protection remain critical to the future safety of the building fabric.

This paper outlines the primary passive system options available for steel frame fire protection to assist with informed decision-making. It looks at the most popular solutions and assesses their strengths and potential drawbacks across a number of critical areas. This paper aims to help the right choice to be made when it comes to protecting the core frame of a building and the people who occupy it.

Reference is also made to the findings of recent research undertaken across the architectural community by PROMAT UK to ascertain views and perceptions about important aspects of structural steel fire protection. Where relevant, these findings have been incorporated to help illustrate the points under discussion.

An overview concerning the information about current fire protection design guidance is also referenced at the end of this document.

For architects and specifier professionals charged with building design, making the right steel frame fire protection choices from the options available is an essential decision. Indeed, in a recent poll undertaken by PROMAT UK, 56% of architects believe they have the largest single influence when it comes to making decisions around steel frame fire protection. However, the final specification of any solution needs to assess a range of important factors, including appropriate application, fire protection performance, cost and ongoing repair and maintenance implications.

We hope you find the content of MAKING THE RIGHT CHOICE thought-provoking, stimulating and helpful.
It is fair to say that as building design and construction becomes ever more complex, pressures facing the specification market around build timescales, cost control, ongoing material performance and whole-life costs will continue.

While the building designer has to consider many facets, fire safety as a prerequisite cannot be underestimated. Each new structure has its own individual issues when it comes to assessing the right choice to be made for steel frame fire protection. The three passive-based system solutions outlined in the next section dominate the market and are examined in the context of the broad principles and key factors to consider when specifying the most appropriate fire protection solution.

The need to get structural steel fire protection right is paramount to ensure the best possible building safety outcomes. The variety of system options to achieve this is wide-ranging and provides the specification market with a number of proven answers that can be appropriately applied. Careful analysis of all the factors involved with structural steel fire protection should help clarify the best course of action and support a fact-based, information-led system choice. A choice that should in all cases be the right one.

Fire Safety Engineering is based upon a risk-based strategic approach using computer modelling. It predicts the performance of a steel section in the event of fire and can allow the architect greater flexibility when it comes to decision-making. Fire Safety Engineering used alongside the guidance documents referenced in the concluding section 8 offer assistance in assessing the fire performance required. Once the relevant steel frame fire protection guidance is understood, and the required fire performance is ascertained, key stakeholders such as the client, architect, contractor, and specialist fire protection contractor need to give consideration to the material type solution to be used.

The material type solutions commonly used within the passive fire protection category for structural steel building frames generally fall within one of three generic groups. They are:

- **Intumescent Paints**
  - Aesthetic benefits
  - Offsite application possible
  - Can aid quick-build programme timescales
  - A common specification choice
Intumescent paint-based fire protection offers the client an aesthetic benefit where exposed steelwork is an integral part of the design.

Application costs have reduced in recent years through advancements in product development and material innovations resulting in thinner solutions. Add this to the increasing number of suppliers entering the market and this system has now become a frequently used method for steel fire protection in the UK, alongside board-based systems.

- **Board-based Systems**
- **Cementitious and Gypsum Sprays**
Intumescent paint systems typically incorporate three coatings: a primer, the water or solvent-based Intumescent layer and a surface coat (commonly referred to as a top coat) which protects the Intumescent layer from any harmful environmental effects and provides a decorative finish. Should a fire occur, the Intumescent layer will rapidly expand by as much as 50 times its original thickness, thereby creating an effective insulating char layer that protects the steelwork.

This type of thin-film system is often much less than 5mm thick and allows the steelwork to remain visible in the completed building so that it can be used as an integral part of the interior design.

Offsite-applied Intumescent coatings have also become increasingly popular in recent years, with the application is carried out under factory conditions, sometimes leading to them being used to clad steel columns which already have spray coating or Intumescent protection, simply to improve the final appearance of steel columns if they are to be left visible within the building.

CEMENTIOUS OR GYPSUM SPRAY

- Lower application costs
- Aesthetic constraints
- Wet application method
- Easy inspection capabilities
- Can speed up a build programme, but depends upon the type of spray material utilised

Cementious or Gypsum spray solutions were a popular method of fire protection in the UK until the mid-1990s. Interestingly, this type of steel protection is still very popular in many other countries throughout the world. In particular, for the protection of non-visible steelwork such as above a suspended ceiling in a typical office environment. The main advantage associated with the Cementious spray option is that application cost is significantly less than board solutions and costs do not increase significantly for higher fire resistance times, as the labour and application equipment are already accounted for.

Final finishes though are not considered to be visually appealing, and as spraying is a wet trade it can require surrounding areas to be sealed off, increasing the time on site and resulting in a slight increase in overall construction costs.

A typical spray system will be based on either Gypsum or cement; with an insulant such as vermiculite or mineral wool added to create the required level of fire protection. Spray products allow for easy application to steel sections with a complex geometry such as beams with web openings, or complex junctions where beams and columns meet. In addition, some spray materials may require just 10mm nominal cover to the inside of the web openings, allowing for services to be routed through the web openings. For clarification, please consult the relevant manufacturer.

Application costs are on average lower than other boards or Intumescent paint solutions, particularly at higher fire resistance periods. The nature of the application of spray systems also makes for easier inspection of the finished installation than is possible with paint, ensuring that an even coating has been applied and thicknesses are in line with the design specification. However, despite the perceived advantages of lower costs and easier application, the use of Cementious or Gypsum sprays has reduced markedly from the UK market in recent years. Indeed, only 28% of architects said they typically specify this method according to PROMAT UK's research. Cementious sprays are, on occasions, the specification choice for prestigious buildings in this country.

The main advantage associated with the Cementious spray option is that application cost is significantly less than board solutions and costs do not increase significantly for higher fire resistance times, as the labour and application equipment are already accounted for.

On building projects, architects tend to recommend Intumescent Paint or Board Protection.
KEY CONSIDERATIONS FOR SPECIFICATION CHOICE

Of the three primary generic passive product systems available for the fire protection of steel structures, choosing the most appropriate for the building in question requires careful assessment of critical points that will influence specification choice. These include cost, the build programme, weather-related factors, curing, and repair and maintenance. Each point is assessed below.

(i) COST

According to a recent industry publication, it was estimated that the applied fire protection system on a typical steel frame equated to approximately 10% – 15% cost of the overall steel frame construction. This is open to question as the generic material types – Intumescent paint, Board-based system or Cementitious and Gypsum spray differ greatly in price, both from a material and installation viewpoint.

It would be inappropriate in this document to offer guidance or to propose one system is more cost-effective than another as the fire protection solution relevant to a particular structure will be dependent on many different factors.

<table>
<thead>
<tr>
<th>Material type</th>
<th>Fire Protection period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 minute</td>
</tr>
<tr>
<td>Onsite Intumescent</td>
<td>£</td>
</tr>
<tr>
<td>Light boards (e.g. Rock fibre)</td>
<td>££££</td>
</tr>
<tr>
<td>Cementitious and Gypsum sprays</td>
<td>£</td>
</tr>
<tr>
<td>Heavy boards (e.g. Calcium Silicate)</td>
<td>££££££££</td>
</tr>
<tr>
<td>Heavy boards (e.g. Gypsum)</td>
<td>££££££££</td>
</tr>
</tbody>
</table>

Relative applied price comparison for each product type x fire protection period

In the recent research carried out by PROMAT UK, when asked about their views on perceived limitations for each generic passive solution, cost was only cited as a concern for the Intumescent paint option and was not highlighted in regard to either Board-based or Cementitious spray solutions.

(ii) THE BUILD PROGRAMME

Speed of construction is an increasingly critical factor when considering what fire protection product should be specified. It is evident that clients are looking for early revenue streams from building space rental, which influences the type of materials used by contractors. As an example, within the supermarket sector it is now commonplace to construct a store of 6000m² within a 22 – 26 week build programme which would not have been possible only a decade ago.

Such programme pressures can influence what fire protection product is selected and when the fire protection is applied.

Offsite-applied Intumescent paint product could be considered to aid a quicker build programme. However, the m² price for solvent-based paints is considerably higher than those of water-based paints. This must be offset by the potential reduction of the overall build programme.

If offsite paint is the desired option, then it must be noted that the general appearance of the paint is not as effective as that of on-site applied paint owing to likely damage during transportation and the touching up required post-erection. This is not to say that an improved aesthetic appearance cannot be achieved, but if required then costs are increased significantly.

Indeed the PROMAT research cited appearance as a key limiting factor for the use of Intumescent paint according to 40% of the architects questioned.

If other fire protection systems are to be considered, owing to the build programme it is highly likely that the product will be subject to moisture ingress and temperature fluctuations, therefore consideration should be given to the details given in tables 1 and 2 to the right.

(iii) WEATHER-RELATED FACTORS

The UK has experienced the wettest winter period on record, following a number of highly inclement winters in recent years. The UK’s typical unsettled and unpredictable weather pattern can have a major influence on the suitability and timescales needed for application of fire protection solutions to steel structures. Careful consideration should be given to this area before deciding on which generic product type is most appropriate for specification.

To help illustrate this point, a scenario of applying fire protection product during UK autumn and winter months is helpful. Highlighted within tables 1 and 2 are the most up-to-date weather statistics supplied by www.gov.uk/government/statistics/energy-trends-section-7-weather

In conclusion, the cost versus performance benefit can only be ascertained once other considerations are assessed.
Assuming that the steelwork supplied to site is pre-primed in accordance with BS EN ISO 12944-2:1998, and the building has a Corrosive Category – C1 classification, a very low corrosion rating, (this is a typical classification for a proposed building use of heated or air conditioned buildings) such as a typical office, retail or school development.

The impact of weather conditions on the successful application of Intumescent paint cannot be over-estimated, with clear guidance from manufacturers cautioning that steelwork should always be protected from rain or condensation during the application and initial drying stages. The surface must be dry and free of dust, salts, grease and any other contaminants immediately before coating. The surface temperature should be a minimum of 5°C and a maximum of 35°C and the temperature of the substrate must also be at least 3°C above the dew-point. The relative humidity should be a maximum 80% – 85% and the product should only be applied when the air and steel temperatures are above 5°C.

Based upon the general manufacturer guidance given for the application of Intumescent paint and bearing in mind the rainfall and temperature details given within tables 1 and 2, serious consideration should be given to the suitability of water-borne Intumescent paint during at least 3 months of the year, in particular December, January and February, and possibly other months dependent on weather conditions at the time.

Consideration should also be given to the timescales in which the water-borne Intumescent paint will be applied. For example, the external envelope of the building is often open to the elements for a period of time and this can affect the product. In all these situations it is imperative that the manufacturer be consulted for guidance. To perhaps illustrate the potential for confusion around the most appropriate use for Intumescent paint solutions, PROMAT UK’s research highlights a lack of awareness among architects that such a product can only be applied at certain points of the year due to weather-related considerations. Only 18% thought weather and climate is a limitation to choosing this option, and over 50% of architects consider weather and climate factors to be important when it comes to considering a fire protection system.

Taking the same scenario for a Calcium Silicate Board-based system tested to EN 12467, the product is impermeable to water, resistant to soak dry and freeze thaw tests and will not disintegrate, warp or swell and can be installed at any time during the building programme, even before the external envelope has been completed and the building is ‘water tight’.

If the Calcium Silicate board is exposed to water/moisture, the product will absorb it and will lose some of its inherent strength, but over a period of time will then dry out and revert back to its original state without any detrimental effect to its fire or mechanical performance. Care should be taken if boards are to be used that they are fully tested to EN 12467. The above is not advocating that boards be used within a fully exposed external environment indefinitely, but they can be left exposed for a period of time during the build programme, without deterioration.

When considering Cemenitious or Gypsum spray products, it is general guidance to give consideration to the air and substrate temperatures, which should typically be at an approximate minimum of 4°C.

If the temperature is below the guidance given, it is generally recommended that temporary heating and / or ventilation should be maintained for 24 hours prior to and during application. In addition, it should also be provided for a minimum of 24 hours post-application. Provisions should also be made for ventilation after the completion of the application in order to cure the product. In enclosed areas lacking natural ventilation, air circulation and ventilation must be provided to achieve a minimum total fresh air exchange rate of 4 times per hour until the material is substantially dry.

Spray-based products can be sourced that incorporate an accelerator to speed up the setting time and reduce the impact of high moisture levels. Again, further guidance should be sought from your preferred manufacturer to ensure installation guidelines are maintained.

(iv) CURING TIME

Once the passive fire protection system has been applied, consideration for curing timing is important.

For both Intumescent paint and Cemenitious spray options, drying times will vary considerably depending upon ambient conditions, method of application, air movement and ventilation, as highlighted below. High humidity and low air movement or low steel temperatures can result in condensation on the steelwork causing prolonged drying times and possibly poor adhesion. This can lead to bubbling or blistering on the steel frame as illustrated below.

Blistering Intumescent paint

It may be possible to repair blistering or bubbling Intumescent paint, but for large areas this can prove to be an expensive exercise, and consultation with the manufacturer should always be sought.

In the case of water ingress causing bubbling or blistering, another option to consider is that of over cladding the area with a fire protection board. This has proven to be a cost-effective method of remedial work, and in essence is based upon the theory that the board is utilised ignoring the added benefit the paint may offer. It is simply installed using the original criteria.
(v) REPAIR AND MAINTENANCE

During the expected lifespan of any building, product maintenance is an important factor. Damage can occur during installation or more commonly post-construction, with repairs to damaged areas requiring attention.

The inspection frequency will depend upon a number of factors such as: is the steelwork hidden, for example above a suspended ceiling? Is a decorative finish imperative? The location of steelwork – is it exposed to potential damage, for example, is the application within a warehouse with high potential for physical damage? Or are environmental issues to the forefront, such as dealing with areas of high humidity and temperature range as typically seen in buildings containing swimming pools or underground/basement car park locations?

In the majority of cases it is accepted that all generic fire protection steel structure systems, if applied within the guidelines defined by the manufacturer, will remain in place for the ‘lifespan of the building’, and will provide the fire protection as required. Minor damage, such as chips and scrapes, will not normally affect the fire protection performance of the material unless the service environment is wet or exposed. In such a case, damage may allow moisture ingress and lead to degradation of, for instance, Intumescent paint protection. Internal exposed steelwork should be inspected during the general maintenance regime of the building.

It is debatable and subjective as to the amount of damage permissible that will impact on the products performance. It is suggested that damaged areas such as ≥150mm² are deemed to be substantial as this type of damage will impair the fire performance and attention should be given to this immediately. It is worth noting that the basecoat used within the repair should be the same type as the one originally applied; the use of another coating may affect the fire performance of the steel section overall.

For installed Board-based systems, a regime of inspection should also be undertaken as outlined above, dependent upon the place of application. As boards are supplied and installed to specific dimensions to suit the steel section, the localised damage is easily detectable. The damaged board can be simply removed and the replacement board reinstated using the manufacturer’s recommendations. As with all generic products, the original thickness of material used should be replaced like for like.

Cementitious spray projects should also follow a regular inspection regime to assess potential damage to the fire protection integrity. The majority of material suppliers will offer the use of spray material applied by trowel and this is highly suitable for localised areas of damage, and allows minimum disruption. If larger areas have been subject to damage it is likely to be more cost efficient to utilise propriety spray equipment, although this could result in major disruption to the client.

<table>
<thead>
<tr>
<th>Cost</th>
<th>Build Programme</th>
<th>Weather-related Factors</th>
<th>Curing Time</th>
<th>Repair &amp; Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intumescent Paint</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Board-based Systems</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Cementitious Spray</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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</tbody>
</table>

The above table summarises the major factors influencing product selection as detailed in the preceding report section.

Due to the different behaviour of cellular beams, it is necessary for additional thermal data to be measured around the web openings and on the web posts. The additional thermal data needs to be assessed in conjunction with a structural model to determine limiting temperatures of beams with web openings.

There are currently a number of structural models that can be used to determine the structural capability of beams with openings in the web. The Steel Construction Institute (SCI) has published a number of structural models over a period of time, based on progressive improvements which uses data derived from tests on products supplied by Association for Specialist Fire Protection (ASFP) members to an agreed test programme.

To provide a consistent structural approach for these beams, the ASFP sponsored the SCI to produce a model capable of considering a wide range of beam designs and opening shapes and spacing. The SCI has published this method under their reference RT 1356. The latest version can be found at: www.steelbiz.org

The method of RT 1356 determines the limiting temperature at which structural failure will occur for all kinds of beam sizes, all opening shapes and spacing between openings. Once the limiting temperature is known, it is necessary to determine the required fire protection thickness for the particular beam design.
Assessing and ensuring the correct thickness of material applied to the steelwork is critical to ensuring compliance with regulatory responsibilities. Guidelines as set out by the ASFP are recommended and can be accessed with the ASFP’s Technical Guidance Document 11: 2008.

**CONDUCTING THE CORRECT THICKNESS CHECKS**

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**INTUMESCENT PAINT:**

Steel sections should be measured in accordance with the following guidelines:

1. **I Sections, Tee Sections and Channels**
   - Webs: Two readings per metre length on each face of web
   - Flanges: Two readings per metre length on the outer face of each flange
   - One reading per metre length on the inner face of each flange

2. **Square and Rectangular Hollow Sections and Angles:**
   - Two readings per metre length on each face

3. **Circular Hollow Sections:**
   - Eight readings per metre length evenly spread around the section

Ideally, all the sections within a site development should be measured. However, due to practicalities this generally does not happen. As guidance it is acceptable to randomly measure approximately 10% of the steel sections and these should be over a range of steel sizes.

**BOARD-BASED:**

As boards are factory controlled, there is no requirement for thickness checks on site, although it is recommended that visual inspections are implemented to ensure fixings are at the correct centres and if required, the framing systems are in place.

**CEMENTITIOUS SPRAY:**

The correct thickness shall be confirmed using a thickness gauge. Excessive thickness may result in delamination or a prolonged drying time, resulting in a reduced yield and excessive shrinkage. It is recommended where feasible to follow the guidelines outlined for Intumescent paint as set out above.

To obtain the required thickness for a particular fire protection material, it is necessary to generate the additional specific temperature information by testing a range of various designs of cellular beams protected with the fire protection material. In order to use the principles of RT 1356, it is necessary for the assessment of solid beams to take the form of an elemental multiple temperature analysis (EMTA) that considers the assessment of the webs and lower flange separately. In the case of cellular beams, the section factor is derived using the dimensions of the upper and lower “T” portions above and below the opening.

It is acceptable to follow the test and assessment protocol for Intumescent coatings. However, it is also acceptable to adopt the principle of using a thickness modification factor for passive fire protection systems.

Cellular beams are usually designed for specific applications and as such will have a limiting temperature calculated by a structural engineer recognised by the Engineering Council. This is the temperature that is used to determine the level of appropriate fire protection. If such a calculated limiting temperature is not available, a limiting temperature of 450°C can be used based on a reduction in strength of 40% (web post buckling failure mode) under normal utilisation. Consideration of other failure modes or utilisation rates may result in a significantly lower limiting temperature.

Where a limiting temperature of 450°C has been provided or one associated with a particular design of cellular beam in accordance with the above principles, the section factor for that beam shall be determined as the highest value derived from the following:

a) The section factor of the “T” section above the opening
b) The section factor of the “T” section below the opening
c) The section factor derived from 1400/tw where tw is the thickness of the web in mm.

In all cases, the thickness of protection obtained based on the section factor and temperature as derived above shall be increased by 20%. The applied thickness shall not exceed the maximum assessed for the product for beam protection.

In order to adopt either of the above approaches, the testing and assessment of the solid beam sections must be carried out in accordance with the test and assessment procedures in the ASFP Yellow Book 5th edition.

Based upon the above, there are a number of considerations concerning the practicality of the generic passive fire protecting systems for such beams.

Generally the Intumescent paint method will require 50 x the original dft (dry film thickness) to allow sufficient char. Considerable care should be taken that proposed services close to the openings do not restrict the Intumescent paint from working. In addition, the practicality of ensuring that the correct thickness of Intumescent paint has been applied to the web openings, the weakest area of a cell beam, also needs attention. Failure to adequately apply sufficient paint to this area could impact quite seriously on the level of fire protection achieved.

For Board-based systems, consideration is required to see if a boarded material is a viable option when using the openings for the passage of services, as well as the labour-intensive requirements to create openings within the boards.

It is feasible to use a Cementitious spray option as a 20% increase in thickness is permissible based upon a similar I Section. Furthermore, it allows for a nominal 10mm to be applied around the edges of the web opening. This keeps the size of the web opening as large as possible to facilitate the running of the various services. Please contact the material manufacturer to access the most up-to-date fire test data if minimal spacing around the web openings is required.

To use the principles of RT 1356, it is necessary for the testing and assessment of the solid beam sections to take the form of an elemental multiple temperature analysis (EMTA) that considers the assessment of the webs and lower flange separately. The applied thickness shall not exceed the maximum assessed for the fire protection material. In order to adopt either of the above approaches, the testing and assessment procedures in the ASFP Yellow Book 5th edition.

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Fire protection for steel structures is an important safety-led consideration for the specification market. Architects acknowledge their responsibilities to ensure the right choice is made from the generic passive options available to the construction industry. While Intumescent paint and Board systems are commonly specified, there has been feedback to suggest that the specification of Cementitious or Gypsum spray remains a viable and cost-effective option. What is clear is that fire protection for steel structures for every project has to be viewed on its own merits and selected product choice needs to be determined appropriately.

Looking at the results of the research PROMAT UK carried out, a number of interesting observations can be made.

SPECIFICATION SWITCHING

Whilst the use of Intumescent paint has grown, it is also clear that the architectural community continues to prefer the use of board systems for the most common UK fire-rated period of 30 to 60 minutes. It could be argued that whilst architects specify this choice, material switches are happening at the construction stage when for various reasons Intumescent paint is being utilised instead. This should be a potential concern for architects who could see their structural steel fire protection objectives compromised during construction as a result. Architects are urged to ensure that their original specification directives are fulfilled in this regard.

WEATHER FACTORS

Secondly, the critical influence of weather conditions on the application performance of Intumescent paint is not fully understood by the architectural community. Manufacturers of this product stress the importance of application in favoured conditions during certain times of the year for an optimised outcome, yet PROMAT UK’s research indicates a lack of awareness of this vital fact across the professionals questioned. This lack of understanding needs to be rectified so that the specification of Cementitious or Gypsum spray remains a viable and cost-effective option. What is clear is that fire protection for steel structures for every project has to be viewed on its own merits and selected product choice needs to be determined appropriately.

In addition to the passive fire protection systems, the documents outlined above also make comment on active systems such as sprinkler systems which have proven to be an effective method of controlling fire spread.