Structural Fire Design: Off-site Applied Thin Film Intumescent Coatings (Second Edition)

The Steel Construction Institute

The Steel Construction Institute

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(Second Edition)

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FOREWORD

The first edition of this publication was published in 1996, following a research project funded by British Steel – Sections, Plates and Commercial Steels, and the Department of the Environment, as part of the Partners in Technology programme.

The first edition provided a new industry standard for the use of off-site applied intumescent coatings, which was then an emerging sector of the supply chain.

The intention to update this document was clearly stated in the Foreword to the first edition. The revision of first edition to second edition relied heavily on the experiences of those involved in the industry. A drafting committee, under the Chairmanship of Clive Newman, was convened to undertake the work of revising the publication. The drafting committee comprised the following:

Bill Allen	Leigh's Paints
Barry Dobbins	Waterman Partnership
John Dowling	Corus Construction & Industrial
Mark Atkins	Enob Treatments Limited
David McBride	Severfield-Reeve Structures Limited
Billy McCann	Bone Steel Limited
Alastair McIntyre	William Hare Limited
Clive Newman (Chair)	Fire Safety Engineering Consultants Limited
Alan Pottage	Severfield-Reeve Structures Limited
Alan Powers	Leigh's Paints
Mike Raynor	International Paint Limited
Ian Simms	The Steel Construction Institute
Ian Stewart	Ameron International
Ian Wells	Site Coat Services Limited

The drafting committee also included the following corresponding members:

Ivan Fisher	Fisher Engineering
Gerry McCarthy	SIAC Butler Steel Limited
Ray Peters	Merseyside Coatings

The committee decided to retain the two-part format of the original document, but extensive revisions were made to both parts.

Part 1 covers the background to the use of off-site applied intumescent coatings for structural steelwork and acts as a reference text for Part 2, which presents a Model Specification. By presenting a Model Specification it is hoped that greater uniformity will be achieved in contract specifications relating to off-site applied intumescent coatings.

In Part 1, the guidance on handling, storing and transporting coated steelwork has been updated to reflect the experience that has been gained in these areas. The guidance provided on the fire protection of beams with web openings, concrete filled hollow sections, connections, composite beams and bracing, reflects the latest guidance available. Information has now been included on the protection of partially exposed members.

The Model Specification, Part 2, has been rewritten.

SCI gratefully acknowledge the following companies who have contributed to the funding of this work.

Ameron International

Bone Group Limited

Corus Group

Fisher Engineering

International Paint Limited

Leigh's Paints

Merseyside Coatings

Severfield-Reeve Structures Limited

SIAC Butler Steel Limited

Site Coat Services Limited

William Hare Limited

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PART 1: Design Guidance

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1 INTRODUCTION

Intumescent coatings are sometimes considered to be a recent addition to the products available to provide fire protection to structural steelwork. However, the first patent on intumescents was granted as early as 1938, and the principles by which these coatings work are well understood. Since then, and in particular during the last twenty years, the use of intumescent coatings has grown significantly.

Intumescent coatings are commonly used to provide fire protection to constructional steelwork and, at the time of writing, have in excess of a 40% share of the multi-storey market. Of this share, two thirds is applied on-site and one third off-site[1].

This Part of the publication provides design guidance relating to the use of off-site applied thin film intumescent coatings for structural steelwork in buildings. It clarifies issues that may arise from the use of the *Model Specification for the use of off-site applied thin film coatings* (Part 2 of this publication). It provides information on intumescent coatings, off-site application methods and their use, fire resistant design and background information relating to the specific requirements of off-site application of thin film intumescent coatings.

The information presented in this document is specific to hot rolled structural sections and hot rolled structural hollow sections, designed for use in buildings.

Guidance on intumescent coatings may be found in the ASFP publication *Fire protection for structural steel in buildings*[2], commonly referred to as the 'Yellow Book'.

1.1 Economics of off-site applied intumescent coatings

Economic viability of a process can be determined by a cost-benefit analysis, provided that all the contributing activities are identified and their corresponding costs accurately established.

When carrying out a cost-benefit analysis, it is important that a correct perception of costs is obtained. A simple cost-benefit analysis that only takes into account product and application costs, but excludes the consequences of the choice and method of application on the total construction programme, will not result in an accurate statement of total construction costs.

An off-site fire protection cost-benefit analysis has been performed for The Steel Construction Institute on a commercial office building[3]. This showed that the main cost savings generated by the off-site application of intumescent coatings resulted from the significant reduction achieved in construction time. For the typical eight storey commercial office building examined, as much as three weeks savings in construction time was shown to be achievable. This was based on an initial 67 week construction period. For shorter construction times, time dependent costs were reduced. Savings were seen in the overhead costs associated with being on-site, reduction in interest costs associated with the borrowing of capital for the development and the additional income associated with early rental or use of the property.

Off-site application also encourages more efficient design because material costs as a percentage of the total are high. Hence, there can be considerable benefits in designing with a view to optimising material and steel costs.

1.2 Benefits of off-site application of intumescent coating systems

The benefits of off-site intumescent coatings can be listed under eight distinct headings:

Faster construction as a result of:

- fire protection being taken off the critical path of the construction process (see Note 1, below)
- reduction in weather sensitivity.

Cost savings which occur because of:

- quicker return on investment as a result of faster construction
- the reduced cost of overheads costs while on-site (see Note 1, below)
- the potential for reducing fire protection material costs
- optimisation of steel and fire protection costs at the design stage.

Improved quality control because:

- application is carried out under carefully controlled and supervised conditions
- strict control of application standards are possible and a certifiable process easily guaranteed
- checks can be easily implemented throughout the application process
- single point responsibility is achievable (see Note 2, below).

Reduction in site disruption because there is:

- no need to seal off areas for fire-protection application
- less labour required on site
- less equipment required on site for less time
- less storage required on site for materials and equipment
- a reduced onus on the main contractor to provide access and facilities for the fire protection applicators.

Environmental benefits as a result of:

- elimination or reduction of problems with overspray
- reduction in the potential solvent emissions on site

- the absence of airborne dust and fibres sometimes associated with other forms of fire protection.

Benefits to servicing and other follow-on trades because:

- the characteristics of a fully dried and hardened intumescent coating allows attachments for services to be connected as soon as the steel is erected.
- follow-on trades in general can start at an earlier stage.

Increased safety on-site is achievable because:

- there are fewer trades on site
- there is less equipment on site
- there is no necessity to apply the coating in potentially dangerous areas on-site, e.g. along edge beams.

Benefits in special cases:

- off-site fire protection can have particular advantages where site access is difficult or where site possession times are restricted (see Note 3 below).

Notes:

1. Main contractors' overhead costs while on-site, consist of costs associated with site management and on-site facilities. Examples are site accommodation, provision of staff, security, plant, etc. Reducing the construction period reduces the time for which these must be provided.
2. Off-site fire protection and associated activities (handling, transportation, erection and repair) can be made the responsibility of one contractor. This minimises or removes the possible incompatibilities and difficulties that could arise when responsibility for the coated steelwork is shared.
3. Restrictions on site possessions can occur where construction demands that access and facilities are limited to certain periods of time, for example, when construction takes place over transport routes.

2 INTUMESCENT COATING SYSTEMS

This Section provides an insight into intumescent coating systems and guidance on specifying a system appropriate for the in-service environment.

2.1 Intumescence

The phenomenon of intumescence can be described as the reaction of active components under the influence of heat to produce significant swelling. These active components, or intumescents, expand to many times their initial thickness in fire and, in doing so, produce a carbonaceous char which provides a protective layer to any substrate to which the coating has been applied.

One of the beneficial uses of the phenomenon of intumescence is in its application to insulate structural steelwork against the effects of fire. An intumescent coating applied to a steel surface can provide sufficient protection to the steel substrate to ensure that most fire resistance periods required to meet building regulations requirements can be achieved.

An intumescent coating system generally has three components, a primer, a basecoat (the part which reacts) and a sealer coat. In some cases the primer and/or sealer coat may not be necessary.

Intumescent coatings usually comprise the following ingredients:

- A catalyst which decomposes to produce a mineral acid such as phosphoric acid. Ammonium polyphosphates are common catalysts.
- A carbonific such as starch which combines with the mineral acid to form a carbonaceous char.
- A binder or resin which softens at a predetermined temperature.
- A spumific agent which decomposes together with the melting of the binder, to liberate large volumes of non-flammable gases. These gases include carbon dioxide, ammonia and water vapour. The production of these gases cause the carbonaceous char to swell or foam and expand to provide an insulating layer many times the original coating thickness.

2.2 Types of intumescent coatings

Two distinct types of intumescents are manufactured. They can be classified as thin film and thick film coatings.

Thin film intumescent coatings are most commonly used in industrial and commercial buildings. They are easy to apply and provide a surface finish which can be aesthetically pleasing. Thick film intumescents tend to be used where more onerous conditions exist, for example, in the petrochemical industry where the threat is from hydrocarbon fires. They are also used for external steelwork.

Coating manufacturers should be consulted about the suitability of their intumescent system for off-site application, and about the on-site conditions to which they will be exposed.

2.2.1 Thin film intumescent coatings

Thin film intumescent coatings can either be solvent or water borne and typically have a dry film thickness (dft) no greater than 5 mm. Intumescent coatings are widely used to protect steelwork for fire resistance periods of 30 and 60 minutes, and are increasingly being used for periods of 90 minutes. In some instances, coatings can achieve 120 minutes fire resistance. In the UK, more than 70% of multi-storey construction (by floor area) has a fire resistance requirement of 60 minutes or less[1].

Most thin film intumescent coatings are designed for internal use or for sheltered protected locations in external environments. During the construction phase, some intumescent coatings can be temporarily exposed to the external environment and a protective sealer coat may be required. For all external exposure, the advice of the intumescent coating manufacturer should be sought.

2.2.2 Thick film intumescent coatings

Thick film intumescent coatings are usually epoxy based and typically have a dry film thickness of up to 25 mm for 120 minutes fire resistance. These materials have been developed predominantly for use with hydrocarbon fires where the test heating regime is much more severe than that used for most industrial and commercial construction. While these materials may be used for off-site application in the construction industry, their use is not specifically covered in this publication. However, readers may find many of the principles outlined in this document applicable.

2.3 Intumescent coating systems

Although the intumescent basecoat is the main component providing the protection from fire, it is only one part of the complete intumescent coating system providing protection to the steelwork. Equal importance has to be placed on all the other components and processes which go towards forming the complete intumescent coating system. For a typical thin film intumescent coating system these include:

- the preparation of the steel surface
- the application, where necessary, of a primer
- the application of an intumescent basecoat
- the application, where necessary, of a sealer coat
- the application of a decorative coat, where specified.

For most intumescent coating systems, the sealer coat and the decorative coat are combined in a single product. It is generally considered good practice in off-site application for a sealer coat to be used but in all cases, the intumescent manufacturer's advice should be sought.

The selection of each individual component must be specific to the needs of the application in question and each component must be considered for compatibility, in both the ambient and fire state, with the other components of the whole coating system.

2.3.1 Life of intumescent coating systems

When specifying an intumescent coating system, consideration should be given to the environmental conditions that the system must withstand. The longevity of the intumescent system will be dependent on the environmental conditions to which it is subjected, during the life of the building.

The life of an intumescent coating system is the time that elapses before maintenance of the coating system is likely to become necessary. This is known as the 'life to first maintenance' and is dependent on the in-service environment and the properties of the selected coating system.

In most cases, correctly applied intumescent coating systems, exposed internally in corrosivity category C1 (see Appendix A, Table A.1), should not require any maintenance over the design life of the building, other than for decorative purposes or where mechanical damage has occurred. For all the other corrosivity categories, periodic maintenance may be required. The advice of the intumescent coating manufacturer on the life to first maintenance should always be sought.

2.3.2 Identification of the environment

When an intumescent coating system is being selected, the environment should be identified by consideration of the following questions:

(a) What is the nature of the general environment?

(b) Will the environment change after completion of the structure or in the foreseeable future?

(c) Is there local pollution present, e.g. sulphur dioxide, which could make the environment more corrosive than is at first apparent?

(d) Are there different environments within the building?

(e) Do any special situations apply, e.g. water splash and residual pools; vulnerability to damage near ground floor level?

More information on the classification of environments is given in Appendix A, Table A.1. This information is taken from References 4 and 5.

3 OFF-SITE APPLICATION OF INTUMESCENT COATING SYSTEMS

This Section discusses the off-site application of thin film intumescent coatings and the technical and economic implications of their use.

Intumescent coating systems are usually spray applied to steelwork off-site at the fabricator's works (remote from the main fabrication line) or at a specialist intumescent applicator's premises. Application may also be by brush or roller.

Off-site intumescent coating systems should be applied under controlled conditions in facilities using good air movement and controlled temperatures, ensuring that an effective system can be applied with assured quality control and in accordance with the manufacturer's technical data sheet.

3.1 Standard of finish of intumescent coated steelwork

As any evaluation of the quality of the surface finish tends to be subjective, it is advisable that an acceptable standard of finish be agreed between the applicator and the specifier/main contractor at an early stage, particularly in cases where a high quality finish is required. In cases where appearance is important, additional care will be required when making repairs to ensure an acceptable standard is achieved.

As with any painting of structural steel, the visual quality of the finish will be affected by the surface quality of the steel substrate. Structural steel, as supplied, will not have a perfectly smooth finish and may contain such features as welded seams, gripper markings and localised surface pitting, even after blast cleaning.

Where high quality finishes are important, provisions should be made for the removal of surface features, such as weld seams, prior to coating the steelwork. The steelwork specification should include minimum requirements regarding the surface condition of the steel. These requirements for surface condition should be modified, if required, to ensure compatibility with the quality of coating finish specified and any special requirements for surface preparation of the steel should also be included in the steelwork specification.

The required coating thickness, steel section shape and section size are factors that will also affect the quality of the surface finish achieved. The advice of an experienced off-site applicator should be sought where the value of coating thickness required is relatively high for a thin-film product and/or small section sizes are to be protected, as this will adversely affect the surface finish achieved.

3.2 Handling, storage and transportation of intumescent coated steelwork

The application of intumescent coatings to structural steelwork off-site requires the implementation of specific procedures for handling, storage and transportation. Such procedures will minimise the amount of touch up and/or repair necessary once the steelwork has been erected. It should be noted that the potential for damage increases with coating thickness, as does the difficulty of repair. Hence, in the case of sections which may require a relatively thick coating, additional care may be required. (e.g. bracings, trim members, light hollow sections, etc.).

The workforce must be fully conversant with the procedures required to minimise damage. It is therefore imperative that the main contractor makes the affected trades aware of these specific procedures, and of their responsibilities, via a suitable system of training.

Coatings should be sufficiently dry before handling and members should be lifted at designated lifting points or by using lifting brackets where available. The use of lifting chains in contact with coated steel is preferred to strops/webbing slings, as the former cause only minimal damage that is normally easy to rectify. Single lift should be used unless specially designed multi-lift cradles are available.

The loading of trailers should be carefully planned, with timber supports positioned, where possible, in uncoated contact areas (e.g. areas to receive bolted connections). Where contact of supports with coated areas is unavoidable, members should be supported on their toes to minimise the contact area. Members which may fill with water should be prevented from doing so by the use of covers which will not react with the intumescent coating system, should they come into contact. Loads are best secured with the careful use of clean chains and it is advised that loaders wear overshoes and where possible avoid walking on coated surfaces in order to minimise contamination.

Where site storage is unavoidable, similar care should be taken in the handling and support of the coated steel using the same lifting and support points as those used in transportation. Where possible, members should not be stacked and water ponding should be avoided using localised protection, where necessary. The main contractor, site management and operatives should be made fully aware of the importance of good handling practice and storage areas should be roped off with signage clearly explaining the need to avoid contamination and mechanical damage to the coating finishes.

3.3 Erection of intumescent coated steelwork

Where a sealer coat is not already in place, it may be necessary to decontaminate the coated steelwork prior to erection. The intumescent coating manufacturer should be consulted as to whether the presences of contaminants, such as road salts, will affect the performance of the coating. Where appearance is important, all visible dirt should be removed from the coating.

In keeping with normal good practice, care should be taken with handling during the erection process. Coated steel should not be dragged over the ground or scraped against other members. The use of lifting techniques which make use of strategically placed holes or attached lifting brackets in the top flanges of beams will limit the potential for damage.

3.4 Remedial works

It is likely that coatings will suffer some minor damage during handling, transportation and erection. However, experience shows that with the implementation of sensible handling procedures for coated steelwork, the requirement for on-site touch up is minimal.

Small areas of damage are unlikely to have a significant effect on fire performance. Therefore, by agreement, when the steelwork is in a dry internal environment that falls within corrosivity category C1 (see Appendix A), repair may not be required. Where repair is required and the protected steel is not to be normally on view (e.g. a beam located above a suspended ceiling), the final appearance of the repaired protection may, by agreement, be deemed not to be important, with the repairs being made to a 'basic' finish.

Where a high quality surface finish has been specified it can be difficult to ensure that the surface texture of any repaired areas will fully match the original shop applied surface finish. To achieve a colour match, it is likely that an additional sealer coat will need to be applied to the full surface area of the member in question.

3.5 Off-site protection and stud welding

In some cases, through deck stud welding may generate sufficient heat to cause a local reaction of the coating leading to a 'blistering' effect. Tests have shown that the issue is not one of intumescent coating reaction, since the temperatures generated are not of sufficient magnitude or duration, but is one of simple blister formation. This is thought to result from gas release caused by a thermoplastic reaction in the binder.

In composite construction, the top flange of the beam contributes little to the overall bending resistance. For fire resistance periods of up to 60 minutes, and assuming that the stud spacing is not less than 80 mm and the blisters are unbroken, there is no requirement in respect to fire performance for them to be repaired. However, the decision to carry out remedial works may be taken for one of the following reasons:

- Appearance is a prime consideration.
- The construction is to remain open to the elements for a significant period.
- The end use situation will be one where the environmental classification is C2 to C5 according to BS EN ISO 12944-2:1988[4], i.e. external exposure or internal environments where condensation and/or high humidity may occur.

Blistering and other detrimental effects can be reduced or eliminated by the following precautions :

- Single lines of studs should be positioned above the flange web junction should be used. Where this is done, experience has shown that no blistering should occur on beams with flanges greater than 12 mm thick.

- Where double lines of shear studs are required, the beam flanges should be at least 15 mm thick to avoid blistering the coating during welding operations.
- The steelwork specification should include the following requirements, in addition to the normal requirements for stud welding:
  - Guidance on the earth contact for stud welding.
  - Provisions for the removal of a small area of coating, sufficient to ensure a suitable earth contact.
  - Additional precautions to ensure that the deck and the top flange of the beam are dry and clean
- Trials should be conducted to determine the minimum current and duration required to achieve a stud weld that is adequate for structural requirements. If this procedure is adopted, additional clauses should be included in the steelwork specification to define the scope and procedure for the trial welds and to define a suitable acceptance criteria for the welds. The risk with this approach is that, by limiting the current too tightly, structural integrity could be compromised.

4 OPTIMISED FIRE RESISTANT DESIGN

Full consideration of the fire resistance requirements at the design stage can lead to reduced fire protection thicknesses, relative to a conservative solution based on the assumption that the member is fully loaded. This has particular implications when using intumescent coatings, where the cost of the material is a considerable part of the total application costs, and also in off-site use where the drying time, and thus the time spent in the applicator's works, is a function of the coating thickness.

Section 4 provides a guide to:

- current fire resistance requirements
- methods by which design can lead to more efficient fire protection specification.

4.1 Thermal response of steel sections

The controlling parameter that defines how quickly a steel section heats up in fire is the ratio between the surface area, A, and the volume, V. This parameter, A/V *, is known as the 'section factor' and will vary between 25 and 335 m^{-1} for the normal steel section range.

A steel section with a large exposed surface area, A, will receive more heat than one with a small surface area. Also, the greater the volume (V) of the section, the greater is its ability to absorb heat. It follows therefore that a section that has a small surface area per unit volume will heat up more slowly than a section where this ratio is greater.

Sections with a low value of A/V will require less fire protection than those with higher values. Sections which are partially protected, such as beams carrying concrete slabs and columns in blockwork walls, will have considerably enhanced fire resistance, due to the fact that the exposed surface area is reduced, but the volume remains the same. In these situations, the partial protection alone may give the required fire resistance but where it does not the coating thickness is considerably less than that required for a fully exposed section, because the A/V value is lower.

Numerous published documents providing comprehensive section factor data for hot rolled structural sections and structural hollow sections are available, one such publication being the Yellow Book[2].

* The latest editions of BS 5950-8[6] and the Yellow Book now define the section factor as A/V in line with Eurocode terminology. Previously in the UK, the 'section factor' was defined as H_p/A, where H_p is the heated perimeter of the cross section and A is the cross-sectional area (m^2). For members with a uniform cross section, the values are identical and are measured in units m^{-1}.

4.2 Limiting temperatures for fire design

The thickness of protection required for steel structural members should be based on the 'limiting temperature' for the member, which can be calculated using the data presented in BS 5950-8. The limiting temperature is defined in BS 5950-8 for beams and columns in a number of common structural scenarios. For a given structural member, the limiting temperature will reduce with increasing load ratio.

Load ratio, as defined by BS 5950-8, is the design load for the fire limit state divided by the cold load-carrying capacity of the member. Normally, a structural member that is fully utilised for ultimate limit state design, is assumed to have a load ratio of 0.6 for fire design.

Generally, the information contained in the Yellow Book is based on a limiting temperature of up to 620°C for beams and up to 550°C for columns, which corresponds to a load ratio of 0.6.

4.3 Fire protection thickness calculations for partial exposure

Most structural beams support concrete floor slabs and are protected assuming an exposure to fire on three sides. Similarly most columns are fire protected assuming an exposure to fire on four sides.

A number of situations are found however where only partial protection is required to the beam or column. The most common cases are *Slimflor* or *Slimdek* beams, block filled columns, columns in walls and shelf angle floor beams.

Taking a column in a perimeter wall as an example, only the exposed flange requires fire protection. To determine the thickness of intumescent coating required, the section factor (or A/V) value is calculated using the exposed perimeter of the column. Figure 4.1 shows a 203 × 203 × 46 universal column section partially protected by a cavity wall, so that only the flange on the internal face of the wall is exposed to fire. The volume of the section is 0.00587 m^3/m.

If the column were exposed to fire on four sides, the section factor would be 200 m^{-1}. Typically, using the data provided in the Yellow Book, an intumescent coating with a dry film thickness (dft) of 1.35 mm is required to provide this column with 60 minutes fire resistance.

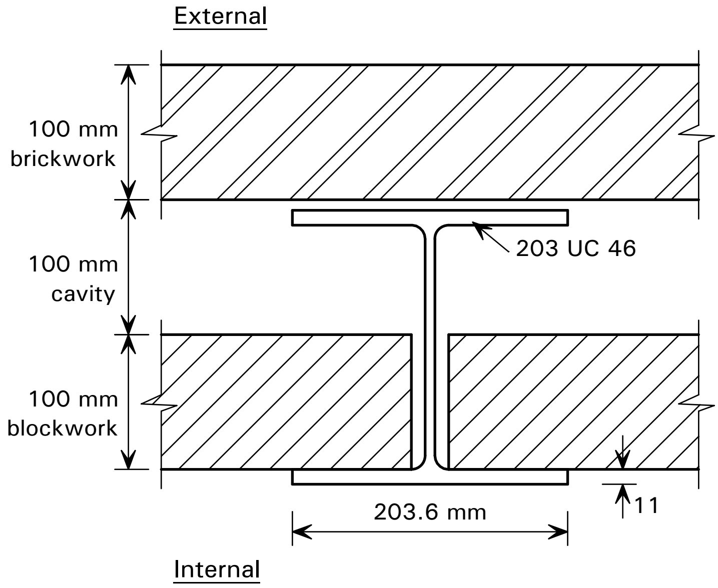


Figure 4.1 *Column, partially protected by cavity wall construction.*

For a partially encased column, as shown in Figure 4.1, the exposed surface area per unit length is

$$A = \left[B + 2T_{\mathrm{f}}\right]L$$

$$A = \left[0.2036 + 2 \times 0.011\right] \times 1 = 0.2256 \ \ \mathrm{m^2/m}$$

This gives a section factor of 38 $\mathrm{m^{-1}}$, for the partial exposed case. Therefore, the dft required on the exposed flange reduces to 0.4 mm, representing a material saving of some 70%.

4.4 Composite beams in fire

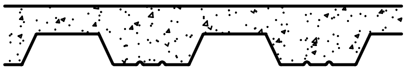
The latest revision of BS 5950-8 includes limiting temperatures for composite beams. These limiting temperatures vary with load ratio and with the degree of shear connection between the steel beam and the concrete floor slab. Therefore, it is important that the structural designer determines the appropriate limiting temperature of the member, to be fire protected. This limiting temperature should be specified in the fire protection contract documents, in addition to the period of fire resistance required.

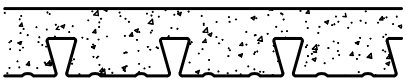
The load ratio on the beam at the time of a fire can be calculated using BS 5950-8. In this code fire is treated as an accidental limit state with specific partial safety factors for dead, imposed and wind loads at the time of the fire. The design load for the fire limit state, and hence the load ratio, depends on the type of building and relative proportions of dead and imposed loading.

For a given load ratio, the limiting temperatures for composite beams are lower than non-composite beams supporting concrete slabs. Therefore, a greater thickness of protection may be required for a beam in composite as opposed to non-composite construction.

Composite beam construction that utilises through deck stud welding is common in UK construction. Steel decking used in the UK usually has a trapezoidal or dovetail profile as shown in Table 4.1. The profile in the deck means that voids exist between the steel sheet and the top flange of the steel beam. This will cause an increase in the temperature of the top flange, relative to that for a beam supporting a flat slab in contact with the top flange along its full length. Tests conducted on this type of composite construction have resulted in comprehensive design guidance[7][8], summarised in Table 4.1.

Table 4.1 *Summary of design guidance for filling voids*

Trapezoidal deck 				
Beam type	**Fire protection on beam**	**Fire resistance (minutes)**		
		Up to 60	**90**	**Over 90**
Composite	**Materials assessed at 550°C**	No increase in protection thickness	Increase protection thickness by 10% or assess thickness using A/V increased by 15%*	Fill voids
	Materials assessed at 620°C	Increase protection thickness by 20% or assess thickness using A/V increased by 30%*	Increase protection thickness by 30% or assess thickness using A/V increased by 50%*	Fill voids
Non-composite	**All types**	Fill voids		

Dovetail decks 				
Beam type	**Fire protection on beam**	**Up to 60**	**90**	**Over 90**
Any	**All types**	Voids may be left unfilled for all periods of fire resistance		

As a general ‘rule of thumb’, it is more cost effective to increase the protection thickness than to fill the voids. However, it should be noted that where the beam forms part of a compartment wall, the voids are required to be filled to maintain the integrity of the compartment.

4.5 Bracing elements in fire

Bracing members tend to be relatively light sections with high section factors (A/V). This means that the cost of fire protecting these members is high, due to the thickness of protection that is required. Avoiding the need to fire protect bracing members can provide significant cost savings and in some cases may be the only practical option.

Some situations where it may not be necessary to fire protect the bracing are as follows.

- Bracing members installed within vertical shafts such as stairwells or lift shafts, which contain minimal fire loads. The walls of these vertical shafts are generally fire resisting and will usually be sufficient to shield the bracing from the effects of any significant fire which may occur within the main body of the building.
- Bracing located within wall cavities; adequate fire resistance will usually be provided by the wall construction.
- Structural frames with several braced bays in two perpendicular directions. Where the floors act as diaphragms that transfer the lateral loads imposed on the building to these braced bays and where horizontal compartmentation is provided, thus preventing all of the bracing being simultaneously affected by fire and ensuring alternative load paths are available if one set of bracing were fire affected. In such circumstances, if due to the reduction in the design load on the bracing members in fire conditions, the building could be demonstrated to have adequate structural stability even when some bracing is affected by the fire, the bracing could be left unprotected.
- Buildings that contain other elements such as beam to column connections and infill masonry walls that are not taken into account in the design of the building at ultimate limit state. If it can be demonstrated that these elements would provide sufficient additional stiffness in the fire limit state to compensate for the reduction in the strength and stiffness of the primary structural bracing, protection of the bracing would not be necessary.

In cases where the bracing will require fire protection, the type of section used will affect the thickness of protection required and hence the cost of protecting the bracing. For example, light tubular sections are often selected because they are structurally efficient and architecturally pleasing. However, these sections usually require a greater thickness of protection compared to an equivalent rolled steel angle (see the example below).

The ASFP Yellow Book[2] and BS 5950-8 recommend that the thickness of protection for bracing members is based on the A/V of the section for 4-side heating, or 200 m^{-1}, which ever is less. The Yellow Book also advises that buildings up to two storeys in height can achieve the required fire resistance without applying fire protection to the bracing. For other multi-storey buildings, protection should be provided or fire resistance demonstrated by other means.

The structural designer may assess the load ratio on the bracing taking into account the reduced partial safety factors for the fire limit state recommended by BS 5950-8. The limiting temperature of the bracing members can then be determined based on this load ratio. Manufacturers of intumescent coating should be able to provide guidance on the thickness of coating required for limiting temperatures other than those tabulated in the Yellow Book.

Example

Take as an example a bracing member acting in tension. In order to support the factored design load for normal design a cross sectional area of 650 mm^2 is required.

This member could be fabricated from a 48.3 × 5.0 CHS 5.34 kg/m, which has a cross sectional area of 680 mm^2. Alternatively, a 65 × 50 × 6 RSA could be used for the bracing member, this has a cross sectional area of 658 mm^2.

The CHS section has a section factor of 225 m^{-1} based on four-sided heating. This can be reduced to 200 m^{-1} following the recommendations of BS 5950-8. The required thickness of a particular typical intumescent product can now be obtained from the Yellow Book. Using the tabulated values for CHS heated on four sides the required thickness of protection is found to be 3.05 mm.

The CHS section has a surface area of 0.152 m^2 per metre, giving a required dry volume of this coating of 0.464 litres per linear metre.

The RSA has a mass of 5.16 kg/m, a cross sectional area of 658 mm^2 and a section factor (A/V) of 340 m^{-1}. Following the recommendations of BS 5950-8 we can again reduce this to 200 m^{-1}. Using the thickness tables for the same intumescent coating, such a section when heated on four sides requires a protection thickness of only 0.65 mm.

The 65 × 50 × 6 RSA has a surface area of 0.230 m^2 per metre, which means that the dry volume of coating required to protect this section is reduced to 0.15 litres per linear metre.

In this example, the CHS requires 3.1 times the volume of coating compared to a rolled steel angle with a broadly equivalent cross sectional area. Choosing an angle in this case would result in a significant cost saving in terms of the reduced coating required and in avoiding the need to apply the coating in two layers. A thinner coating is less susceptible to mechanical damage and, if damaged, is more easily reinstated.

4.6 Fire protection of connections

The most common steelwork connections are beam-to-beam connections, beam-to-column connections, column splices and bracing attachments. A typical beam-to-column connection detail is shown in Figure 4.2.

The fire protection of structural steelwork connections cannot be completed during off-site application of intumescent coatings and the applicator will usually need to make provision for the protection of the bolts and possibly some areas of the connection on-site, after erection of the steelwork has been completed.

The applicator must ensure that, where required, the contact faces between the connected members are masked off during the application process. For connections fitted with ordinary bolts, masking off the contact faces will be required when the dry film thickness of the coating, applied to the steelwork, is greater than 1 mm, although some applicators use masking at lower thicknesses. Experience has shown that an excessive build up of coating on the contact faces can cause problems with bolt tightening, especially when high dry film thicknesses are applied.

For High Strength Friction Grip (HSFG) bolts, including tension control bolts, no intumescent coating should be applied to the contacted faces of the connected ply. Care should also be taken with the outside faces of the connected ply as excessive coating thicknesses under the head of the bolt or the nut may affect the preload in the HSFG bolt. Although, no data is available on the behaviour of these connections with off-site applied coatings, it is likely that the structural performance could be affected by coating thicknesses greater than 20 microns (this value is the limit given in the Specification for Highway Works)[9].

During application of an intumescent coating, the connection components will normally receive the same thickness of coating as the member to which they are attached. Consider as an example the flexible endplate connection shown in Figure 4.2. The endplate is welded to the beam member during fabrication and the exposed face of the plate would therefore receive the same thickness of coating as the rest of the beam. The column flange to which the connection is made will receive the same thickness of protection as the rest of the column. This is generally adequate, provided that the utilisation of the connection is similar to the utilisation of the connected structural members.

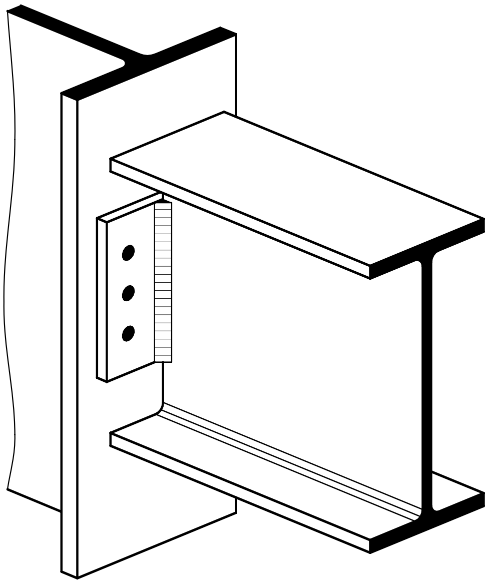


Figure 4.2 *Flexible end plate beam-to-column connection*

It is possible to reduce the coating thickness on structural elements when they are less than fully loaded. In cases where the thickness of intumescent coating has been decreased in this way, applying this thickness to the connection between the structural elements may not provide sufficient fire protection to enable the connection to achieve the required fire resistance, as the connection may have a lower limiting temperature. In these circumstances, BS 5950-8 recommends that the thickness of the fire protection applied to the connection be increased, to ensure that it has adequate fire resistance. BS 5950-8 proposes the use of an approximate method of calculating the required coating thickness for the connection. Using this approximate calculation method, the appropriate coating thickness for a connection is determined by assuming that the connected member is subject to the same load ratio (see Section 4.2) as the connection. This increased thickness of protection must be applied to the connection components. If in doubt, the connection should be protected with the coating thickness appropriate to the fully loaded beam.

4.6.2 Unprotected bolts

The on-site protection of bolts adds to the cost of off-site application of intumescent coatings. In some cases, manufacturers of intumescent coatings have conducted their own research to investigate the feasibility of leaving bolts unprotected. The temperature of the steel in the region of the connection is usually lower than the rest of the structural member, due to the increased thickness of steel and the shielding affect of the connected members. Given this reduction in temperature in the region of the connection, the build up of intumescent char on the connected ply may shield the bolts sufficiently to provide adequate fire resistance. BS 5950-8 recognises that the intumescent coating applied to the connection may be reduced in this way, if suitable test evidence is available.

4.6.3 Connections for hollow section bracing members

Hollow sections are commonly used as bracing members. On a very strict interpretation of the design rules in BS 5950-8, the connection between the bracing and the structural frame should have a protection thickness equal to that of the hollow section. Appling this thickness of protection to the connection is often difficult in practice. The design guidance in BS 5950-8 was intended to ensure connections were adequately protected when differences in load ratios exist between the connection and the protected member and its application to bracing members is not appropriate. The behaviour of intumescent coatings is very different on hollow sections (compared to open sections) and higher thicknesses of protection are generally required. The main reasons for this are problems with debonding of thin coatings on hollow sections due to the absence of a re-entrant profile for the coating to key onto. As the thickness coating applied to hollow sections has little to do with heating rate or high load ratios, it is reasonable to conclude that the connection does not require the same fire protection thickness as the hollow section.

In these circumstances, the thickness of protection that should be applied to the connection can be determined using tables of coating thickness for beams subject to heating from four sides. The section factor of the connection can be calculated based on the thickness of the fin plate with which the connection is made, using the following equation.

$$A / V = \frac{2000}{t_{\mathrm{p}}}$$

Where t_{p} is the fin plate thickness in mm.

This coating thickness can be applied to the endplate, fin plates and bolts.

4.7 Beams with discrete web openings in fire

Recent research on beams with closely spaced web openings has shown that web posts between adjacent openings become significantly hotter than the bottom flange of the section and that buckling of the web post can often be the critical mode of failure for the beam. For a beam with web openings at a given load ratio, web post failure may occur before the section reaches the limiting temperature given by BS 5950-8, for members in bending. Therefore, in order to achieve adequate fire resistance, the thickness of intumescent coating applied to this type of section generally needs to be increased to ensure that the beam performs adequately in fire.

Interim guidance on the thickness of intumescent coating required for composite beams with closely spaced and discrete web openings has been produced by the

SCI[10],[11]. The scope of application of design guidance given in the form of tabulated data these publications is limited to the following (see Figure 4.3):

- circular openings with diameters up to 80% of the beam depth, D
- width of end posts, E, not less than 30% of the opening diameter
- the ratio of opening spacing to opening diameter (S/d_o) not less than 1.4
- beams subject to typical office building load combinations.

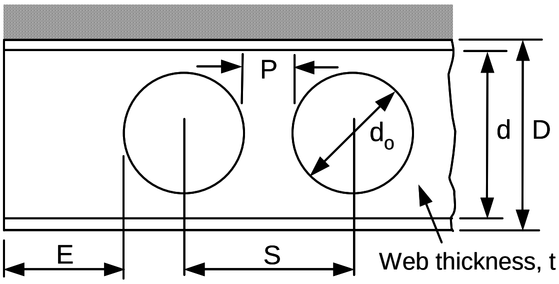


Figure 4.3 *Geometric parameters for beams with web openings*

These limitations only apply to the tabular data and should not be taken to imply that beams outside this range cannot be successfully fire protected using intumescent coatings.

Given that limited test information is currently available, the fire protection of beams with web openings is an area that requires further research. The availability of additional information may result in the revision to the design guidance currently available or in new sources of information becoming available in the near future. The references given represent the best design guidance available at the time of publication. However, specifiers of intumescent coatings would be advised to keep abreast of the most recent developments in this area.

4.8 Externally protected hollow sections in fire

Structural hollow sections acting as columns can be protected in three ways.

1. By applying fire protection, usually an intumescent coating, to the exposed face
2. By filling the section with plain concrete to provide a heat sink and applying a reduced intumescent coating thickness to the exposed face[12].
3. By filling the section with concrete, containing bar or fibre reinforcement. This can provide up to two hours fire resistance without protecting the outer (i.e. exposed) face of the section[13].

The extent of the reduction in coating thickness, for concrete-filled sections will vary with section factor and fire resistance period, but reductions of up to 80% can be expected.

The size of hollow section on which this can be used will however be limited by the ability to get the concrete into the tube. The method cannot be used on tubes smaller than 114.3 mm CHS or RHS.

The cost of intumescent coatings tends to be an exponential function of the thickness, once that thickness exceeds about 1.0 mm. Therefore, when deciding whether to use concrete filling to reduce the external coating thickness, the specifier must try to strike a balance. On one hand, concrete filling has the benefits of reduced intumescent coating costs, quicker application with less time in the applicator's works, reduced risk of damage and improved potential for achieving a high quality surface finish. On the other hand, concrete filling will add to weight and may impact foundation design. In addition, the cost penalty associated with concrete filling may not be compensated by the reduced cost of the coating.

4.9 Lattice girders in fire

Lattice girders must be treated as a special case in fire. This is as a consequence of the nature of their design and the mechanism of collapse. Once an element fails, a swift progressive collapse of the remainder of the elements follows. The advice of the UK based sections manufacturer, Corus, is that all elements of the lattice girder be fire protected to prevent them reaching 550°C, i.e. for four sided exposure, regardless of the load which they are carrying.

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APPENDIX A Classification of environment type

Environments can be classified into atmospheric-corrosivity categories. BS EN ISO 12944-2: 1998[4] has classified environments into six different groups labelled C1 to C5-M. Table A.1 identifies categories in greater detail.

The corrosivity categories are defined as follows based on a measure of corrosion rates:

C1	Very low
C2	Low
C3	Medium
C4	High
C5-I	Very high (Industry)
C5-M	Very high (Marine)

For corrosivity category C1, which includes most internal steelwork, corrosion protection is not usually required. However, reference should be made to the intumescent manufacturers' information to determine whether a primer is required to ensure good basecoat adhesion.

Table A.1 *Classification of Environment Types*

Corrosivity category	Mass loss per unit surface/thickness loss (first year to exposure)				Examples of typical environment in a temperate climate (information only)	
	Low-carbon steel		Zinc			
	mass loss (g/m^2)	thickness loss (μm)	mass loss (g/m^2)	thickness loss (μm)	Exterior	Interior
C1	≤10	≤1.3	≤0.7	≤0.1	—	Inside heated buildings with clean atmospheres, e.g. offices, schools, shops, hotels.
C2	10-200	1.3-25	0.7-5	0.1-0.7	Atmospheres with low level of pollution and dry climate. Mostly rural areas.	Unheated buildings where condensation may occur, e.g. depots, sports halls.
C3	200-400	25-50	5-15	0.7-2.1	Urban and industrial atmospheres, moderate sulphur dioxide pollution. Coastal areas with low salinity.	Production rooms with high humidity and some air pollution, e.g. food, processing plants, laundries, breweries, dairies.
C4	400-650	50-80	15-30	2.1-4.2	Industrial areas and coastal areas with moderate salinity	Chemical plants, swimming pools, coastal ship and boat yards.
C5-I	650-1500	80-200	30-60	4.2-8.4	Industrial areas with high humidity and aggressive atmosphere.	Buildings or areas with almost permanent condensation and with high pollution.
C5-M	650-1500	80-200	30-60	4.2-8.4	Coastal and offshore areas with high salinity.	Buildings or areas with almost permanent condensation and with high pollution.

Note 1 The loss values used for the corrosivity categories are identical to those given in ISO 9223: Corrosion of Metals and Alloys [5]

Note 2 In coastal areas in hot humid zones, the mass or thickness losses can exceed the limits of category C5-M. Special precautions must be taken when selecting protective paints.

STRUCTURAL FIRE DESIGN: OFF-SITE APPLIED THIN FILM INTUMESCENT COATINGS

PART 2: Model Specification

This Part of the publication provides the user with Model Specification Clauses for use in the preparation of Contract Documentation relating to off-site applied thin film coatings.

The standard clauses can be modified or omitted as required by the user, so as to make them contract specific. However, the majority should be capable of use without the need for modification.

The list of clauses is extensive and is based on the combined experience of the specifiers, manufacturers and off-site applicators forming the drafting committee.

The Model Specification is also available (free access) to download as a Word document from www.steelbiz.org.

Part 2: Model Specification

Contents

1 GENERAL

1.1 Definitions

R100 The term 'Specifier' in this specification refers to:

....

R110 The term 'Contract Administrator' in this specification refers to:

....

R120 The term 'Contractor' in this specification refers to the company responsible for the execution of the intumescent protection works and is:

....

R130 The term 'Applicator' in this specification refers to the company responsible for the application of the intumescent protection works and is:

....

R140 The term 'Coating Manufacturer' refers to the company or companies who manufacture the materials used in the protection system supplied by the 'Applicator'.

1.2 Scope of Works

R150 The Contractor shall provide an off-site intumescent coating suitable for the defined period(s) of fire resistance and environment exposure conditions.

R160 This specification shall be read in conjunction with the Contract Specification for Structural Steelwork and the Contract documents.

R170 Intumescent coating is required to be provided as an off-site applied product with on-site completion works.

R180 The chosen coating system shall be suitable for final use and also for the conditions that may prevail from time to time during the off-site application process, including:

- Application methods
- Drying time limitations
- Temperature range
- Storage conditions
- Erection conditions and handling methods
- Short-term exposure to direct weathering on site prior to erection of the cladding system.

1.3 Competence

R190 The Contractor shall be appropriately skilled in the application of intumescent paint protection systems and knowledge of the issues relating to off-site application. The Contractor shall provide evidence of competence to this effect to the Contract Administrator.

1.4 Design of fire protection

R200 In order to determine the required thickness of intumescent coating, the following information has been provided as part of the Contract Documentation.

- Fire resistance period required.
- Steelwork arrangement drawings, clearly marked to show the members to be protected and the extent of the protection.
- Steelwork section sizes.
- Nature of any partial protection provided by concrete floors, fire resistant walls, etc.

Any discrepancies shall be highlighted to the Contract Administrator for clarification.

R210 The coating system shall comprise an appropriate intumescent basecoat and, where necessary, a primer and a sealer coat. Refer to Clause *R460* for quality of finishes.

R220 The Contractor shall be responsible for the determination of dry film thicknesses. Such thicknesses may be obtained from manufacturer's literature or determined by calculation methods in accordance with BS 5950-8 [1] (or an equivalent CEN Standard).

R230 The Specifier shall be responsible for providing the Contractor with all relevant structural information, including that relating to steelwork connections, which may affect the limiting temperatures to be used in designing the fire protection thicknesses.

R240 Generally, the fire protection thickness shall be based on the section factor concept (A/V) except in the case of concrete filled hollow sections.

R250 Dry film thicknesses shall be as recommended by a competent person to suit product, period of fire protection, section size, type and weight.

R260 Fire design shall comply with current BSI or CEN Standards.

R270 For castellated/cellular beams or beams with web penetrations, the thickness of intumescent coating shall be increased by an appropriate amount over that required for the base section. Design information, demonstrating that an appropriate thickness increase has been determined, shall be submitted to the Contract Administrator.

R280 The design shall provide for additional intumescent coating thickness, as necessary, to account for the effect of unfilled voids between the decking and the top flange of the beam. Guidance given in the 'Yellow Book'[2] may be used to determine the additional thickness required. If voids are to be filled this shall be clearly noted by the Contractor on the metal decking fabrication drawings.

R290 The Contractor shall prepare a schedule of intumescent coating thicknesses required to provide fire protection to each of the steel sections to achieve the fire resistance periods given in the contract documents. This schedule shall be submitted to the Contract Administrator for review, prior to commencing the works. The schedule shall include, but not be limited to, the following:

(i) Fire resistance period(s) required.

(ii) Steelwork references as noted on General Arrangement Drawings.

(iii) Steelwork section sizes and section factors.

(iv) Details of any partial fire protection provided by concrete floor slabs, etc.

(v) Name of intumescent product(s) specified.

(vi) Method used to determine required coating thicknesses.

The average measured dry film thickness of any face of any member shall not exceed the manufacturer's recommended maximum thickness for the particular member shape and orientation.

R300 Environment exposure category to be corrosivity category …. in accordance with BS EN ISO 12944 (1998)[3].

2 MATERIALS

2.1 Material properties

R310 The intumescent coating shall have been fire tested to the requirements of BS 476: Parts 20 and 21: 1987[4]or an equivalent CEN Standard, and its performance shall have been assessed by a competent person in accordance with the principles stated in Fire Test Study Group Resolution 84[5].

R320 Confirmation shall be obtained from the intumescent coating manufacturer that the materials supplied are suitable for off-site application and for the on-site conditions (inc. duration of exposed site works if applicable) to which it will be exposed.

R330 The Contractor shall satisfy the Contract Administrator that the intumescent basecoat material is compatible with the materials used for the primer and sealer coats and that the proposed surface preparation of the sub-strata will be compatable with the coating system. Confirmation of this should be submitted in writing at the time of tender.

R340 The product data sheet, together with the product details shall be supplied indicating the anticipated life of the coating system to first maintenance. If anticipated changes to the building environments have been specified, the need for additional maintenance in such circumstances shall be highlighted.

R350 The materials used shall be appropriate for use for the construction environment and the permanent works environment.

3 ENVIRONMENTAL AND HEALTH AND SAFETY CONSIDERATIONS

R360 The Contractor shall adopt off-site coating application procedures that demonstrate quality control in accordance with BS EN ISO 9001:2000[6]. and BS EN ISO 14001[7].

R370 When selecting the method of application, the Contractor shall take cognizance of relevant environmental legislation and guidance.

R380 The Contractor shall provide details of his health and safety policy to the Contract Administrator prior to commencing the works, together with a statement as to how the works will be undertaken in a safe manner (This statement shall cover, *inter alia*, access arrangements and the provision of personal protective equipment.

4 WORKMANSHIP

R390 The Contractor shall be responsible for the co-ordination of all activities, including application, storage and delivery of materials to site.

4.1 Substrate preparation

R400 The steel substrate shall be prepared in accordance with the steelwork specification and meet the written requirements of the coating manufacturer(s).

4.2 Method statement

R410 A method statement for the application of the coating system, including the procedures for on-site completion works, shall be submitted to the Contract Administrator for review, prior to application. The method statement shall demonstrate that application will be in accordance with the coating manufacturer's written recommendations.

4.3 Application

R420 The Applicator shall ensure that materials are stored and applied in accordance with the coating manufacturer's written recommendations and that they are used before the shelf life expiry dates.

R430 The primer shall be applied in accordance with manufacturer's recommendations and the dry film thickness shall be measured in accordance with BS EN ISO 2808[8]. Where the measured thickness is not in accordance with the specification, remedial measures shall be taken, based on advice from both the primer and intumescent coating manufacturers.

R440 The applicator shall ensure that areas defined as requiring no fire protection during the off-site application process are adequately masked.

R450 The final intumescent coating dry film thickness shall be in accordance with that stated in the schedule of thicknesses (see *R280*). The thickness of the intumescent coating shall be measured in accordance with the method given in *R600*.

R460 Where a sealer coat is specified, it shall be applied in accordance with the coating manufacturer's recommendations. Care shall be taken to ensure that the intumescent basecoat has been allowed to dry/cure in accordance with the coating manufacturer's recommendations prior to the application of any sealer coat.

R470 The quality of finishes fall under the following categories:

(i) Basic Finish:

The coating system achieves the required fire performance and corrosion protection performance, but is not required to achieve any requirement for standard of finish.

(ii) Decorative Finish:

In addition to the requirements for (i) above, a good standard of cosmetic finish is generally required, when viewed from a distance of 5 m. Minor orange peel or other texture resulting from application or localised repair is acceptable.

(iii) Bespoke Finish:

In addition to the requirements for (i) above, the coating finish is required to have a standard of evenness, smoothness and gloss agreed between the Specifier and Contractor.

When agreeing a bespoke standard of finish, the Specifier and Contractor should take account of the effects of steel size, section shape, design complexity and the required period of fire resistance.

The Contractor shall provide for a basic finish unless otherwise noted in the Contract Documentation

R480 Where a Decorative Finish or a Bespoke Finish is required, the Contractor shall provide the Specifier with representative sample(s), prior to the commencement of the works, as a guide to the standard(s) of finish(s) that can be achieved with the intumescent coating system specified. Alternatively, by agreement, reference can be made to other completed projects.

4.4 Handling, storage and transportation

R490 Written procedures shall be established covering the handling and storage of the coated steelwork to minimise damage to the coatings. These procedures shall be included in the Contractors Method Statement.

4.5 Erection

R500 Erection of the coated steelwork shall be undertaken by competent personnel who are familiar with the lifting and handling procedures required to minimise damage to the coating.

4.6 Remedial Works

R510 Where necessary, repairs shall be carried out to ensure that the standard of fire protection, surface integrity and finish is in accordance with the original specification.

R520 Before carrying out on-site remedial works, a written Method Statement for repair procedures shall be prepared by the Contractor and submitted to the Contract Administrator for review.

R530 The Contractor shall be responsible for identifying all areas requiring remedial works and for rectification in accordance with the coating manufacturer's recommendations.

R540 Where a decorative finish or bespoke finish has been specified, the Contractor shall make provision for the removal of all visible dirt from the surface of the coating, following erection of the steelwork.

R550 If the dry film thickness of the intumescent coating, measured in accordance with *R600*, does not comply with the nominal dry film thickness stated in the schedule of thickness (see *R380*), remedial works shall be undertaken to bring the affected area up to the required thickness.

4.7 Areas requiring on-site completion

R560 Localised areas requiring on-site completion of the intumescent coating, such as bolted connections, any exposed steel surfaces or areas subject to on-site welding, shall be treated in accordance with the approved method statement. (see *R380*)

5 APPROVALS, INSPECTION, RECORDS AND REPORTS

5.1 Inspection

R570 The Contractor shall be responsible for the overall inspection and monitoring regime and for provision of the quality control records for incorporation in the Operations and Maintenance Manual.

5.2 Product certification

R580 A copy of the appropriate fire performance assessment for the selected intumescent protection system shall be forwarded to the Contract Administrator for comment prior to procurement of materials. The assessment shall be in accordance with the principles stated in Fire Test Study Group Resolution 84[5].

5.3 Application documentation

R590 The Contractor shall provide written confirmation that the Intumescent system has been applied in accordance with the manufacturer's recommendations to achieve the specified fire resistance period(s).

R600 The Contractor shall provide manufacturers written confirmation that the coating materials used are suitable for their intended environments, as required by *R320*.

5.4 Testing

R610 The coating thickness acceptance criteria shall be as follows, based on the required thickness stated in the schedule of thickness (see *R290*), being a nominal value:

(i) The average dry film thickness applied to each element shall be greater than or equal to the specified nominal value.

(ii) The average measured dry film thickness on any face of any member shall not be less than 80% of the specified nominal value

(iii) Dry film thickness values less than 80% of the specified nominal value are acceptable, provided that such values are isolated and that no more than 10% of the readings on a member are less than 80% of the specified nominal value.

Where any single thickness reading is found to be less than 80%

of the specified nominal value, a further two, or where possible three, readings shall be taken within 150 to 300 mm of the low reading. The initial reading may be considered isolated if all the additional readings are at least 80% of the specified nominal value. If one or more of the additional readings are less than 80% of the specified nominal value, further readings shall be made to determine the extent of the area of under thickness.

(iv) All dry film thicknesses shall be at least 50% of the nominal value

R620 The method of thickness testing shall use a gauge employing the electro-magnetic induction principle. Such instruments shall have a range appropriate to the specified dry film thickness and shall be calibrated on a smooth plate prior to use. The instruments shall be capable of storing data.

R630 Offsite testing

All members shall be tested in accordance with the following:

(i) I Sections, Tee Sections and Channels

Webs: Two readings per metre length on each face of the web.

Flanges: Two readings per metre length on the outer face of each flange. One reading per metre length on the inner faces of each flange.

(ii) Square and Rectangular Hollow Sections and Angles
Two readings per metre length on each face.

(iii) Circular Hollow Sections.
Eight reading per metre length evenly spread around the section.

(iv) Where members are less than 2 m in length, three sets of readings shall be taken, one near to each end and one at the centre of the member. Each set shall comprise the number of readings on each face given by (i), (ii) or (iii) above, as appropriate.

5.5 Reporting

R640 The Contractor shall maintain a schedule of measured coating thicknesses as works proceed. On request, these readings shall be made available for inspection by the Contract Administrator during the works and as a quality control record on a clearly identifiable member-by-member basis on completion of the contract.

Dry thickness readings shall be recorded for each element on a schedule indicating:

(i) The member identification mark.

(ii) The number of readings.

(iii) Maximum coating thickness reading.

(iv) Minimum coating thickness reading.

(v) Average coating thickness readings.

(vi) Supplementary readings as necessary to demonstrate the measured values under 80% of the nominal thickness are isolated readings. (see *R590* item (iv)).

R650 Written records shall be maintained including any re-measurements after remedial works.

R660 Coating thickness measurements for coated steel members delivered to site shall, where requested, be provided to the Contract Administrator within an agreed and reasonable time period.

6 INFORMATION TO BE SUPPLIED BY THE CONTRACTOR

6.1 Contractor supplied information

R670 The following submissions shall be made to the Contract Administrator at the time stated. Detailed requirements are listed under the relevant clause number.

Sections	Item	At Tender	Prior to Commencing the Works	During the Works
2	Statement on Competence	*R180*		
	Schedule of Paint Thickness and/or Thickness Marked Up on Fabrication Drawings		*R270*	
2 and 5	Product Data Sheet	*R310*		
	Representative Sample	*R470**		
	Paint Life to First Maintenance	*R310*		
	Health and Safety Policy		*R350*	
4 and 5	Compatibility of Coating Materials		*R370*	
	Application Method Statement		*R380*	
	Remedial Works Method Statement		*R510*	
5 and 6	Production of O&M Info			*R550*
	Product Certification			*R560*
	Application Documentation			*R570*
	Thickness Control Results			*R640*

* Only when requested by the Specifier.

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3. BS EN ISO 12944-2:1998 Paints and varnishes. Corrosion protection of steel structures by protective paints systems. Classification of environments
British Standards Institution

4. BS 476: Fire tests on building materials and structures
BS 476-20:1987 Method of determination of the fire resistance of elements of construction (General Principles)
BS 276-21:1987: Method of determination of the fire resistance of loadbearing elements of construction
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5. Resolution No. 84: Assessment of fire protection to structural steelwork
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6. BS EN ISO 9001:2000 Quality management systems. Requirements
British Standards Institution

7. BS EN ISO 14001:2004 Environmental management systems. Requirements with guidance for use
British Standards Institution

8. BS EN ISO 2808:2001 Paints and varnishes. Determination of film thickness
British Standards Institution