FPA Design guide

for the Fire Protection of Buildings

CORE DOCUMENT

COMPARTMENTATION

FPA Fire Protection Association

InFiReS

IMPORTANT NOTICE

This document is one of a number which go to make up the *FPA Design guide for the fire protection of buildings,* a development from the *LPC Design guide for the fire protection of buildings 2000*. That development is part of a programme of work being carried out by the Fire Protection Association under the sponsorship of the Insurers' Fire Research Strategy Funding Scheme (InFiReS). The scheme is operated by a group of insurance companies supporting a series of expert working groups developing and promulgating best practice for the protection of property and business from loss due to fire and other risks. The technical expertise for the *Design guide* is provided by the Technical Directorate of the FPA and experts from the insurance industry who form the InFiReS Passive Working Group.

The aim of the *FPA Design guide* is to provide loss prevention guidance for those who design, construct and equip industrial and commercial buildings. The *Design guide* documents continue a long tradition of providing authoritative guidance on loss prevention issues started by the Fire Offices' Committee of the British insurance industry over a hundred years ago and build upon earlier publications from the LPC and the Association of British Insurers.

FPA Design Guide: Essential Principles

The objectives of the Design Guide are to:

- reduce the likelihood of fire, either accidental or malicious;
- minimise the effect of fire on a business;
- protect the buildings within a business; and
- maintain the health and safety of those in and around the building (including firefighters).

This objective will be achieved by addressing essential principles to be followed in the design and construction of commercial and industrial premises.

The essential principles are:

Reaction in the event of fire:

1. The building shall be constructed in such a manner that if a fire starts, the extent of fire and smoke damage will be minimised and confined as close to the source of fire outbreak as is practical/feasible.
2. With the exception of joinery products, the building shall be constructed from building materials/products that will not make a significant contribution to the early stages of a fire or contribute to the spread of fire.
3. Suitable measures will be taken for the prevention of premature structural collapse and excessive deflection.
4. Consideration shall be given at the design stage to the potential damage from firefighting water and to ensuring, as far as practical, that the effect on the environment of the fire effluent will be minimised.

Workmanship:

5. As a minimum, all fire protection products shall be third-party certificated to an appropriate product or performance-based standard (attestation level 1 for CE marking).
6. All fire protection products/systems shall be installed by adequately trained specialist installers.

Response to fire:

7. The building shall be fitted with an appropriate automatic fire alarm system.
8. The fire protection systems shall be regularly maintained so that they are able to perform their intended function throughout the life of the building.

Fire prevention:

9. There shall be adequate provision to prevent an arson attack.
10. The building shall be so constructed that fire cannot spread into the premises from an adjoining building or other external fire source.

Fire safety management:

11. The building owner shall ensure an adequate standard of fire safety management throughout the life of the building.
12. Any fuel-burning appliance and services or electrical appliance and services shall be designed, constructed and installed in a manner that reduces their potential as an accidental source of ignition.

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FPA DESIGN GUIDE: THE FIRE PROTECTION OF BUILDINGS

COMPARTMENTATION

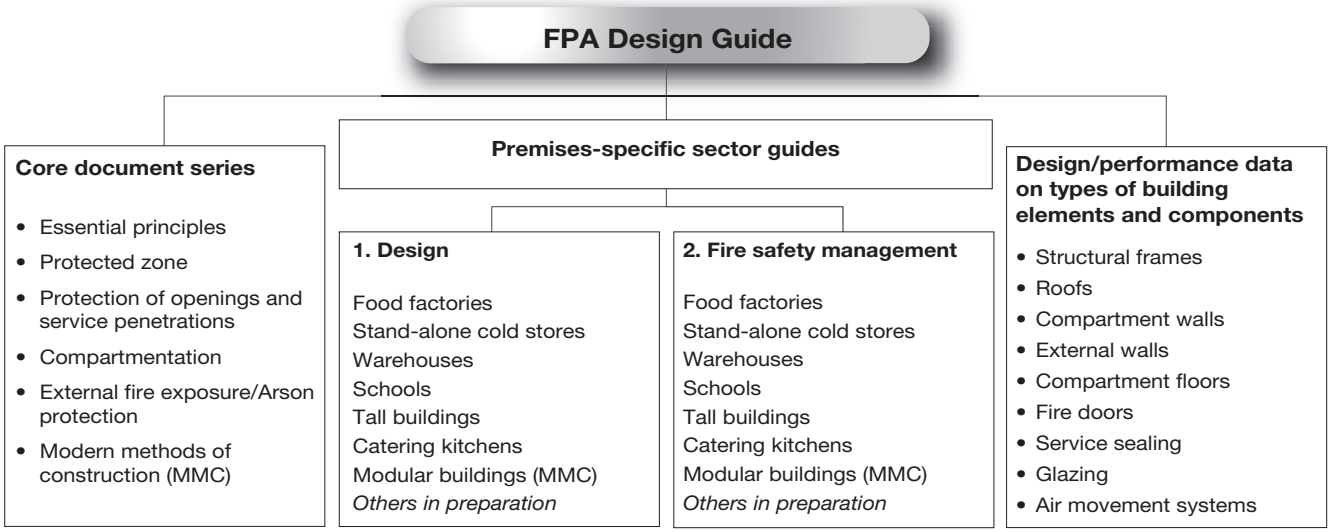
InFiReS

FPA Design Guide: the Fire Protection of Buildings

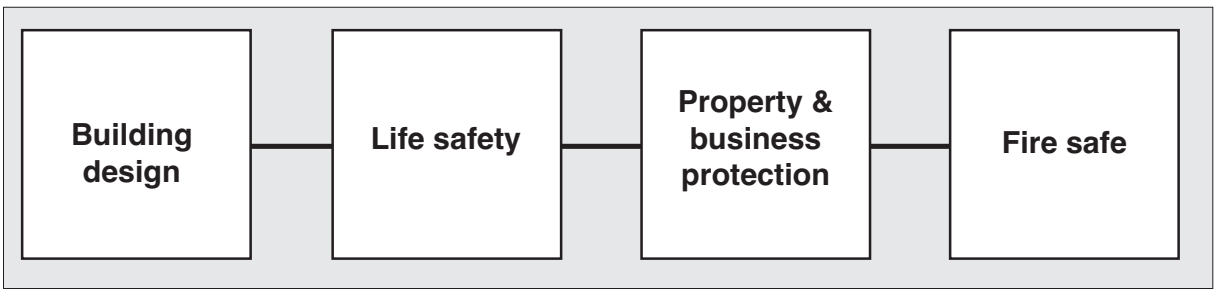
The FPA Design Guide is a series of publications which have been developed from predecessor documents and also cover new ground. The Design Guide informs architects and designers about the business risk management issues which relate to the fire protection of buildings, issues which supplement in very important ways the life safety requirements contained in the principal legislative controls. It will give designers a more complete view about designing fire-safe buildings.

The Design Guide has been recast in three main parts:

- core documents: a set of publications on fundamental design topics;
- premises-specific sector guides: for each type there will be a design guide and a document concerning fire safety management; and
- design/performance data on building products: the datasheets are accessible on *www.thefpa.co.uk/Resources/Design+Guide/.*



It is also proposed to produce a document which concentrates on technical data, definitions of terms and details of sources of reference and information, as commonly used for insurance underwriting purposes, to support the suite of Design Guide publications.



Basic fire safety design framework

Emphasis is placed on the importance of early consultation among architects, those who manage risks in industry and commerce, and insurers, and on the value of risk assessment in order to use the *Design Guide's* recommendations to best effect.

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Section 1
USE OF GUIDANCE

1.1 Core documents

1.1.1 Introduction

This document is one of a number which go to make up the *FPA Design guide for the fire protection of buildings*, a development from the *LPC Design guide for the fire protection of buildings 2000*. That development is part of a programme of work being carried out by the Fire Protection Association under the sponsorship of the Insurers' Fire Research Strategy Funding Scheme (InFiReS). The scheme is operated by a group of insurance companies supporting a series of expert working groups developing and promulgating best practice for the protection of property and business from loss due to fire and other risks. The technical expertise for the *Design guide* is provided by the Technical Directorate of the FPA and experts from the insurance industry, who form the InFiReS Passive Working Group.

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Lists of other publications on loss control are available at *www.thefpa.co.uk* and from the FPA at:

Fire Protection Association
London Road
Moreton in Marsh
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Copies of publications can be purchased from the FPA at that address or by calling +44 (0)1608 812500 or emailing sales@thefpa.co.uk.

1.1.2 Essential principles

National building regulations are intended to ensure that a reasonable standard of life safety is provided in case of fire. The protection of property, including the building itself, may require additional measures.

It is the objective of the *FPA Design guide* to describe aspects of fire safety in buildings which will both reduce the risk of fire and make them better able to cope with the effect of fire in the event that it should break out. The aims are to:

- reduce the likelihood of fire, either accidental or malicious;
- minimise the effect of fire on a business;
- protect the buildings within a business; and
- maintain the health and safety of those in and around the building (including firefighters).

This objective will be achieved by addressing essential principles to be followed in the design and construction of commercial and industrial premises.

The essential principles (to be taken as requirements) are:

Reaction in the event of fire:

1. The building shall be constructed in such a manner that if a fire starts, the extent of fire and smoke damage will be minimised and confined as close to the source of fire outbreak as is practical/feasible.
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11. The building owner shall ensure an adequate standard of fire safety management throughout the life of the building.
12. Any fuel-burning appliance and services or electrical appliance and services shall be designed, constructed and installed in a manner that reduces their potential as an accidental source of ignition.

1.1.3 Limitations

The *FPA Design guide for the fire protection of buildings* is made up of many documents, including a number of core documents. Core documents are a set of publications which expand upon fundamental design topics.

This core document deals with the fundamental design topic of compartmentation. It describes in detail the function of compartmentation, and how it can be achieved.

This core document does not describe the requirements for the provision of compartmentation. These are described in sector guides which describe the fire safety design and fire resistance performance requirements for buildings put to specific uses. Sector guides describe:

- how to undertake a risk assessment to determine the risk category of a premises;
- the location/s where compartmentation is required in premises of different risk categories; and
- the degree of fire resistance required for compartmentation in premises of different risk categories.

The provisions of this core document are intended to support the property protection goals of sector guides. They may prove useful to those that are applying compartmentation in response to life safety standards but, in common with other parts of the *Design guide*, this core document is not intended to give specific guidance on life safety and means of escape.

While this document contains technical guidance concerning the general design principles for compartment walls and floors, advice should always be sought from the insurer in relation to their intended purpose and design at the earliest possible stage of the design process.

1.1.4 The audience

This advice is addressed mainly to those professionals – architects, developers, surveyors, fire engineers and builders – that need help to understand and apply the principles of fire safety in the design and construction of buildings, by adherence to fundamental guidance given in the FPA's *Design guide: Essential principles.* It will also be of value to those that survey and assess the fire safety attributes of buildings on behalf of insurance companies.

It should also be of help to building owners and fire safety managers.

1.2 Compartmentation

1.2.1 Scope

The advice contained in this core document is applicable to:

- all new buildings, excluding dwelling houses, maisonettes, and stand-alone car parks for light vehicles – for all these, the provisions of the supporting documents to the Building Regulations are considered to provide adequate property protection; and
- major extensions and the refurbishment and upgrading of existing buildings within the purpose groups covered.

This core document addresses:

- the fire integrity of compartments;
- guidance with respect to the interaction between walls, floors, structural framing and roofs; and
- the importance of the interface with service and other penetrations, fire door and shutter assemblies and stairway enclosures (although these subjects are dealt with more fully in the core document *Protection of openings and service penetrations from fire*).

1.2.2 Arrangement of sections

This core document deals with the principles of compartmenting buildings to resist the spread of fire. It covers the following:

- the role of compartmentation and aspects of compartmentation;
- compartment walls, their purpose, fire resistance and construction;
- compartment floors, their purpose, fire resistance and construction;
- openings in compartmentation;
- the protected zone and the control of roof exposure hazard;
- the structural frame and the part it plays in maintaining compartmentation; and
- materials and their behaviour in a fire.

The majority of this document provides guidance on appropriate measures for protecting a business by the provision of adequate levels of fire resisting compartmentation. Where reference is made to essential principles, these shall be taken as requirements.

1.3 Depicting passive fire protection measures

The following descriptions make reference to products and/or systems. It is not the purpose of this design guidance to recommend proprietary products, but in the main text there are references to the need for selecting products which are approved via appropriate third-party testing and certification bodies. On the FPA's website are data sheets which provide more information about broad types of products or systems (*www.thefpa.co.uk/Resources/Design+Guide*).

1.3.1 Structural framework

Structural framework is usually steel, but it can be reinforced concrete or timber. As well as providing a robust framework to support all the loads presented by or imposed upon a building, it needs to maintain its loadbearing capacity in a fire for an appropriate duration. Structural steel may require protection against the effects of fire by the application of a suitable protection material or coating. The ability to be able to transfer load from the fire zone is an important consideration.

1.3.2 Roofs

Very often, the roofs of industrial/commercial buildings are made of composite panels with fire resistance performance characteristics appropriate to their purpose. Where portions of a roof are within the protected zone (see Glossary of terms), then additionally they shall have the ability to resist the spread of fire from inside to outside (and from outside to inside).

1.3.3 Compartment walls

These provide vertical barriers to prevent fire spreading horizontally between compartments within a building (see appropriate sector guide). A compartment wall shall be designed to maintain its integrity for a specified duration and to restrict the rise of temperature on its face not exposed to the fire to the level required to prevent the spread of fire by the conduction of heat. In all cases, a compartment wall will extend from floor to floor without the need for cavity barriers.

1.3.4 External walls

External walls shall make no significant contribution to a developing fire but shall meet any requirements specified for thermal insulation. An external wall shall prevent fire spread around a compartment wall, where the two adjoin, by meeting the fire resistance requirements appropriate to the protected zone. It is necessary to specify a product that can resist fire spread from both inside and outside (see appropriate sector guide).

1.3.5 Compartment floors

These provide horizontal barriers to prevent the vertical spread of fire between compartments within a building as required by the appropriate sector guide.

A compartment floor shall be designed to maintain its loadbearing capacity in a fire, to contribute appropriately to the stability of a building and to ensure that escape routes remain accessible. It shall also restrict an increase in temperature on the surface of the floor not exposed to fire (thus preventing fire spread by heat conduction) for the period specified in the appropriate sector guide.

1.3.6 Fire doors and shutters

The function of fire-resisting doors and shutters is to maintain the fire, heat and smoke separation performance of a compartment wall (or large cavity barrier) when such openings need to be provided to permit the passage of persons or objects. It is essential to specify a product for which there exists test evidence of suitability for its location and design purpose.

1.3.7 Service sealing

The adequate fire-stopping of gaps around service pipes, at penetrations through compartment walls and floors, is essential to maintain the fire resistance performance of those walls/floors. There is a multiplicity of sealing products and systems and it is vital to acknowledge the need to repair imperfect fits and to choose a product/system that is suitable for the location and design purpose.

1.3.8 Fire-resistant glazing systems and framing

The principal function of fire-resistant glass is to maintain the integrity of a compartment wall for the duration specified in the appropriate sector guide. It is essential to specify a system (glass and framing) that delivers the complete range of fire-resisting features appropriate to the intended location and use.

1.3.9 Air distribution systems

Where air distribution ductwork is fitted, then if it passes through compartment walls/floors it shall maintain fire compartmentation. This will require the specification of steel ductwork (which may be protected by fire protection systems – such as detection devices linked to fire dampers) or of duct systems constructed from fire protection systems. The appropriate service sealing product or system should be employed where such distribution systems penetrate compartment walls/floors.

1.3.10 Fire-rated partitions

Lightweight internal partition walls shall be constructed of materials which do not contribute to the overall fire loading of the building. They are not compartment walls (see 1.3.3) as often they only go up to suspended ceiling level and not to the floor above.

Section 2

THE ROLE OF COMPARTMENTATION AND ASPECTS OF COMPARTMENTATION

2.1 Commentary

Compartmentation is the division of a building into fire-resisting compartments, comprising one or more rooms, spaces or storeys, by elements of construction designed to contain a fire for a predetermined duration. It should be noted that fire resistance periods are not related to the anticipated duration of a fire but to the fire load in the fire compartment and other related factors.

In codes and standards which address life safety, the purpose of compartmentation is to limit the theoretical maximum size of a fire in order to facilitate safe evacuation. In the *FPA Design guide*, compartmentation is used to limit the spread of fire in order to:

- prevent excessive damage caused by fire and smoke;
- protect valuable materials; and
- limit the damage caused to resources so that following a fire, there will be minimal interruption to business.

Compartmentation is achieved through design incorporating:

- compartment walls;
- compartment floors;
- a protected zone; and
- adequate stability of the structure.

2.1.1 Compartment walls

In this core document, compartment walls are divided into two types:

- Type 1 compartment walls must not contain any openings for doors, glazing or services (except insulating, secure doors fitted with an emergency access device for means of escape), such as:
  - walls which separate two different occupancies (ownerships/tenancies); and
- Type 2 compartment walls may contain openings for doors, glazing or services. These shall maintain the fire resistance of the compartment wall, such as:
  - walls which separate different areas of a premises in single occupancy;
  - walls designed to separate purpose groups (for example, walls separating a factory from its offices or a shop from its storage warehouse);

- walls designed to restrict the sizes of compartments within a purpose group to those areas recommended in the appropriate sector guide of the *FPA Design guide;* and
- walls designed to segregate a hazard, high-value goods or sensitive equipment within an occupancy.

Advice should always be sought from the insurer in relation to the intended purpose and design of compartment walls.

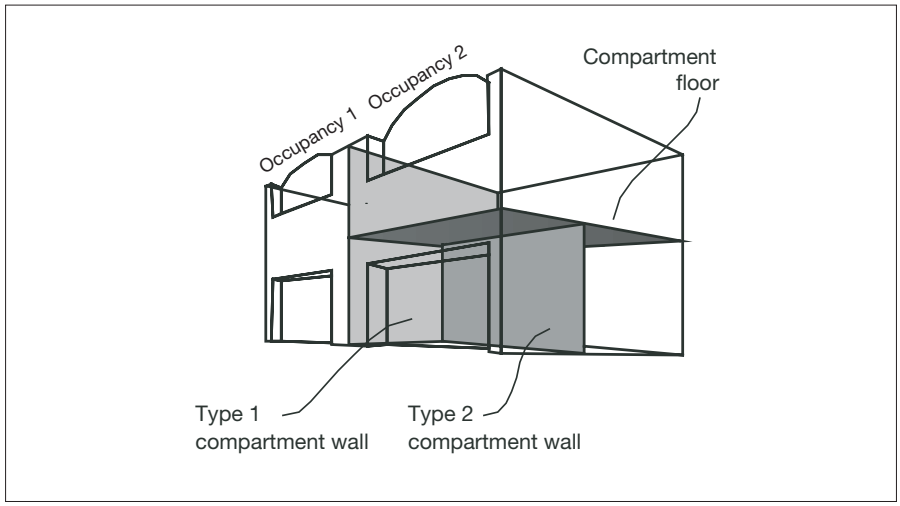


Figure 2.1: Aspects of compartmentation

2.1.2 Compartment floors

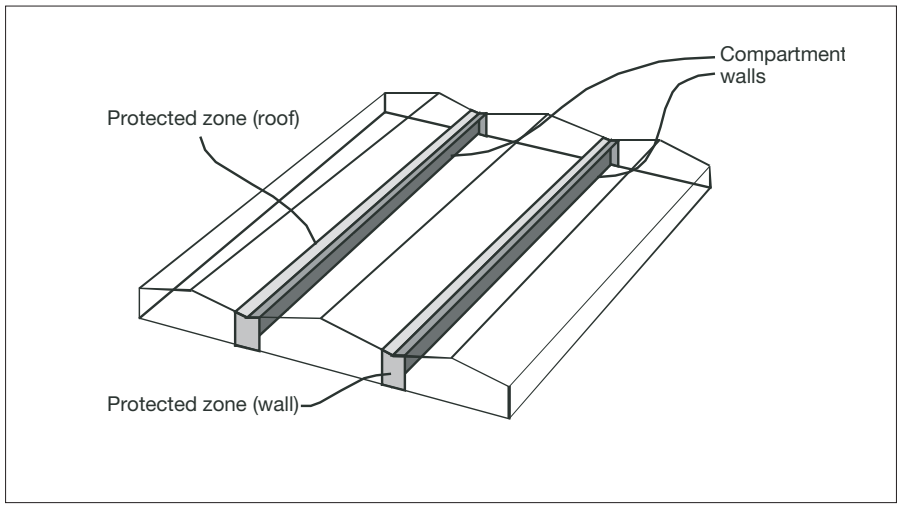


Figure 2.2: The protected zone and compartment walls

Compartment floors are covered in detail in section 4.

2.1.3 The protected zone

The protected zone is specified to reduce the possibility of fire bypassing the compartment wall at the junction between the wall and the external cladding or through the cladding itself. This is shown above in relation to a single-storey building. With respect to multi-storey buildings, specific guidance is given later in this document for compartment floors.

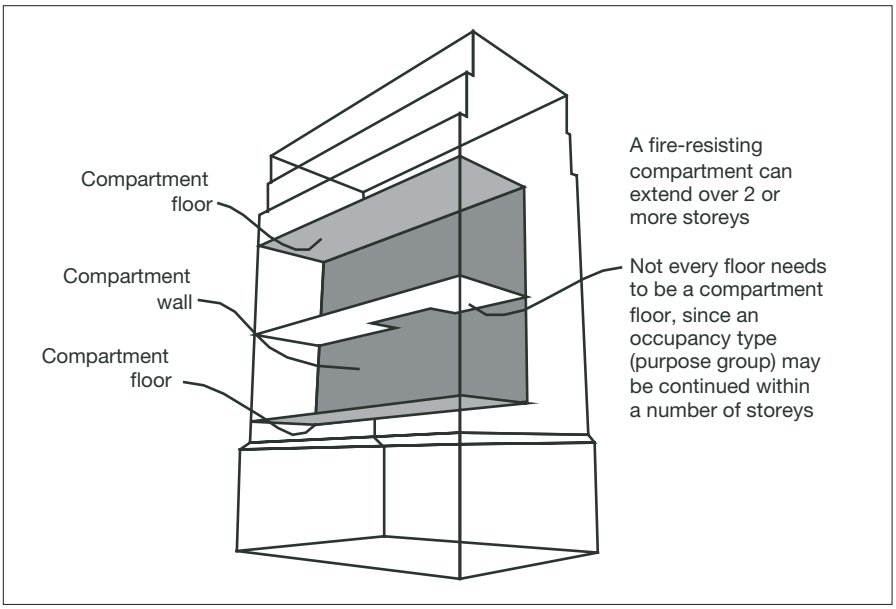


Figure 2.3: A fire-resisting compartment can extend over two or more floors

All compartment walls have the purpose of resisting the spread of a fully-developed fire, but their different locations in a particular premises will call for an understanding of the design approach that is required.

Design principles: compartment walls

A compartment wall shall:

- maintain the fire integrity of the wall for the duration specified;
- restrict the rise in temperature on the face not exposed to fire to the level required to prevent fire spread by preventing ignition of materials at or near the unexposed face, for the duration specified;
- not make a significant contribution to the growth or intensity of the fire;
- restrict the passage of smoke for the same duration as its specified duration of fire integrity;
- withstand the loading and deflection experienced in use and during fire exposure without affecting the performance requirements listed above;
- be suitable for service penetrations and the fire-stopping thereof without detriment to the fire separation provided, in terms of integrity, temperature rise and smoke restriction; and
- maintain its separating performance over the lifetime of the building and in relation to the conditions of use and occupancy existing in the building, as determined by risk assessment.

Design principles: compartment floors

A compartment floor shall:

- maintain a loadbearing capacity under fire conditions for the duration specified, thus ensuring that the building structure maintains its stability for a reasonable/acceptable period;

- maintain a loadbearing capacity for the duration specified, thus ensuring that the circulation/escape routes remote from the fire storey remain accessible;
- provide an imperforate barrier by appropriate use of protected shafts, whose integrity against vertical fire spread is ensured for the duration specified;
- restrict an increase in temperature on its upper surface (unexposed to fire), thereby preventing the spread of fire via conducted heat for the period specified;
- restrict smoke spread between floors, ideally for a period equal to its fire integrity;
- not be capable of spreading flaming on its lower surface (that is, the ceiling of the room below);
- not contribute unduly to the growth and development of fire within the room below;
- withstand the loading and deflection experienced in use and during fire exposure without affecting its performance requirements listed above;
- be suitable for service penetrations and the passage of ducts, and the fire-stopping thereof, without detriment to the fire separation provided, in terms of integrity, temperature rise and smoke restriction; and
- maintain its separating performance over the lifetime of the building, and in relation to the conditions of use and occupancy existing in the building, as determined by risk assessment.

Multi-storey buildings

The application of the protected zone concept to multi-storey buildings where compartment floors are used will depend on a number of different factors:

- if the building is fully sprinkler protected;
- the type of building product used for the external fabric, noting whether the system has fire resistance; and
- if the compartment floor is separating one tenancy from another (or another critical application identified by the insurer).

The need for provision of a protected zone in multi-storey buildings may be determined as illustrated in Figure 2.4.

Note: Floors separating different purpose groups in the same occupancy may also need the provision of a protected zone.

The fire resistance required and the location/extent of the protected zone will be as specified in the appropriate sector guide. (The FPA is, at the time of publication, writing an architects' guide. Contact the FPA for more details.)

Compartmentation and the risk assessment

The objectives of fire compartmentation are to prevent the spread of fire within or between buildings and to improve the level of asset and business interruption protection. The extent of compartmentation required can only generally be decided after a fire risk assessment has been completed.

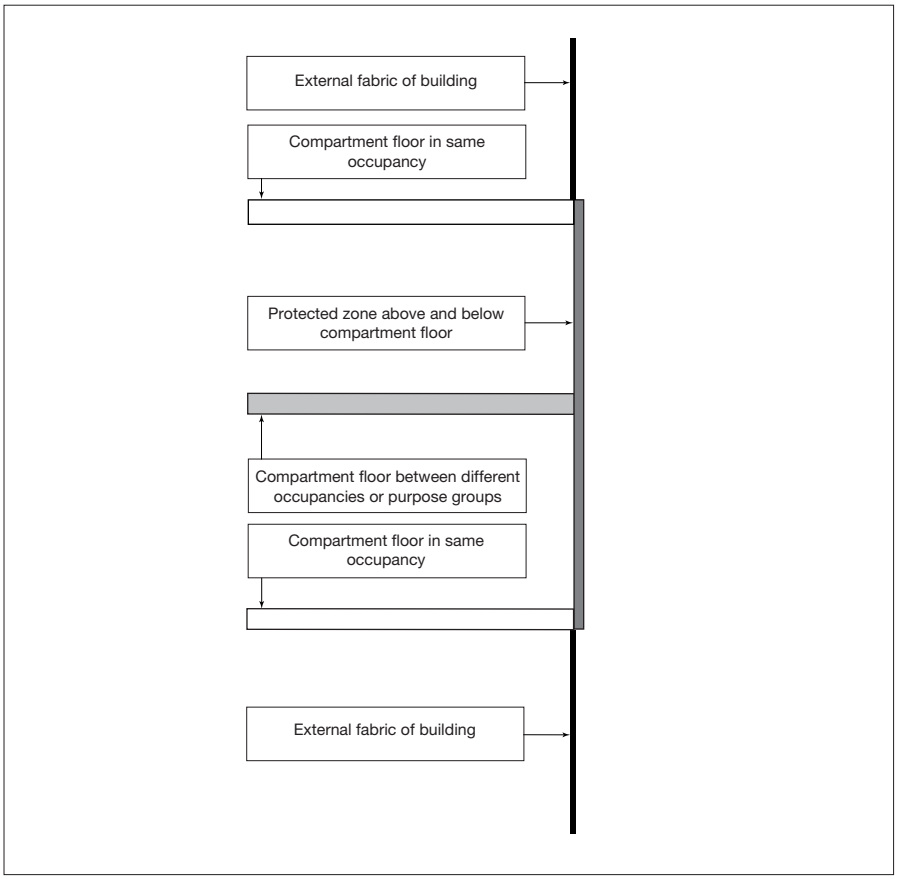


Figure 2.4: Protected zone in multi-storey building

Its findings will provide the fundamental information on which the design will be based. Close and early consultation with insurers is vital.

The risk assessment plays a key role in establishing the need for compartmentation within a building. It will be by involvement in, and with knowledge of, the findings of the risk assessment that the designer will gain fundamental information which will provide specific requirements for the design.

Compartmentation by design

Protection of a business and its assets demands adequate division and subdivision of buildings to achieve effective separation of:

- the potentially hazardous materials, features and processes therein; and
- high-value/business-critical areas.

This is achieved through:

- compartmentation by compartment walls and/or compartment floors intended to restrict both lateral and vertical spread of fire and/or smoke;
- provision of adequate fire resistance of all components, including supporting and attached structures, which give stability to compartmentation; and
- restriction of compartment size in accordance with recommendations in sector guides.

It is necessary to specify materials, products and systems that have been certified by a nationally accredited, independent third-party certification body acceptable to insurers. This usually means certification with a scheme which has UKAS accreditation. Installation and maintenance work should be carried out by an appropriately assessed and qualified competent contractor, who should ideally also have suitable third-party accreditation.

2.2 Compartmentation and the whole building

The scope of the present document was outlined in the Introduction. It aims to present advice for designers which covers the areas detailed below:

General requirements

Compartment walls/floors must provide fire resistance of a type and duration specified but are also required to achieve:

- longevity and robustness in use relative to the environment;
- resistance to cold smoke leakage;
- easy erection and maintenance without the need for excessive supervision; and
- stability under fire conditions in reaction with other building elements such as doors, glazing and services.

Behaviour of the whole building

Regardless of how well an individual element is designed and constructed and even, to some extent, how it is installed, prevention of fire spread can only be effective if the building itself behaves in a predictable manner. The interaction between the elements should not cause elements exposed to a fire to move and produce large gaps or to collapse prematurely. It is recommended that before a building is accepted as satisfying the compartmentation requirements, an analysis is made of the behaviour of the building as a whole. See 'The building as an entity', Appendix B.

Fire resistance

The following sections deal with the fire performance of compartment walls and floors. They identify where the performance of some walls and floors is more critical – for example, between separate purpose groups (occupancies) – and where performance can be relaxed because the implications of failure are less critical. The basic fire resistance ratings are given in tables in the appropriate sector guide.

Designers are likely to have access to their own sources of reference information. For specialist information about the likely fire resistance performance of passive fire protection (construction) materials and products, they may also wish to refer to the appropriate part of the FPA's website where there are data sheets which survey the broad types of products and systems and pay particular attention to the factor of fire resistance. See *www.thefpa.co.uk/Resources/Design+Guide.*

Fire integrity and insulation

The fire integrity and insulation of compartmentation can be compromised by the behaviour of adjacent elements of construction. It is vital, where any elements of lower or non-existent fire resistance adjoin or are adjacent to a compartment wall or floor, that adequate fire protection is provided to each

element involved. Guidance is given in section 3 on the methods of approaching the potential problems associated with the various elements and the interactions between them.

External spread of fire

The potential for fire spread externally via the roof, as well as between the top of elements of construction forming the compartmentation and the underside of the roof is also considered, and guidance is given to eliminate or reduce the risk of a fire bypassing the wall. The potential behaviour of roofs in fire may need to be improved. Certain constructional details such as eaves, junctions at roof lights and adequate protection of combustible materials will require special attention to avoid penetration of fire into the building.

Prevention of smoke spread

It is not possible to quantify the smoke tightness of compartment walls or floors, since a standard test procedure only exists for fire-resisting doorset assemblies. Since smoke damage is a major contributor to losses in the event of a fire, the qualitative smoke tightness of the elements of construction, methods of jointing and sealing of any penetrations for the passage of personnel, goods or services need to be carefully considered.

A number of recommendations are made throughout the *FPA Design guide* series for the need to adequately control and prevent the leakage of smoke, but in the absence of suitable test methods for walls and floors, for example, this is done by giving appropriate guidance. With respect to doorset and shutter assemblies, BS 476-31.1 provides for quantifiable leakage not exceeding $3m^2/h$ in respect of smoke at ambient temperature. An alternative test method is described in BS EN 1634-3: 2004 and classified according to BS EN 13501-2: 2003 ($20m^2/h$ for a single-leaf doorset or $30m^2/h$ for a double-leaf doorset at a test pressure of 50Pa).

Care also needs to be taken that materials specified for use should not generate large quantities of smoke, for example, on the unexposed face. For permeable materials, such as fibrous or open cell foams, their surfaces should be sealed by an impervious coating to prevent cold smoke leakage.

See appropriate sector guides for recommended fire resistance levels for compartment walls and floors.

Protection of openings and services

Consideration is given to designing the protection of openings and services in compartmentation in the *FPA Design guide: Protection of openings and service penetrations from fire*. The sections of direct relevance in that book are:

Section 2 – Fire-resisting and/or smoke control door and shutter assemblies:

- 12 – Fire-resisting glazing and glazed screens;
- 13.1 – Protection of ducts;
- 14 – Penetration seals; and
- 15 – Cavity barriers.

Section 3

COMPARTMENT WALLS: THEIR PURPOSE, FIRE RESISTANCE AND CONSTRUCTION

3.1 Compartment walls: purpose and function

A compartment wall is a loadbearing or non-loadbearing, vertical, fire-resisting, separating element of construction designed to contain a fire within an area for a predetermined duration in order to minimise the risk of lateral fire spread. It has the additional function of helping to resist the spread of fire into a building from an adjoining building or from outside. To fulfil its function, the wall shall be continuous to the floor or roof above and achieve the recommended level of fire resistance appropriate to the risk. (A compartment wall of 240 minutes fire resistance without openings or penetrations is what insurers may call a fire break wall. Such a wall may be required by an insurer in certain instances.)

An account of the types of compartment walls is provided in 3.2 but note that, while all compartment walls have the purpose of resisting the spread of a developed fire, their different locations in a particular premises may require different design approaches: see sections 4 and 5.

Within any compartment, further subdivision may be required to meet operational needs or insurers' recommendations. The need for such subdivision is likely to be identified as an outcome of the fire risk assessment. It may relate to a requirement to provide particular protection of areas containing critical business equipment, or areas of high risk or high value.

3.2 Compartment walls: fire resistance and construction

The following general recommendations relate to the construction of compartment walls. Throughout the period of fire resistance specified, the wall:

- should not permit the spread of flame and smoke through, over or around it;
- should maintain its integrity, insulation and, if appropriate, loadbearing capacity requirements (as specified in BS 476-20 to 23: 1987); and
- should not deflect in such a way as to compromise the level of separation. (It should be noted that fire resistance tests are carried out on a single element of construction. The effect of deflection of one element on another is not considered.)

In addition, compartment walls:

- should be constructed of materials which have longevity and are sufficiently robust to resist damage; and
- should be capable of being reinstated, following a fire, with minimum disturbance to the adjoining building(s).

3.3 Compartment walls enclosing hazardous areas

In addition to providing the recommended levels of fire resistance, compartment walls used in this application may, in fire conditions, suffer significant impacts from objects such as burning aerosol cans, which can hit wall surfaces at a significant velocity. It is imperative that the designer specifies only robust materials, such as masonry or concrete, for this application in order to prevent potential early breach of fire integrity. Other systems may be used if adequate evidence is available that they have significant impact to resistance.

Section 4

COMPARTMENT FLOORS: THEIR PURPOSE, FIRE RESISTANCE AND CONSTRUCTION

4.1 Compartment floors: purpose and function

A compartment floor is a horizontal, fire-resisting floor designed to contain fire within an area for a predetermined duration in order to minimise the risk of vertical fire spread. It will be bounded by fire-resisting elements of construction, such as compartment walls or external walls. The fire resistance of compartment floors can be compromised if the enclosure of any shaft (such as a lift or stairwell) is inadequately protected or if penetrations of compartment floors made for the passage of services (for example, pipes, cables etc) are not fire protected to the same standard as the floor.

All floors must have a degree of fire resistance because of the need to carry the load imposed by the contents, but this may be compromised if any penetration, edge junction or duct is not sealed to resist fire and smoke (see section 5.8, 'Protection of floor openings').

4.2 Categories of compartment floors: construction and fire resistance

The appropriate sector guide gives guidance on the levels of fire resistance required for each type of compartment floor.

General recommendations

The following general recommendations should be noted for consideration in the construction of all compartment floors:

- throughout the period of fire resistance specified, the floor should:
  - not deflect to the extent of compromising the compartmentation;
  - resist the spread of flame or smoke through or around the floor; and
  - maintain its loadbearing capacity and integrity, and satisfy the insulation criteria over all surfaces;
- the recommendations for the protection of any opening – for example, stair or lift shafts, ducts, conveyors, cable and pipe openings, edge junctions and similar features – are given in the following section; and
- the floor and any floor opening should be capable of reinstatement, following a fire, with the minimum interruption, particularly floors between different occupancies or purpose groups.

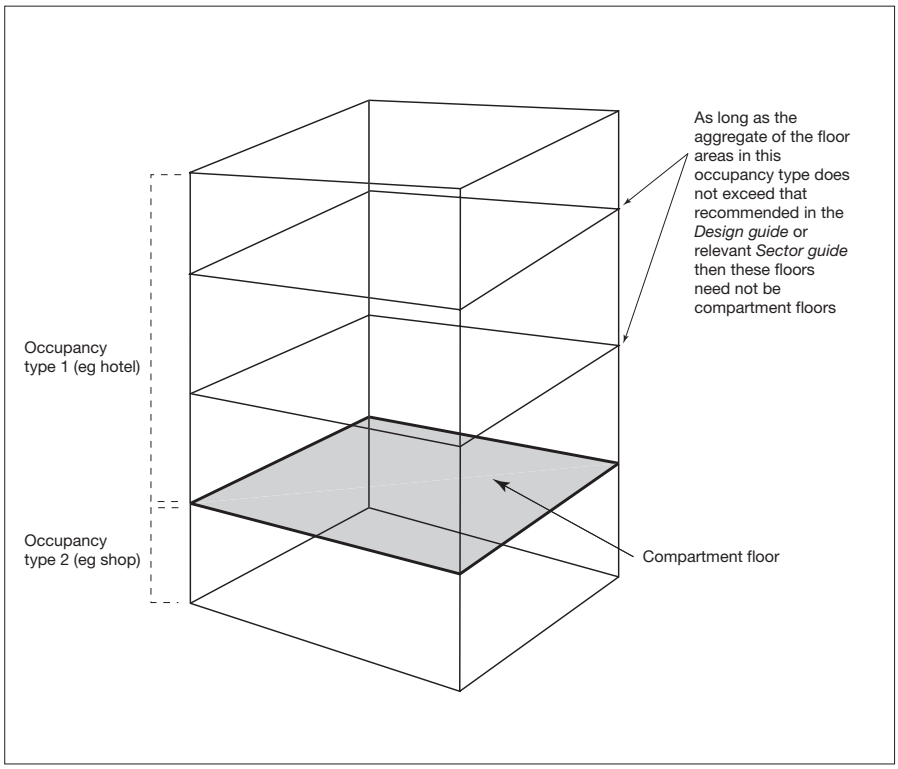


Figure 4.1: Compartment floor between different occupancy types (note: fire can spread from floor to floor via unprotected shafts)

Section 5
OPENINGS IN COMPARTMENTATION

5.1 Openings in compartment walls/floors

It is necessary for openings and penetrations in compartment walls and floors to be protected in such ways as to prevent the spread of fire and/or smoke. Each opening should be provided with a closure that at least maintains the required fire integrity of the compartment wall or floor (see the *FPA Design guide: Protection of openings and service penetrations from fire*).

5.2 Openings in walls for doors and services

Openings in walls are allowed, subject to compliance with the detailed requirements for openings specified in the *FPA Design guide: Protection of openings and service penetrations from fire* and with the following conditions: doors should not be provided in walls separating different occupancies unless unavoidable to provide adequate means of escape. In such cases, the doors should fully satisfy the requirements for fire resistance, insulation and smoke leakage cited in this section and in the above-mentioned volume in the FPA Design guide series:

- service openings should not be provided in walls separating different occupancies;
- openings in walls which separate areas within a premises in single occupancy may be protected by insulated or uninsulated doorsets or shutter assemblies depending on the outcome of a suitable risk assessment; and
- such doorsets and shutter assemblies shall be certified by an accredited, third-party certification body as reaching the performance requirements of an appropriate technical standard.

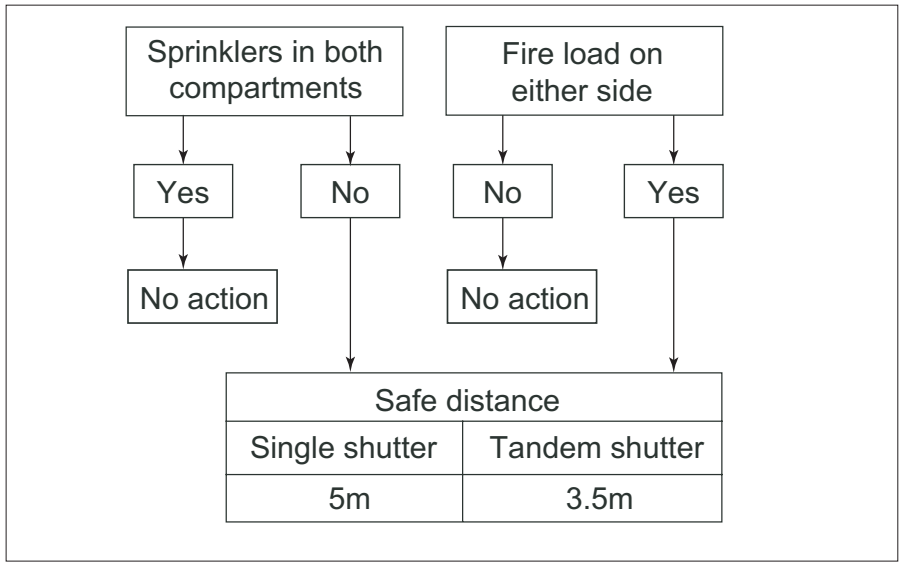


Figure 5.1: Gauging safe distance from an uninsulated door which separates two compartments in which combustible materials are stored. For further information, see section 3.1 of *FPA Design guide: Protection of openings and service penetrations from fire*

5.3 Uninsulated doorsets

Where uninsulated doors are used, the following should be considered in order of preference:

- full sprinkler protection of both compartments;
- the provision of a lobby, having an enclosure (walls and roof), with doors at each end of the lobby and providing a fire resistance not less than that for the compartment wall (the ability of doors in such an arrangement to provide the required fire resistance should be established by test or assessment); or
- a door assembly provided on each face of the compartment wall, which have been tested or assessed to give a combined fire resistance not less than the wall at the intended spacing, this spacing being greater than or equal to the thickness of the wall, as depicted in Figure 5.2.

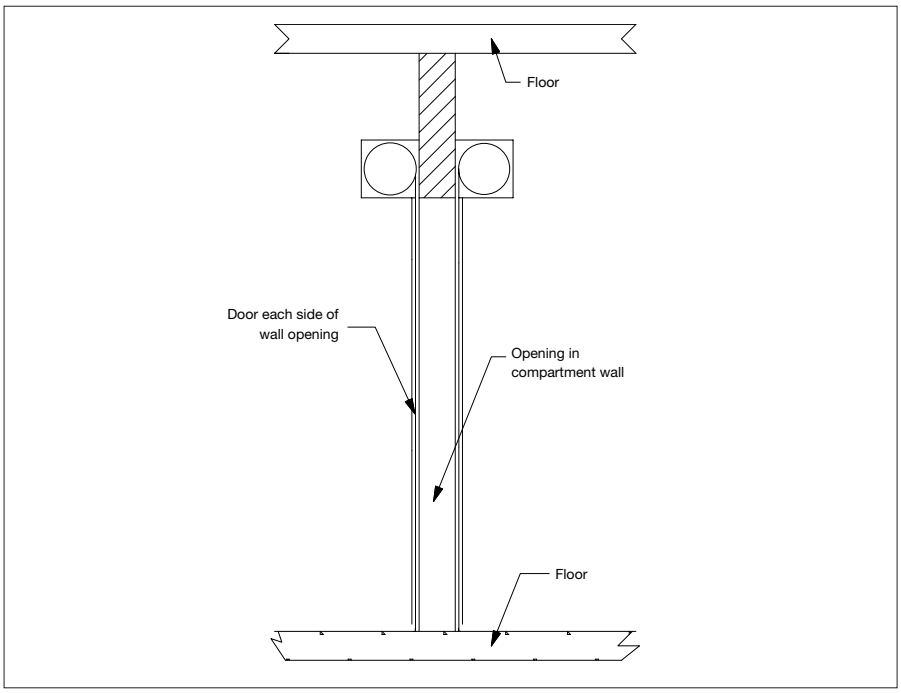


Figure 5.2: Door on each side of opening

In all cases, the creation of a clear zone on each side of the opening in which no combustible goods or fixed combustible materials will be placed is recommended (see Figure 5.3).

Further guidance is given in the *FPA Design guide: Protection of openings and service penetrations from fire.*

5.4 Smoke leakage

As far as possible, and particularly where the need is identified by the risk assessment, doors and shutters should comply with the smoke leakage requirements specified in section 5 of the *FPA Design guide: Protection of openings and service penetrations from fire*. The provision of a smoke-resistant lobby on one or both sides of the opening may be an acceptable alternative where the doors cannot satisfy the smoke leakage requirements. The enclosing walls and ceiling of such a lobby should be made of materials which:

- are non-combustible or of limited combustibility; and
- have demonstrated under appropriate test that they will not make a significant contribution to fire growth;

As an alternative to the above, where door assemblies do not have a smoke leakage rating, the addition of suitable smoke curtains may be considered.

5.5 Penetrations for services and ducts

The following should be observed:

- where openings for the passage of pipes, ducts or cables are needed to provide essential services, any service penetration shall maintain the integrity and insulation characteristics of the wall and the pipe, duct or cable should satisfy the insulation requirement for at least 150mm and preferably 500mm on either side of the compartment wall; and
- conveyor openings and openings for air distribution ducts should be given special attention where they pass through compartment walls and floors.

Reference should be made to the *FPA Design guide: Protection of openings and service penetrations from fire*, sections 13 and 14, in which appropriate guidance is given.

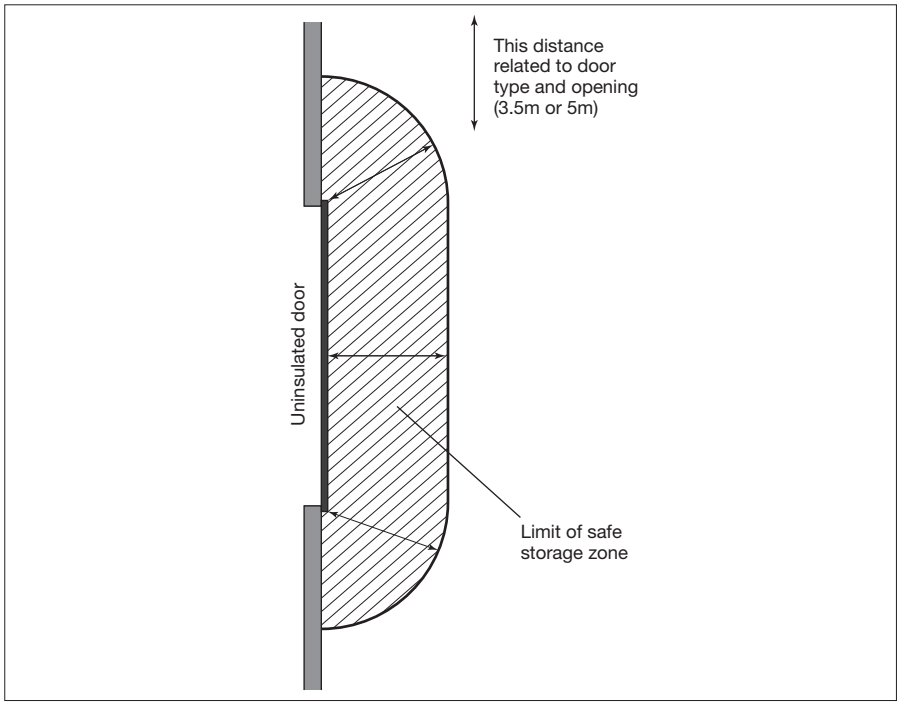


Figure 5.3: Method of defining radiation hazard zone

5.6 Glazed areas

The provision of glazed areas is permitted in compartment walls of Category 2 and in doors installed in compartment walls, subject to:

- the specified level of fire resistance being provided;
- compliance with LPS 1158 issue 2, or an equivalent standard for testing and third-party approval of fire-resisting glazing, subject to size or aspect ratio restrictions given in the *FPA Design guide: Protection of openings and service penetrations from fire*, Appendix C;

- the passage of smoke through the assembly or produced from the glazing itself being prevented for the period of fire resistance specified;
- care being exercised when considering extrapolation for different (non-test) sizes (see, for example, the conditions laid down in LPS 1158, issue 2 or an equivalent standard); and
- any doors containing glass should fall within the scope of an appropriate technical standard for test and evaluation and any test or assessment thereof shall have been made using the configuration and size of glass proposed.

5.7 Floor openings: fire resistance recommendations

Appropriate sector guides give guidance on the levels of fire resistance and insulation required for enclosures to floor openings and doors thereto.

These should be read in conjunction with the section on structural requirements (see section 7 of this design guidance) and the recommendations for the protection of floor openings in the following section should be noted:

- as far as possible, and particularly where the need is identified by the risk assessment, doors in vertical shafts should comply with the smoke leakage requirements specified in *FPA Design guide: Protection of openings and service penetrations from fire*, section 5;
- openings for escalators protected by escalator shutters should be surrounded on each upper level by a suitable non-combustible, insulated lobby able to restrict the passage of smoke. The provision of active fire protection may, in some circumstances, be deemed to be a suitable alternative to such an enclosure;
- conveyor and escalator openings and penetrations for the passage of pipes, cables etc. should be protected to the same standard as that required for shafts and ducts; and
- all pipes and cables are to be routed within fire-resisting service ducts that have been tested to EN 1366-5.

5.8 Protection of floor openings

The following should be observed:

- a duct which carries services through an opening in a compartment floor shall have fire resistance of not less than 50% of that of the compartment floor, subject to the provision of a fire barrier penetration sealing system having the same fire resistance as the duct (Figure 5.4 (a));
- if no fire barrier is provided, the duct should have equal fire resistance to the floor (Figure 5.4 (b));
- any services passing through a compartment floor which are not within a fire-resisting duct shall pass through a penetration sealing system which satisfies the requirements for integrity and insulation for the specified periods. The insulation criteria should additionally be satisfied for a distance of at least 150mm and preferably 500mm into the compartment above and 100mm into the compartment below (Figure 5.4 (c)); and

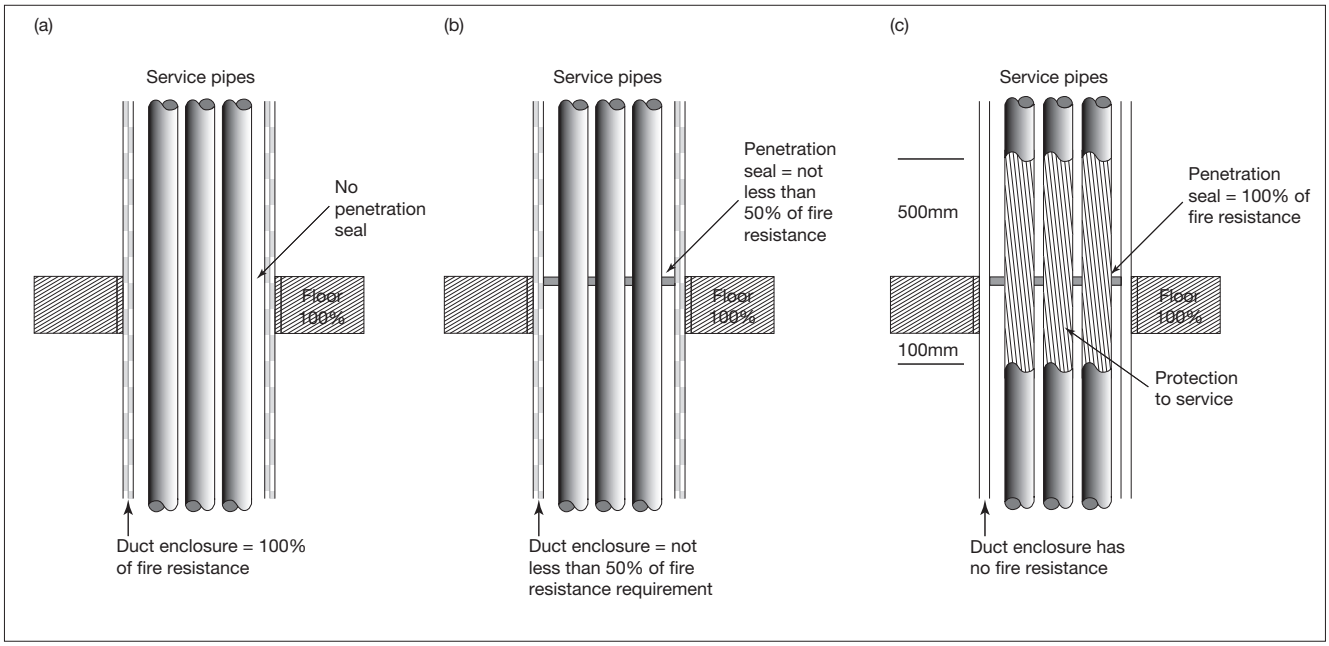


Figure 5.4: Service duct, with and without penetration seal around service pipes at the floor level

- the enclosure and the floor should be capable of reinstatement with the minimum of interruption after a fire.

The materials of construction should have longevity and be sufficiently robust to resist damage (see section 8.1).

Section 6

THE PROTECTED ZONE AND THE CONTROL OF EXTERNAL FIRE EXPOSURE HAZARDS

6.1 Preventing fire spread bypassing a compartment wall or floor externally

The capacity of a compartment wall or floor to resist the spread of fire can be nullified as a result of:

- the external wall collapsing and effectively leaving the compartment wall or floor unsealed; or
- the external wall being penetrated by a fire at, or close to, its junction with a compartment wall or floor, typically due to unsealed gaps or poor choice of external cladding. This will allow the fire to spread from one compartment to another (see Figure 6.4).

Guidance for compartment walls and floors is given below.

6.1.1 External walls: horizontal fire spread

In order to reduce the risk of horizontal fire spread, the external wall and subsidiary supporting frame and bracing on each side of the compartment wall should, within the protected zone:

- satisfy the integrity criterion (see BS 476-20 or BS EN 1363-1) (see Figure 6.4);
- provide insulation for not less than 15 minutes from inside to outside and, in addition, outside to inside, when tested to BS 476-22: 1987/BS EN 1364-1: 1999).

If part of the external wall is less than 1000mm from the relevant boundary, as defined in the documents supporting building regulations, higher levels of performance will be required (see Paragraph 13.3 and Table A2 of Approved Document B (ADB).

Relevant boundary

A boundary is of relevance to an external wall of a building if it coincides with that external wall or is parallel to it or is at an angle of not more than 80° to that side of the building.

Figure 6.5 provides guidance on the protection of the structural frame close to the compartment wall, this being required in order that stability is not compromised.

6.1.2 External walls: vertical fire spread

Knowledge gained empirically and from test evidence indicates that the risk of vertical fire spread is much reduced in buildings where each floor is sprinklered.

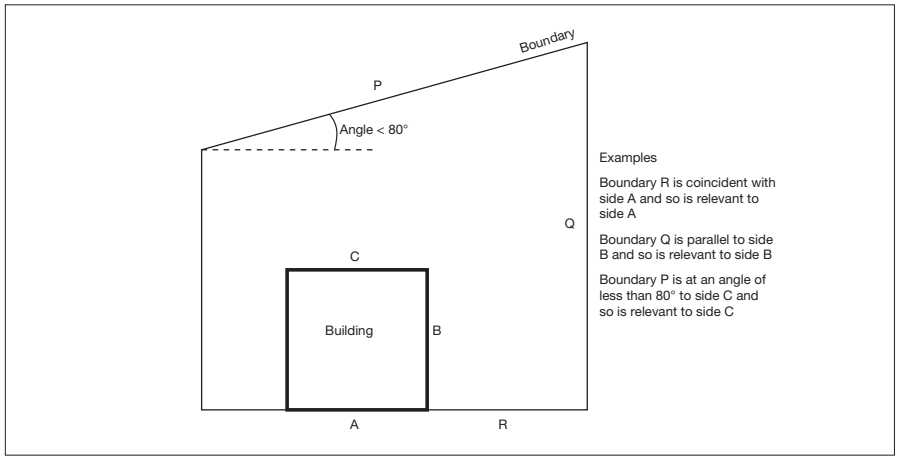


Figure 6.1: The relevant boundary

Where sprinklers are not installed it is sometimes difficult to build in measures that will prevent vertical fire spread via windows without substantially affecting the nature or aesthetics of a building.

It is important to assess the risk in order to identify whether additional protection, over and above what is specified for the protected zone, is necessary to overcome or reduce the potential threat to floors containing operations which are vital to the business.

6.1.3 Doors and other openings in external walls

No door or window in the external wall shall be located closer than 2.5m from either side of a compartment wall (see Figure 6.2).

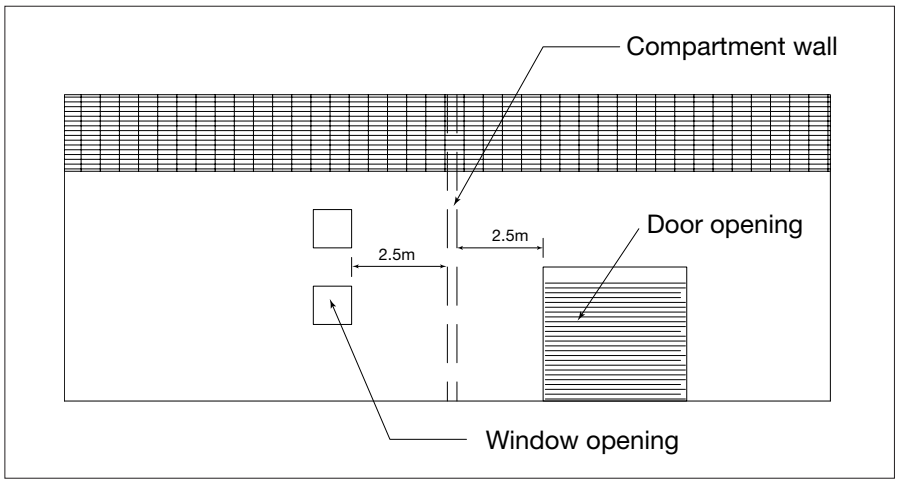


Figure 6.2: Openings in external walls – minimum distances from compartment walls

6.1.4 Roof lights

Unless they have fire resistance, roof lights shall not be located closer than 2.5m from any compartment wall.

6.2 Concept of the protected zone

Figure 6.3 depicts the protected zone, which comprises sections of the roof, external walls and supporting frame of a single-storey building (or, where applicable, multi-storey building) which are adjacent to and within a specified distance on each side of a compartment wall.

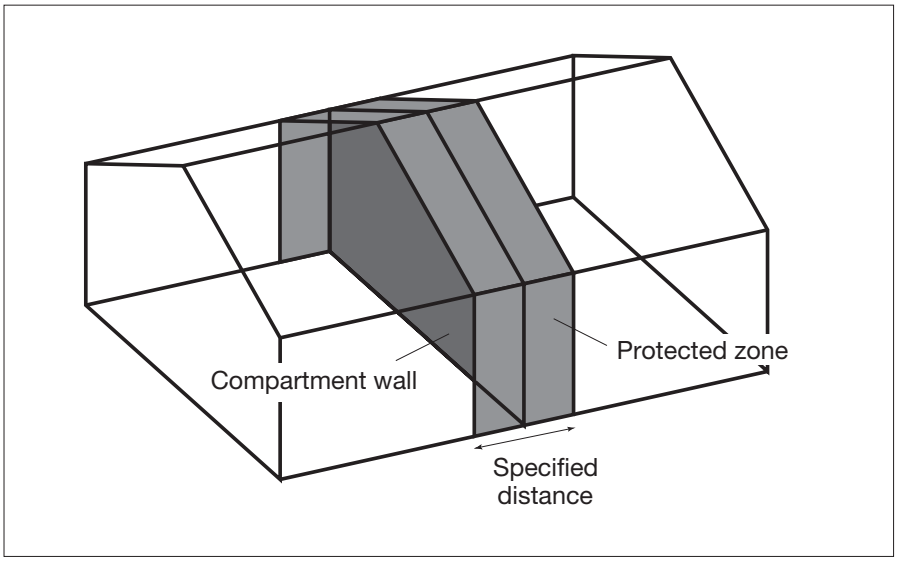


Figure 6.3: The protected zone

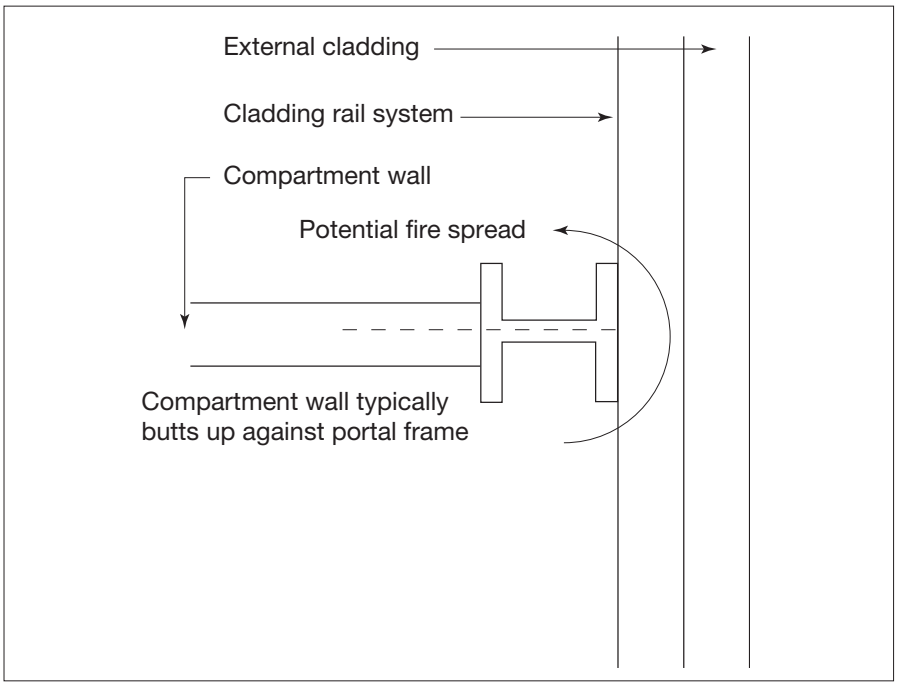


Figure 6.4: Within the protected zone, potential fire spread must be prevented

The purpose of the protected zone is to prevent fire from bypassing the compartment wall at a junction with an external wall or roof. In addition, the external wall should not collapse or allow the passage of fire to other parts of the building. The concept of the protected zone is illustrated in Figure 6.3, and Figure 6.4 shows how fire spread may be prevented within the protected zone. This is a feature to which the *FPA Design guide* attaches particular importance, principally in relation to single-storey buildings and for specific compartment floors in multi-storey buildings.

It is vital that walls, roofs and supporting frameworks, within a protected zone on one or both sides of a compartment wall, are provided with adequate fire resistance or alternative protection to prevent the early spread of fire from one side to the other.

6.3 The protected zone and fire resistance

A principal concern is to ensure that, at the junction between the wall, any structural member and the external cladding, no gaps are left that will allow the passage of fire, nor can such gaps develop. Any gaps will allow compartmentation to be breached.

The objective is to provide, at a junction of a compartment wall, structural frame and wall/roof, the same level of fire resistance as the compartment wall. Consideration should be given to the possibility of gaps opening because of deformation of any structural element and/or external cladding.

A possible solution is shown in Figure 6.5, with fire protection boards being used to improve the performance of the portal frame in a fire. The Z section is intended to minimise distortion of the external cladding at the compartment wall.

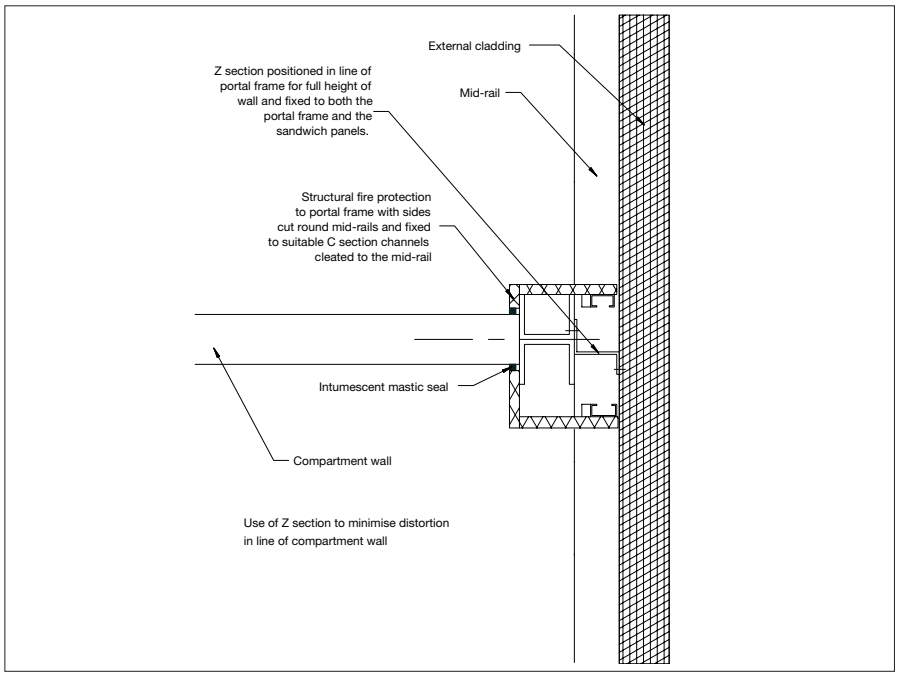


Figure 6.5: Steel framework is protected by fire-resisting boards. The Z section is fixed to the portal frame and external cladding to minimise distortion at the line of the compartment wall

An alternative solution is illustrated in Figure 6.6.

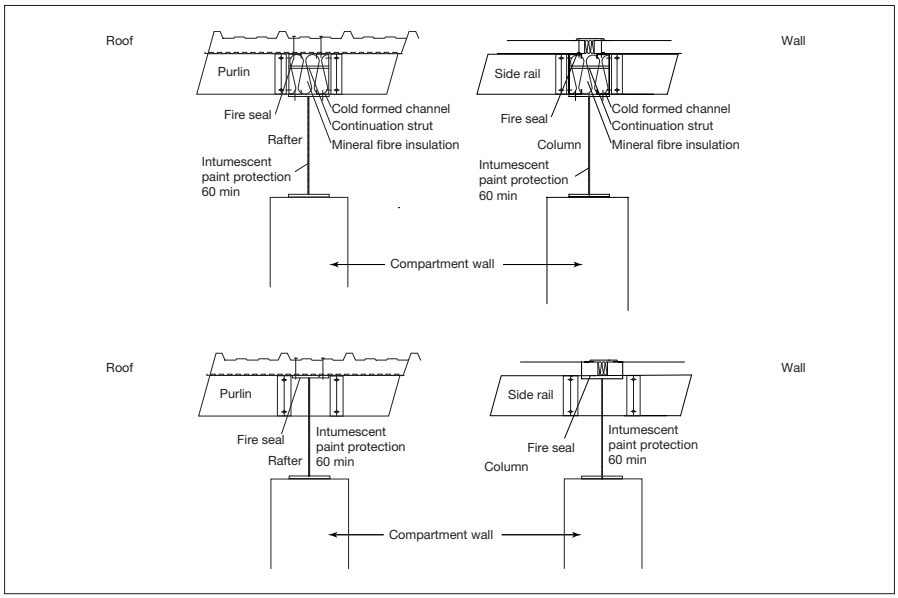


Figure 6.6: Alternative examples of compartment wall junction details

The examples in Figure 6.6 show the structural member protected by an intumescent coating having 60 minutes' fire resistance and this should be regarded as a minimum. This will be based on loadbearing capacity only and may not satisfy other requirements such as insulation.

6.4 Compartmentation: control of roof exposure hazard

6.4.1 General

This part of fire compartmentation deals with roofs that span over, or are supported on, compartment walls.

Earlier in this document there was emphasis on the need to carry out a risk assessment in order to help ensure that the assets of the business and its ability to continue trading are adequately protected. The possibility of fire spreading via the roof over a compartment wall must be considered as part of that risk assessment process.

Additionally, the review of the likely performance of the building as a single entity, as recommended in the preliminary pages and in section 2 (and see also Appendix B), will help to ensure that the protection of the structure and roof framework is adequate to prevent deflection and early collapse of a compartment wall.

Consideration must be given to the establishment of a protected zone on both sides of any compartment wall. It may be necessary to consider the provision of active fire protection – sprinklers, for example – where it is not practical to provide extensive passive protection to that part of the roof which is in the protected zone.

The extension of the compartment wall by a distance not less than 0.5m above the roof might be an acceptable solution in some instances. In all cases, attention to constructional detail is essential to ensure that all junctions of the roof with other elements of the building are properly fire-stopped.

6.4.2 Extent of the protected zone

The extent of the protected zone will vary according to the orientation of the compartment wall which it serves to protect. It shall extend not less than 2.5m from each side of the compartment wall. No openings and service penetrations whatsoever will be permitted in the protected zone.

6.4.3 Fire resistance of the protected zone: roof and framework

The level of fire resistance required within the protected zone will be dependent on the needs identified in the risk assessment. In some cases, for reasons of practicality, it may be necessary to consider a combination of active and passive protection. In all cases, it is essential that the roof and framework do not compromise the compartmentation and that a fire is prevented from bypassing the compartment wall.

Within the protected zone of the roof, the following protection should be considered:

- the roof and any subsidiary supporting framework within the protected zone, unless having at least 30 minutes' fire resistance, should be protected by a ceiling having fire resistance with integrity not less than 30 minutes and also satisfying the insulation requirements for at least 15 minutes. The provision of a roof comprising panels complying with grade not less than EXT. A15 of LPS 1181: Part 1 meets this requirement. In such cases, the

supporting purlins and any bracing members should have a fire resistance in respect of loadbearing capacity of not less than 30 minutes (alternatively, it may be considered that the provisions within 2.3(a) requiring bracing of the wall to the structural frame will prevent distortion and subsequent deflection of the wall);

- requirements for the protection of the portal frame where it is incorporated in the compartment and external walls are described within sections 3.1 and 3.5;
- a fire exposure rating of EXT AA when tested to BS 476-3/ LPS 1505*;
- if the roof is supporting plant, it shall have the fire resistance specified in the appropriate sector guide (documents supporting building regulations may also make requirements concerning the fire resistance of a roof and its supporting structure in some limited circumstances – for example, when the roof is part of the means of escape);
- roof lights should not be provided within the protected zone unless they have at least 30 minutes' fire resistance in terms of integrity; and
- roof vents should not be provided in the protected zone.

The parts of the roof outside the protected zone should be constructed of materials which:

- are non-combustible or of limited combustibility; or
- shall have demonstrated under an appropriate test that they will not make a significant contribution to fire growth (for example, LPS 1181: Part 1 EXT B); and
- have a fire exposure rating of EXT AA when tested to BS 476-3/LPS 1505*.

** LPS 1505, whilst currently in draft form, will maintain the flame spread requirement of BS 476-3 when that test is replaced by the EN standard which uses the penetration test only.*

6.4.4 Other protection measures for roofs

A lattice-framed roof requires detailed attention to fire-stopping where it spans a compartment wall. In such a specific location, it should have equal fire resistance to that required for the wall in terms of loadbearing capacity, integrity and insulation. The following should be observed:

- where the compartment wall is built up to the underside of a portal frame, any gap between the top of the frame and the roof deck should be fire-stopped to the same standard of fire resistance as the wall in terms of integrity and insulation;
- where the wall is built up to the underside of the roof deck, any gaps should be filled by a system to the same standard of fire resistance as the wall in terms of integrity and insulation;
- in every case where internal ceilings are provided, the compartment wall must pass through the ceiling and be sealed to the underside of the roof deck or covering;
- experience from actual fires has shown that fire can enter a roof space through soffit ventilation gaps. Any soffit ventilation incorporated in

a roof which overhangs the external wall is vulnerable to penetration by flames rising up the external wall. Such flames may originate from an external fire at ground level or from a flame or hot gas plume breaking out from non-fire rated windows in the facade below. Ideally, ventilation should be provided by means of ventilated roof tiles above the eaves. Partially protected vents set in the fascia or down-facing vents in the soffit boards should generally not be used, although they may be acceptable if the soffit boxes and any thermal insulation in the roof space are comprised of non-combustible materials and the roof is sub-divided by robust cavity barriers; and

- fascia or soffit boards should ideally be constructed from non-combustible materials. Plastic fascias or soffits are not recommended, but timber may be used provided it is not less than 19mm thick.

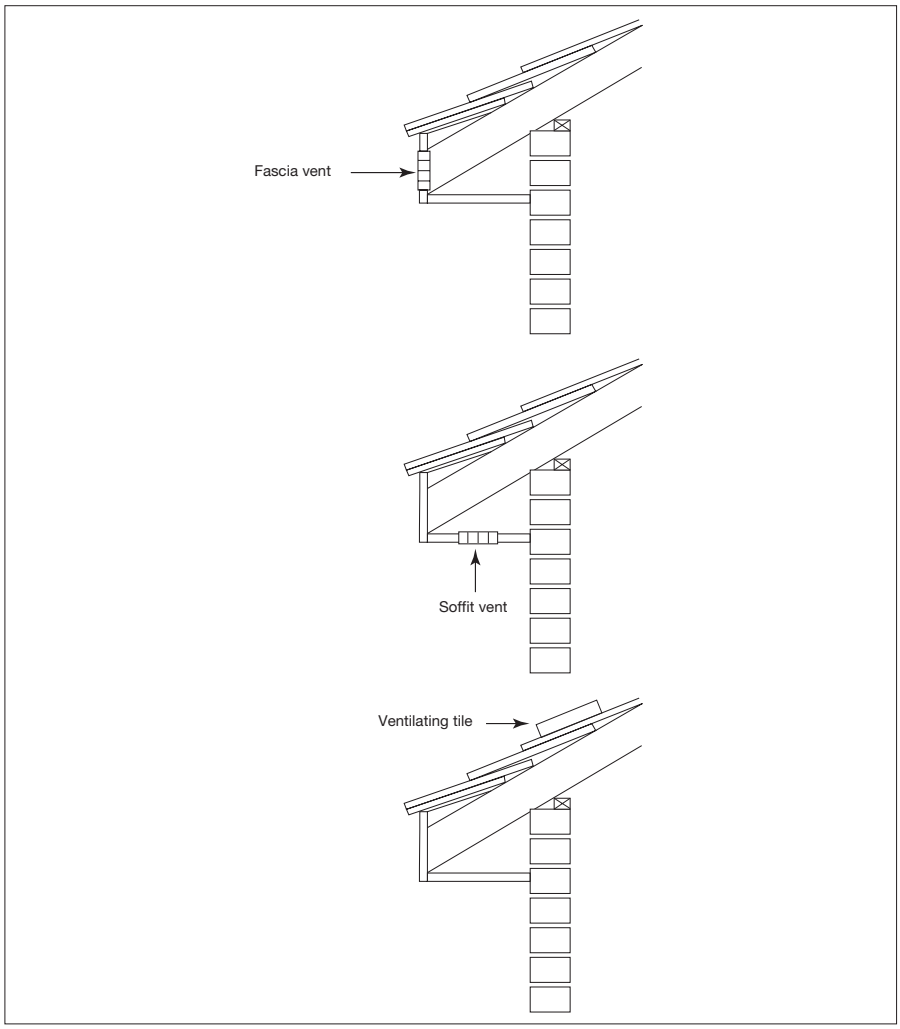


Figure 6.7: Alternative methods of ventilating pitched roofs

Section 7

THE STRUCTURAL FRAME AND THE PART IT PLAYS IN MAINTAINING COMPARTMENTATION

7.1 Structural frame

If damage is to be restricted in the event of a fire it is important that the structural frame of a building – which comprises all the elements of construction required to support the dead load of the building itself and the imposed design loads associated with the building's use – performs its design function (Essential Principle 3). The structural frame may therefore include columns, beams, floors and walls.

7.2 Fire behaviour of the building

For single-storey buildings, the requirement is for the maintenance of compartmentation (Essential Principle 1).

For multi-storey buildings, the requirements are both the prevention of building collapse (Essential Principle 3) and the maintenance of compartmentation (Essential Principle 1).

7.2.1 Prevention of building collapse

The loadbearing elements of structure should maintain their loadbearing capacity under fire conditions in order to prevent the premature collapse of the building. In some types of building, local failure of a loadbearing element can cause progressive structural collapse leading to complete destruction of the building.

The level of fire resistance required for loadbearing elements of structure is effectively a function of building size and fire load. For tall buildings, the periods of fire resistance required are higher due to the potentially more serious consequences of collapse of part or all of the building structure.

7.2.2 Maintenance of compartmentation

Loadbearing elements of the structure may support or even form part of the compartment walls or compartment floors that enclose compartments. Where such elements form part of the wall, or floor, they should not compromise the level of separation and under fire attack they, together with any associated construction, should satisfy the integrity and insulation requirements of BS 476-21 or BS EN 1365-1 to the levels recommended in this Design guide appropriate to the element, as well as loadbearing capacity.

It is important that, under fire exposure, the thermally induced deflections experienced by the loadbearing elements, either supporting or local to the fire compartment, do not disrupt the compartmentation by causing failure of the compartment walls or floors or by causing excessive gaps to open up between the appropriate elements of structure.

To accommodate a degree of thermally induced deflection (see section 7.2.7), loadbearing elements of the frame should be provided with adequate levels of fire resistance either as a feature of the basic design or, in the case of a building alteration, by the application of suitable additional fire protection.

7.2.3 Protection to aid reinstatement post-fire

By providing loadbearing elements of construction with an appropriate level of fire resistance, the time and costs involved in reinstating a building after a fire may be reduced. Inadequate protection of loadbearing elements of construction is likely to result in large deflections of the structural frame, both locally to the fire compartment and throughout the rest of the affected building. Large residual deflections after a fire would render most building structures unusable and fit only for demolition; prudent measures taken at the design stage to aid protection of the structural frame may mitigate the effects of fire on the building itself and on adjacent premises.

Appendix B gives information about the behaviour of different building materials in a fire.

7.2.4 Design and construction of the structural frame

The following should be observed:

- the fire resistance of elements forming the structural frame, whether separating or not, shall be specified with respect to the criteria of BS 476-21: 1987 or the appropriate part of BS EN 1365 (the test procedures for determining the fire resistance of loadbearing elements);
- the structural frame should have a fire resistance not less than that of the compartment walls or compartment floors in order that it will not compromise the fire compartmentation;
- the frame should not distort so as to cause gaps to develop between elements of construction that may compromise the compartmentation; and
- the interaction between the elements and the frame should not cause failure of the compartmentation.

The following sections give guidance on how the frame should be designed and constructed to ensure that the required performance is obtained.

7.2.5 Establishing the level of fire resistance

The minimum fire resistance requirements for loadbearing elements of construction are given in this section. Where a fire engineered solution is used in the design of a building then it will have been achieved through the efforts of a qualitative design review (QDR) carried out by a team of people analysing the fire safety objectives. The recommendations of the appropriate sector guides continue to apply unless the solution achieved by fire safety engineering takes into account other measures which are, for example, accepted by an insurance representative who is on the QDR team.

If a loadbearing element supports a compartment wall or compartment floor then, in the event of fire, it should be capable of supporting the load for the period of fire resistance stated in the appropriate sector guide without the resulting deflections compromising the compartmentation (see Appendix B for detailed guidance).

If a loadbearing element of construction is common to more than one compartment (that is, forms part of a compartment wall), then the fire resistance required by the element should be the greater (or greatest) of the fire resistances determined for each of the compartments that the element divides.

7.2.6 Junction between separating elements and beams and floors

If compartments are enclosed by loadbearing compartment walls and loadbearing compartment floors, the transfer of load from one element to another under fire conditions is possible. Such features shall be designed to ensure that such load transfer can be accommodated by the adjacent structure. If non-loadbearing compartment walls are used, load transfer from a deflecting compartment floor construction or beam could cause disruption of the non-loadbearing element and lead to a premature integrity failure.

Where non-loadbearing compartment walls may be subjected to transferred vertical loads as a result of fire in compartments above, it is important:

- to ensure that adequate clearance is provided between the soffits of floors and beams and the tops of any non-loadbearing compartment walls over which they pass;
- to provide higher levels of fire resistance to the loadbearing floors or beams than those required in the appropriate sector guide in order to reduce the anticipated/calculated degree of deflection; or
- to use protected loadbearing columns to support the flexural element, thereby restricting its deflection at the non-loadbearing compartment wall location.

These three concepts are shown in Figure 7.1.

7.2.7 Clearance for differential movements

Where clearance is being provided to accommodate differential movements between loadbearing elements and other components, then – as a rule of thumb – a clearance of span/30 should ideally be allowed mid-span of the flexural element to accommodate thermally induced deflections, the span being the length of the flexural element between supports. As a minimum, the deflection at mid-span of a beam should be taken as not less than span/100. This clearance can be reduced proportionately at locations remote from the mid-span location of the flexural element. The clearance gap should be adequately fire-stopped (see recommendations given in the *FPA Design guide: Protection of openings and service penetrations from fire*).

Similarly, where a non-loadbearing compartment wall abuts a loadbearing compartment wall or column, deflection of the loadbearing element could disrupt the non-loadbearing wall. As a rule of thumb, a minimum clearance of height/40 should be allowed at mid-height of the loadbearing element to accommodate any lateral thermally induced deflections, where 'height' is equal to the vertical height between the upper and lower end fixings of the loadbearing element.

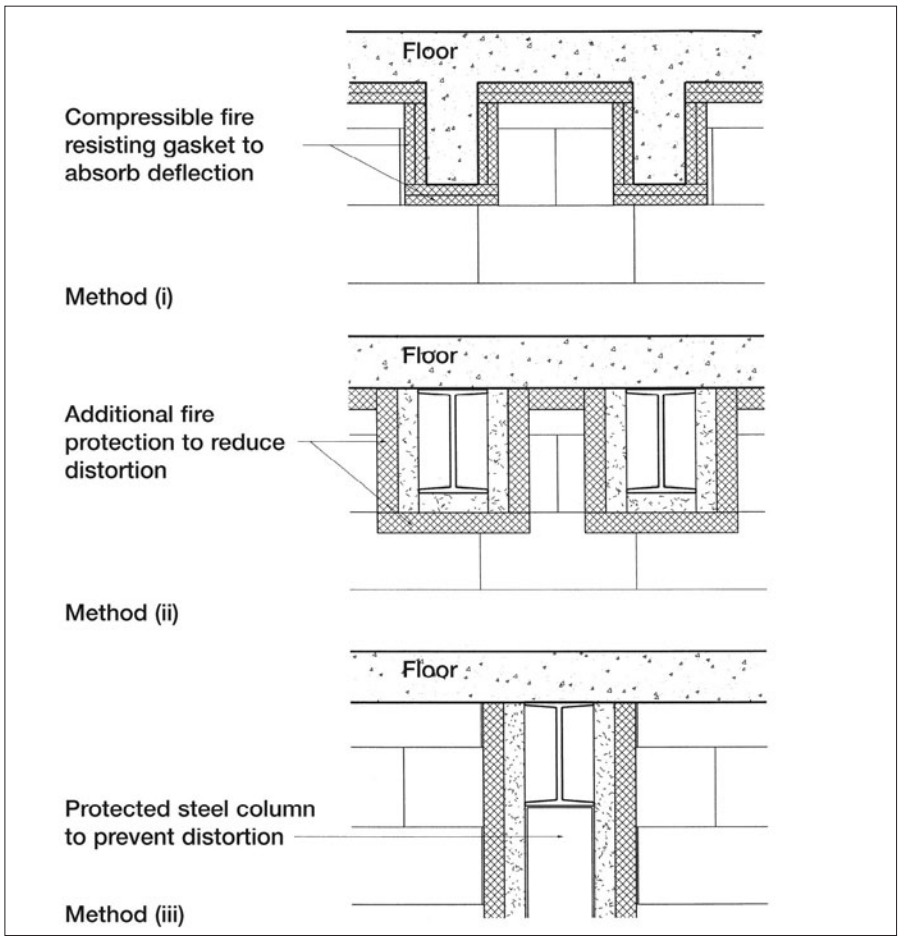


Figure 7.1: Accommodating or preventing distortion of floor between supports

7.3 Specific structural details

The details given below are particularly applicable to single-storey buildings where collapse of the roof or structural frame tend to lead to premature collapse of any compartment wall unless adequate compensatory features are incorporated.

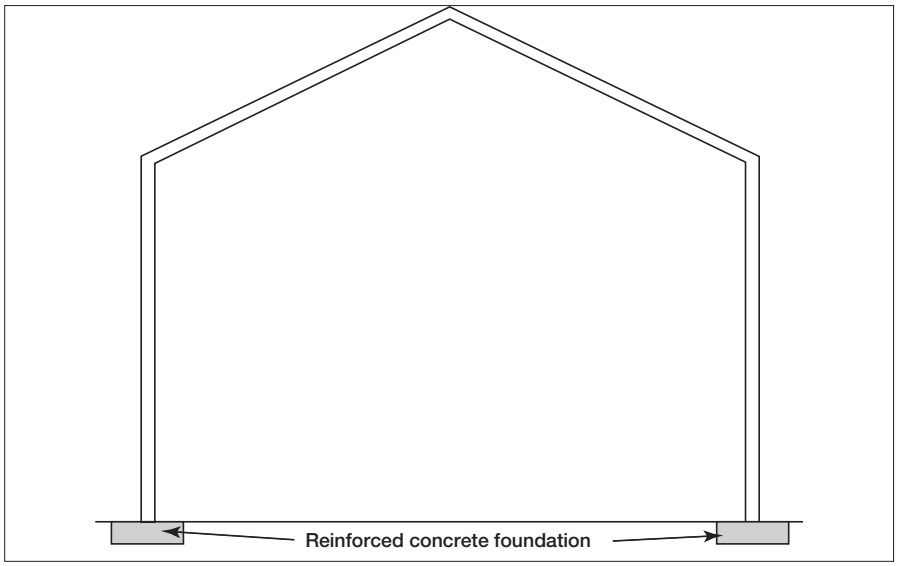


Figure 7.2: Typical steel portal frame profile. At their bases the stanchions may be fixed (see Figure 7.3) or pinned or partially fixed (see Figure 7.4)

7.3.1 Interactions between walls and portal or lattice frames

There are no fire resistance requirements for portal or lattice frames if the frames do not affect the fire stability of the compartment wall(s).

7.3.2 Compartment wall infilling between portal or lattice frame stanchions

Where a compartment wall infills between portal or lattice frame columns in a building and runs at right angles to the span, the columns of portal or lattice frames should be protected to provide the same level of fire resistance as the wall construction.

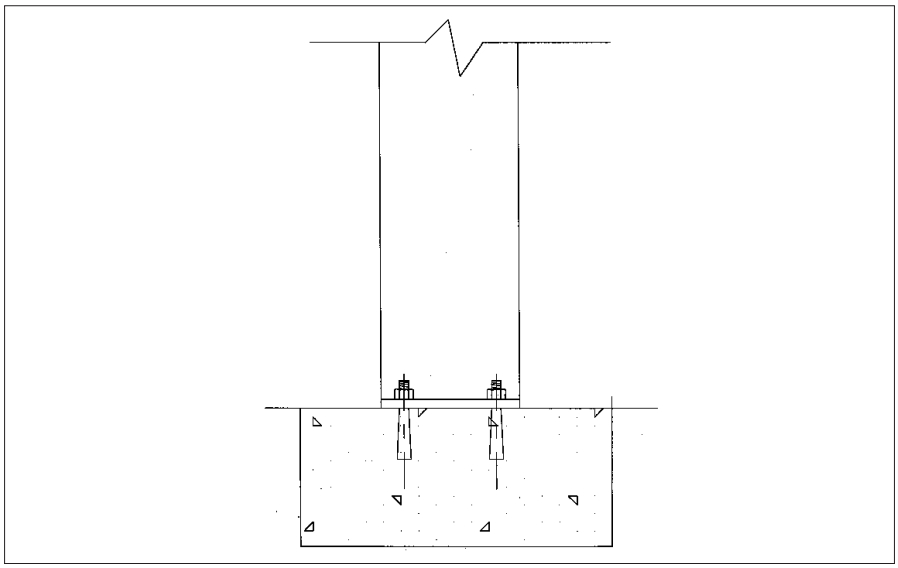


Figure 7.3: Fixed end of steel frame upright

Where the portal or lattice frame uprights have fixed bases (see Figure 7.3):

- the infill wall construction between the columns may then be of brickwork, concrete, brickwork or dry wall construction;
- masonry walls should be restrained laterally at the head by means of ties attached to horizontal framing members protected to the same fire resistance level as required for the compartment wall; or
- in the case of frames with lower levels of restraint, for example, pinned or partially fixed bases (see Figure 7.4):
  - the infill wall should be of masonry construction;
  - if a plastic damp proof course is provided at the bottom of the wall (Figure 7.5), then in a fire it will allow the wall to tilt from the base rather than break half way up; and
  - masonry walls should be laterally restrained at the head (see Figure 7.5), by means of ties attached to horizontal framing members fixed back to the portal or lattice frame columns and protected to the same level of fire resistance as required for the compartment wall.

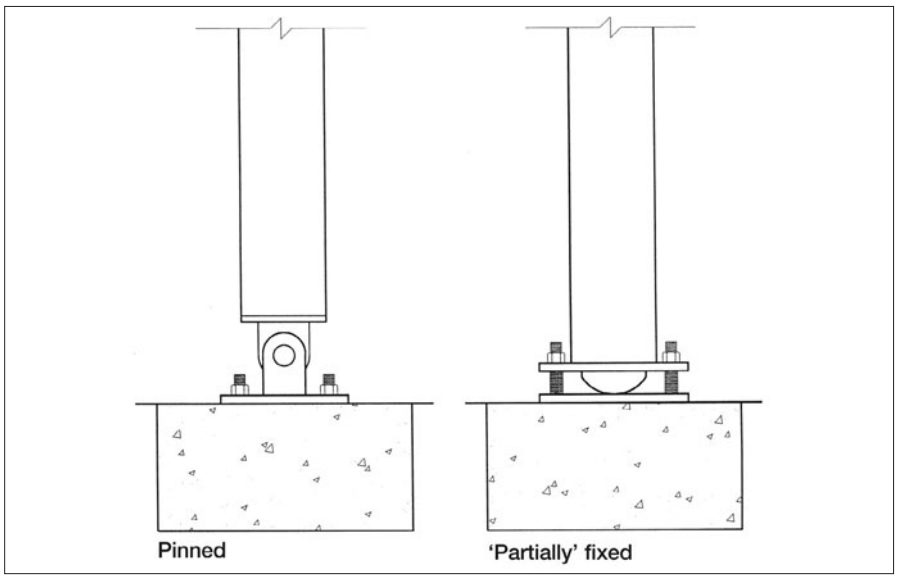


Figure 7.4: Details of portal frame base connections, pinned and 'partially' fixed

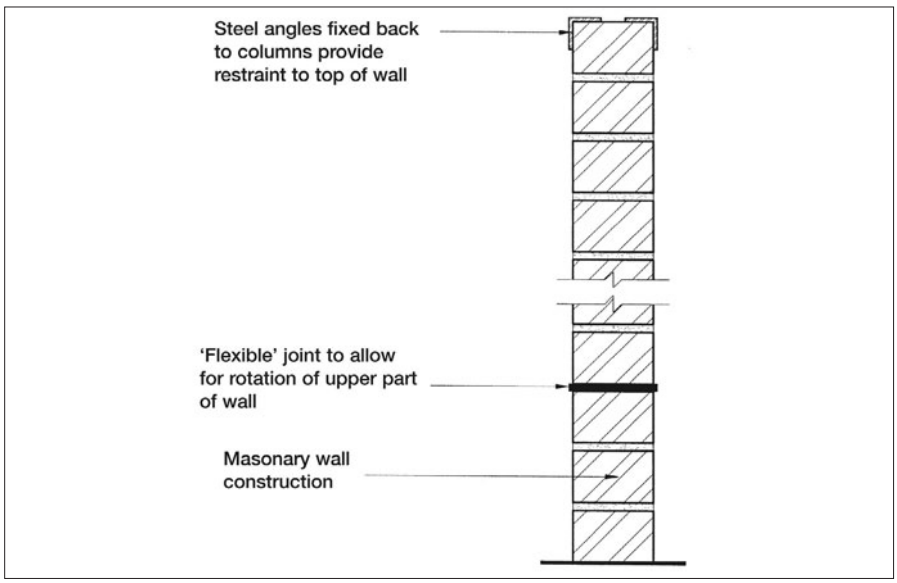


Figure 7.5a: Method of restraining masonry wall

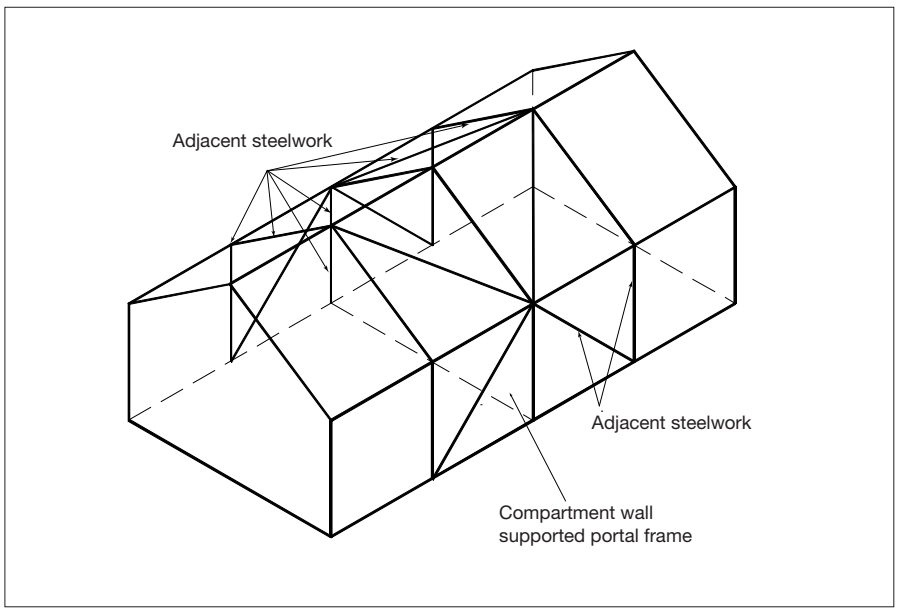


Figure 7.5b: Compartment wall supported by portal frame and adjacent steelwork

7.3.3 Compartment walls running parallel to portal or lattice frames

If compartment walls run parallel to the span of a portal or lattice frame:

- where a compartment wall is built up to the underside of a portal or lattice frame, such framing should have the same level of fire resistance as that required for the compartment wall;
- at the wall/roof junction fire-stopping should be applied if necessary to maintain the continuity of fire resistance;
- portal or lattice frames on each side of the wall – together with the connecting lateral beams and any secondary roof supporting structure which is important to the stability of the wall spanning between those portal or lattice frames – should be protected to the same level of fire resistance as the compartment wall (see Figure 7.5b above) (steel sections having an Hp/A ratio greater than $260m^{-1}$ may not be able to be economically protected to the same standard); or
- the compartment wall should be designed to have sufficient loadbearing capacity in order to resist any overturning moment applied by the roof construction if fire causes the portal or lattice frames on one side to collapse; or
- a section should be designed into the roof construction or supporting members, adjacent to the point where the roof spans or bears on the compartment wall, which has adequate strength in the cold state, but which is weaker in the 'hot' state so that collapse of the roof on the fire side minimises the potential for failure of the compartment wall. A possible method is illustrated in Figure 7.6 below.

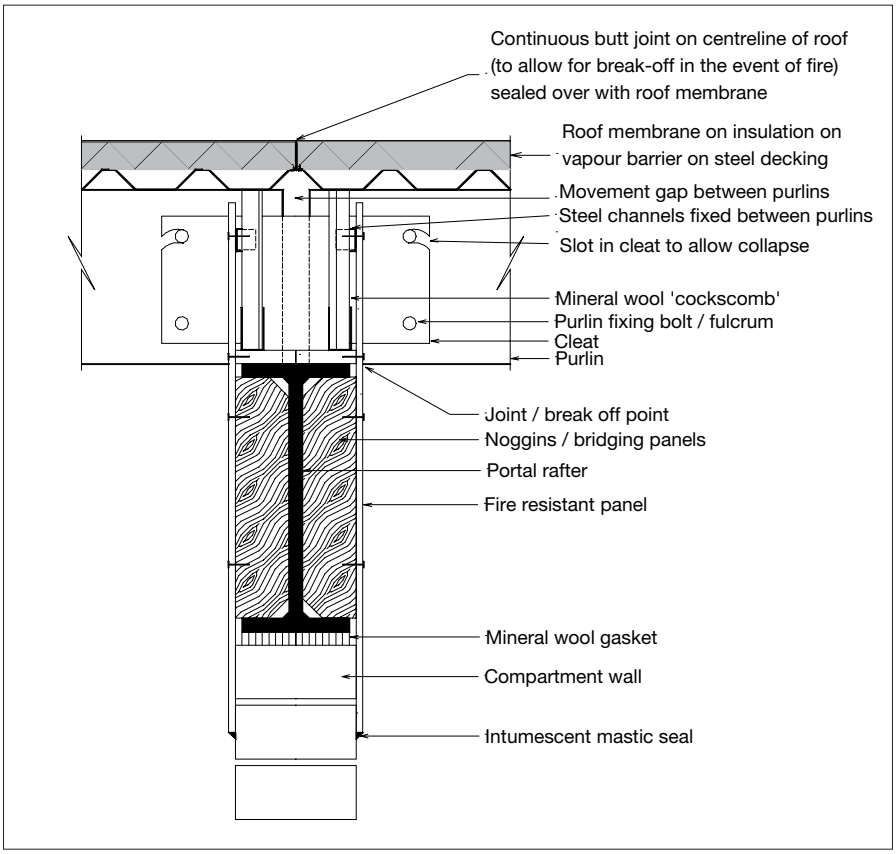


Figure 7.6: Example of hot-state collapse mechanism

7.3.4 Comb connections

This is a connection design, which transmits only minor reaction forces to the fire wall in case of failure of the connected unprotected beam. This type of connection is characterised by open slotted holes. The open slotted holes enable the failing beam to slide out of the connection without damaging the fire wall. To avoid thermally induced restraining forces, the slots are elongated, enabling thermal elongation of the connected beam during the heating process (see Figure 7.7).

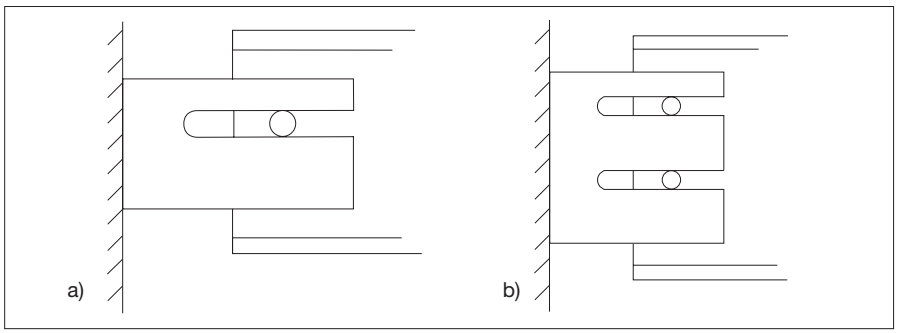


Figure 7.7: Comb connections

The torsional loadbearing capacity of comb connections is not sufficient to provide torsional support. As a result, the lateral torsional buckling capacity of the beam is reduced significantly if no restraint of the rotation at the comb connections is provided.

7.3.5 Combination of pull-off connections and comb connections

Both design concepts can be combined (see Figure 7.8).

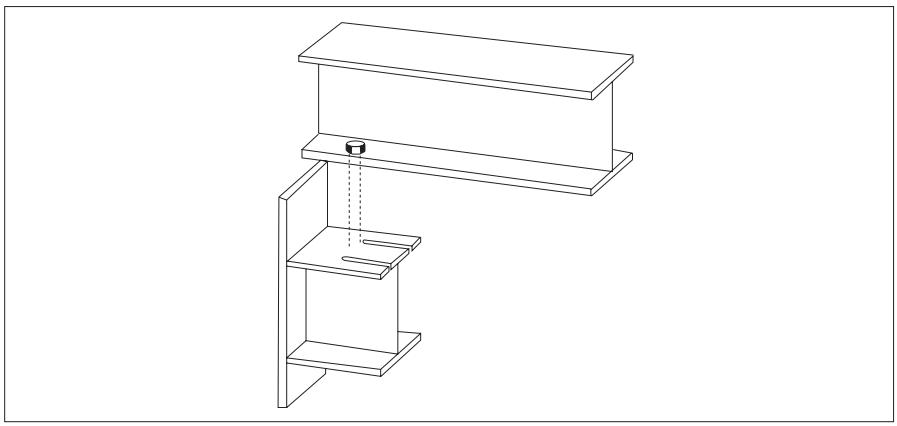


Figure 7.8: Combination of maximum tensile resistance of bolts and comb connection

This type of connection allows the beam to slide off the bracket for load cases involving movement which is perpendicular to the fire wall. For a load case involving rotation a bending moment is activated, which is limited by the maximum tensional loadbearing capacity of the bolts.

Section 8

MATERIALS AND THEIR BEHAVIOUR IN A FIRE

8.1 Robust materials

The following table gives some guidance on robust materials that could he used for compartment walls and floors to give sufficient resistance to impact and other mechanical damage, subject to them conforming to the relevant standard of fire resistance.

PRODUCT DESCRIPTION	DIMENSIONS
Brick and blockwork	Density not less than 600kg/m^2 and not less than 100mm thick (subject to a slenderness ratio (thickness/height) not less than 0.025)
Studs	
Timber	> 47mm x 89mm softwood > 400kg/m^2
Steel	> 50mm x 150mm mild steel channel or Z section – 1mm thick
Joists	
Timber	> 471mm x 225mm softwood > 400kg/m^2
Steel	> 70mm x 250mm mild steel – 1mm thick
Boards/linings	
Gypsum-based	
Plasterboard	19mm thick as a single layer
Plasterboard	12mm thick as part of a multiple layer
Reinforced plasterboard	15mm thick as a single layer
Reinforced plasterboard	10mm thick as part of a multiple layer
Glass-reinforced Gypsum	12mm thick as a single layer
Glass-reinforced Gypsum	9mm thick as part of a multiple layer
Calcium silicate-based	
Flexural strength (dry) 5-7.5 (N/mm^2)	15mm as a single layer
Flexural strength (dry) 5-7.5 (N/mm^2)	10mm as part of a multi-layer system
Flexural strength (dry) Above 7.5 (N/mm^2)	12mm as a single layer
Flexural strength (dry) Above 7.5 (N/mm^2)	9mm as part of a multi-layer system
Composite boards	
Gypsum-based chipboard	15mm as a single layer
Gypsum-based chipboard	10mm as part of a multi-layer system
Cement-based chipboard	12mm as a single layer
Fire-resisting glazing	
Wired glass (fire and safety)	6mm
Laminated fire-resisting glass	12mm thick or greater
Solid fire-resisting monolithic glasses	10mm thick or greater
Glazing installed behind permanent screen protection	(See Approved Document N, Building Regulations 2000)
Metal-faced insulated panels	Steel faced mineral wool panels. Density of mineral wool not less than 100kg/m^3 and a minimum thickness of 100mm Thickness of steel not less than 0.7mm

8.2 Passive fire protection products and installation standards

All passive fire protection products falling within the scope of this document shall be subject to certain measures relating to their specification and installation, since they are the subject of a number of the *Design guide's* essential principles, in particular:

- building materials should be used which will not make a significant contribution to a fire at any stage of its growth (Principle 2);
- a building's structure should be designed to have resistance to collapse or excessive deflection in the event of a fire (Principle 3); and
- the building should be constructed in such a way as to minimise the extent of fire and smoke damage in the event of fire (Principle 10).

These are supported by two other principles:

- only third-party certificated fire protection products should be specified (Principle 5); and
- competent, specialist installers should be commissioned to fit fire protection products/systems (Principle 6). (Installers shall be third-party certified to install the specific product/system when an appropriate scheme is available – for example, FIRAS or LPCB).

Even the best and safest of designs will be undermined if inappropriate or substandard products are used; or if the products and systems are properly specified but the standard of installation and workmanship is inadequate or unsupervised.

The *Design guide's* associated construction design and product performance data sheets – which give generic information about the performance of types of passive fire protection products and systems – are available via the FPA website: *www.thefpa.co.uk/Resources/Design+Guide.*

Some trade associations publish advice about such products and installation standards and reference could be made to documents produced by the Passive Fire Protection Federation, the Association for Specialist Fire Protection and the Steel Construction Institute, as well as those of other organisations which are listed in the references.

It is important that the designer has confidence in products which are specified for the building under design and it is also vital that the standard of installation matches the quality and purpose of the products.

GLOSSARY OF TERMS

The following explanations apply to terms used in this publication.

Assessment

An opinion of the likely performance of a component or element of structure if it were to be subjected to a standard fire resistance test. (See PFPF *Guide to undertaking assessments in lieu of fire tests.*)

Building services

Services supplied or collected by pipes, ducts and cables, such as water, gas and electricity, air conditioning, heating, communications, drains etc.

Cavity barrier

A fire-resisting barrier, not less than 100mm high, installed in a ceiling or floor void or roof space, that is able to provide the required fire resistance (and other) requirements of this guidance, as appropriate. (For the purposes of this *Design guide*, cavity barriers are not permitted above compartment walls.)

Compartment floor

A horizontal, fire-resisting floor designed to contain fire within an area for a predetermined duration in order to minimise the risk of fire spread.

Compartment wall

A loadbearing or non-loadbearing vertical fire-resisting wall designed to contain a fire within an area for a predetermined duration in order to minimise the risk of fire spread. (Insurers formerly referred to a compartment wall of 240 minutes' fire resistance as a fire-break wall.)

Compartmentation

The division of a building into fire-resisting compartments, comprising one or more rooms, spaces or storeys, by elements of construction designed to contain a fire for a predetermined duration.

Competent contractor

An installation company which is approved/certificated under a recognised third-party installer scheme.

Cotton pad criterion

During testing described in the BS 476-20 series, one measure involves the use of cotton wool pads which are placed in the vicinity of the non-fire side of the product or joint which is being tested. The time taken for ignition of the pad may contribute to determining whether or not the product/joint passes the test.

Doorset

A complete, factory-produced door unit, comprising the frame, the door leaf itself, architrave and hardware. A door frame may or may not include a stop, but it should not be seen as a separate component. In the UK, many doors are now double swing and do not have a stop. Consequently, they rely on correctly set door closers to maintain the doors in a closed position when exposed to a fire.

Double door (doors in tandem)

In the context of this design guidance, this refers to the use of two or more door assemblies in series – that is, in tandem – in order to provide increased fire resistance with respect to one or more criteria (for example, reduction in radiation if uninsulated).

Elements of construction

This term covers: structural framework, walls (internal and external), floors, roofs, stairs and enclosures to floor openings.

In this design guidance it is given a slightly broader meaning than in some official guidance. It includes, for example, the roof of a building, a feature not covered by the definition of the similar term 'element of construction' in Approved Document B to the Building Regulations.

Direct field of application

Rules in a published standard that allow for slight changes to the tested product without the need to apply an expert judgement. Simple assessments can be assumed to fit within this definition.

Evidence of performance

Evidence in the form of a result of an appropriate fire test, performed in a laboratory approved by the United Kingdom Accreditation Scheme (UKAS), for carrying out the test, or from an assessment by a suitably qualified and competent body that demonstrates that the construction satisfies the relevant criteria and, in the case of a fire-resisting element, maintains performance for a suitable duration.

Extended field of application

An expert technical evaluation of the likely performance of an element of structure if it were subjected to a standard fire resistance test. Such an assessment would be undertaken using the appropriate CEN EXAP standard and established engineering principles. Complex assessments can be assumed to fit within this definition.

Fire-break wall

A term formerly used by insurers to describe an imperforate compartment wall with at least 240 minutes' fire resistance, used to separate different occupancies within a building or to separate two buildings. Note: no fire resistance level above 240 minutes is recognised within the European classification system.

Fire engineered solution

A design in which the performance of the building or its elements of construction has been established in a quantitative way which takes into account all relevant factors and is in accordance with proven or published methodology (see BS 7974-0).

Fire engineering

See *Fire safety engineering.*

Fire hazard

A source or situation which has the potential to cause a fire.

Fire integrity

See Integrity.

Fire load

Fire load is the sum of the individual calorific values of the materials used in the construction of the building and of the building contents.

Fire resistance

Often cited in terms of a length of time, fire resistance is the ability of a building material or an element of construction, in a fire:

- to continue to bear a certain load for that length of time without failure or deflection;
- to prevent fire passing from one compartment to another for that duration; or
- both of the above.

Various test criteria exist under the different parts of BS 476 in relation to the fire resistances of different building materials/elements for varying applications.

Fire-resisting doorset or shutter assembly

A doorset or shutter assembly, of any design and construction which, when tested to methods 6, 7 or 8 given in BS 476-22: 1987 or when tested to BS EN 1634-1, provides the specified level of fire resistance and any other requirements of this section of the *Design guide*, as appropriate to its design and use. The doorset or shutter may be insulated or uninsulated.

Fire-resisting duct

A duct used for the distribution of air that, when tested to BS 476-24: 1987 (ISO 6944: 1985) or BS EN 1366-1, provides the required fire resistance and other requirements of this design guidance. Note: BS EN 1366-1 is technically a better standard than BS 476-24.

Fire risk

The product of the probability of fire occurring and the magnitude of the consequences of that fire.

Fire safety engineering

The application of scientific and engineering concepts to the design and construction of a building so that the building will satisfy the fire safety demands placed on it in relation to its size, layout, use and location.

Fire-stopping

A seal designed and tested to make good any imperfections in fit such that the required fire resistance of the wall or floor, in terms of integrity, and insulation if appropriate, is maintained.

Flexural element

A beam or loadbearing floor that is subjected primarily to bending stresses.

Hp/A ratio

This is the ratio used to express the rate at which steel members absorb heat from their environment, expressed in 'per metre' units. It is the ratio of the heated perimeter, Hp, to the area of cross-section, A, of the steel member. Steel hollow sections with a low Hp/A ratio respond more slowly to heat and so have a longer duration of fire resistance.

Height of building

This depends on the type of building and the roof configuration. For guidance, see Diagram C3 of Appendix C to Approved Document B to the Building Regulations (accessible via *www.communities.gov.uk* and follow links to 'Building Regulations – Documents and publications').

Insulated door

Insulated doors can typically be either of timber construction, generally up to 60 minutes' fire resistance, or of a timber-faced, and possibly lipped, mineral-cored and/or framed construction, or be of an insulated steel-faced flush door or a metal-framed stile and rail construction incorporating insulating glass. The performance of an insulated door is evaluated via the procedures of clause 6 of BS 476-22 or BS EN 1634-1.

Insulation

The ability of an element of construction to restrict the transfer of heat from the fire side to the non-fire side of the element (BS 476-20 or BS EN 1363-1).

Integrity

The ability of an element of construction to restrict the spread of fire, smoke and combustion gases from the fire side to the non-fire side of the element (BS 476-20 or BS EN 1363-1).

Masonry

Masonry elements are constructed from bricks or blocks made from fired clay, concrete with class 1 or class 2 aggregates or aerated concretes with densities between 480 and 1800kg/m^2.

Material of limited combustibility

For the purposes of this *Design guide*, a material of limited combustibility is:

- any non-combustible material;
- any material of density 300kg/m^2 or more which, when tested to BS 476-11, does not flame and for which the rise in temperature on the furnace thermocouple is not more than 20°C;
- any material with a non-combustible core at least 8mm thick having combustible facings (on one or both sides) not more than 0.5mm thick (where a flame spread rating is specified, these materials should also meet the appropriate test requirements); and
- any material of density less than 300kg/m^2 which, when tested to BS 476-11, does not flame for more than 10 seconds and for which the rise in temperature on the centre (specimen) thermocouple is not more than 35°C and on the furnace thermocouple is not more than 25°C.

Non-combustible

A material may be considered to be non-combustible if it satisfies the requirements for non-combustibility when tested in accordance with BS 476-4 and 11 – that is, it does not flame and there is no rise in temperature on certain specified test thermocouples.

Occupancy

In this guidance, occupancy refers to a building or buildings which are occupied by the same company irrespective of the purpose group or groups which may be involved.

Occupancy type

See *Purpose group*.

Penetration seal

A system for sealing any void in a compartment wall or floor through which building services pass which, when tested to EN 1366-3, provides the integrity and insulation requirement specified in this design guidance.

Purpose group

In this guidance, purpose group refers to the principal purpose of and activity within a building or part of a building, and also to adjoining building(s). May also be known as occupancy type.

Occupancy

A building or part of a building in one ownership or tenancy.

Qualitative design review

A process which establishes the fire safety objectives for a building under design, as part of a fire safety engineering analysis, and is normally carried out in a multi-disciplinary team.

Relevant boundary

A boundary is a boundary of relevance to an external wall of a building if it coincides with that external wall, is parallel to it or is at an angle of no more than 80° to that side of the building.

Self-closing device

A device or mechanism, attached to or part of a fire-resisting doorset or shutter assembly, which provides a return to the closed position. Rising butt hinges are not permitted.

Smoke-resistant lobby

An enclosure built around an opening in a compartment wall or floor, incorporating smoke control doors, which has been constructed to prevent the flow of smoke from one compartment to another.

Structural frame

The structural frame of a building comprises the elements of construction required to support the dead load of the building itself and the imposed design loads associated with the building's use. The structural frame may therefore include columns, beams, floors and walls.

Third-party certification body

In the UK, the national accreditation body is the United Kingdom Accreditation Service (UKAS); the Loss Prevention Certification Board (LPCB) is an example of a third-party certification body.

Uninsulated door

An uninsulated door does not possess the ability to restrict the rise of temperature on the non-fire side of the door which, would result in fire being transmitted only when integrity fails. That is, it does not restrict the passage of conducted and radiated heat in the manner of an insulated door.

REFERENCES

British and European standards

BS 476:		*Fire tests on building materials and structures*
	Part 4: 1970	*Non-combustibility test for materials*
	Part 7: 1997	*Method of test to determine the classification of the surface spread of flame of products*
	Part 11: 1982	*Method for assessing the heat emission from building materials*
	Part 21: 1987	*Methods for determination of the fire resistance of loadbearing elements of construction*
	Part 22: 1987	*Methods for determination of the fire resistance of non-loadbearing elements of construction*
	Part 23: 1987	*Methods for determination of the contribution of components to the fire resistance of a structure*
	Part 24: 1987 ISO 6944: 1985	*Method for determination of the fire resistance of ventilation ducts*
	Part 31.1: 1983	*Methods for measuring smoke penetration through doorsets and shutter assemblies. Method of measurement under ambient temperature conditions*
BS EN 1363 Part 1: 1999		*Fire resistance tests. General requirements*
BS EN 1364 Part 1: 1999		*Fire resistance tests for non-loadbearing elements. Walls*
BS EN 1365		*Fire resistance tests for loadbearing elements*
	Part 1: 1999	*Walls*
	Part 2: 2000	*Floors and roofs*
	Part 3: 2000	*Beams*
	Part 4: 1999	*Columns*
BS EN 1366		*Fire resistance tests for service installations*
	Part 1: 1999	*Ducts*
	Part 2: 1999	*Fire resisting dampers*
	Part 3: 2004	*Penetration seals*
	Part 4: 2006	*Linear gap seals*
	Part 5; 2003	*Service ducts and shafts*
	Part 7: 2004	*Conveyor systems and their closures*
BS EN 1634		*Fire resistance tests for door and shutter assemblies*
	Part 1: 2000	*Fire doors and shutters*
	Part 3: 2004	*Smoke control doors and shutters*
BS 5234 Part l: 1992		*Partitions (including matching linings). Code of practice for design and installation*

BS 5268		*Structural use of timber*
	Part 4.1: 1978	*Recommendations for calculating fire resistance of timber members*
	Part 4.2: 1990	*Fire resistance of timber structures. Recommendations for calculating fire resistance of timber stud walls and joisted floor constructions*
BS 5588	Part 12: 2004	*Fire precautions in the design, construction and use of buildings. Managing fire safety*
BS 5628	Part 2: 2005	*Code of practice for use of masonry. Structural use of reinforced and pre-stressed masonry*
BS 5950	Part 1: 2000	*Structural use of steelwork in building. Code of practice for design. Rolled and welded sections*
BS 7974: 2001		*Application of fire safety engineering principles to the design of buildings. Code of practice*
BS 8110	Part 1: 1997	*Structural use of concrete. Code of practice for design and construction*
BS EN 12845: 2004		*Fixed firefighting systems. Automatic sprinkler systems. Design, installation and maintenance*
BS EN 13501		*Fire classification of construction products and building elements*
	Part 1: 2002	*Classification using test data from reaction to fire tests*
	Part 2: 2003	*Classification using data from fire resistance tests, excluding ventilation services*
	Part 3: 2005	*Classification using data from fire resistance tests, fire resisting ducts and fire dampers*

Fire Protection Association publications

Fire risk management in the workplace, 3rd edition, Adair Lewis and William Dailey, 2006.

FPA Design guide: Protection of openings and service penetrations from fire, 2005.

FPA Design guide: Protected zone, 2004.

FPA Design guide: Food processing factories, Part 1. Design principles, 2004.

LPC Rules for automatic sprinkler installations, incorporating BS EN 12845, 2003.

Loss Prevention Certification Board publications

List of approved fire and security products and services (annual).

Loss Prevention Standards

LPS 1158, issue 2: *Requirements and tests for fire-resisting glazing systems.*

LPS 1208 Issue 2:1 September 2005: *LPCB Fire resistance requirements for elements of construction used to provide compartmentation.*

LPS 1181: Part 1: Issue 1.1: *Series of fire growth tests for LPCB approval and listing of construction product system: Requirements and tests for built-up cladding and sandwich panel systems for use as the external envelope of buildings.*

LPS 1181: Part 2: Issue 2.0: *Series of fire growth tests for LPCB approval and listing of construction product systems: Requirements and tests for sandwich panels and built-up systems for use as internal constructions in buildings.*

LPS 1181: Part 4: Issue 1: *Series of fire growth tests for LPCB approval and listing of construction product systems: Requirements and tests for external thermal insulated cladding systems with rendered finishes (ETICS) or rain screen cladding systems (RSC) applied to the face of a building.*

LPS 1182: Issue 2: 1994: *Requirements and tests for LPCB approval of fixed fabric smoke curtains, fixed metal smoke curtains and powered smoke curtains.*

Official documents

The Building Regulations 2000, Approved Document B, Fire safety, Volume 2, Buildings other than Dwelling Houses (2006 edition).

The Building Regulations 2000, Approved Document N, Glazing – safety in relation to impact opening and cleaning, 1998 (amended 2000).

Publications from trade associations and other groups

Ensuring best practice for passive fire protection in buildings, Association for Specialist Fire Protection (ASFP), 2003.

Fire protection for structural steel in buildings, 4th edition, ASFP (with Steel Construction Institute/Fire Test Study Group), 2007.

Fire and smoke resisting dampers, ASFP, 2007.

Fire resisting non-loadbearing partitions, ASFP, 2007.

Fire stopping and penetration seals for the construction industry, ASFP, 2007.

Fire resisting ductwork, ASFP, 2007.

Guide to demonstrating the performance of passive fire protection products, Passive Fire Protection Federation, 2004.

Guide to undertaking assessments in lieu of fire tests, Passive Fire Protection Federation, 2000.

Ensuring best practice for passive fire protection in buildings, Association for Specialist Fire Protection, 2003.

A guide to best practice in the specification and use of fire-resistant glazed systems, Glass and Glazing Federation.

The IFSA code: Sealing apertures and service penetrations to maintain fire resistance, Intumescent Fire Seals Association.

GAI Code of practice, building hardware for fire-resisting doors and doorsets, Guild of Architectural Ironmongery and Door & Hardware Federation.

Code of practice for fire resisting metal doorsets, Door and Hardware Federation.

Best practice guide to timber fire doors, Architectural & Specialist Door Manufacturers Association, 2002.

Appendix A: Risk assessment: the principles

Far too often, industrial and commercial buildings are designed and constructed with no considered thought given to an assessment of the hazards, including fire hazards, which may be introduced into the buildings by their occupiers. All too rarely do the designer, the occupier and the insurer manage to sit down together at an early stage to consider the matter, let alone carry out a risk assessment.

Risk assessment is, of course, an aspect of planning, and one which designers should be able to take in their stride. The importance of carrying out such an assessment cannot be over emphasised, since the establishment of property

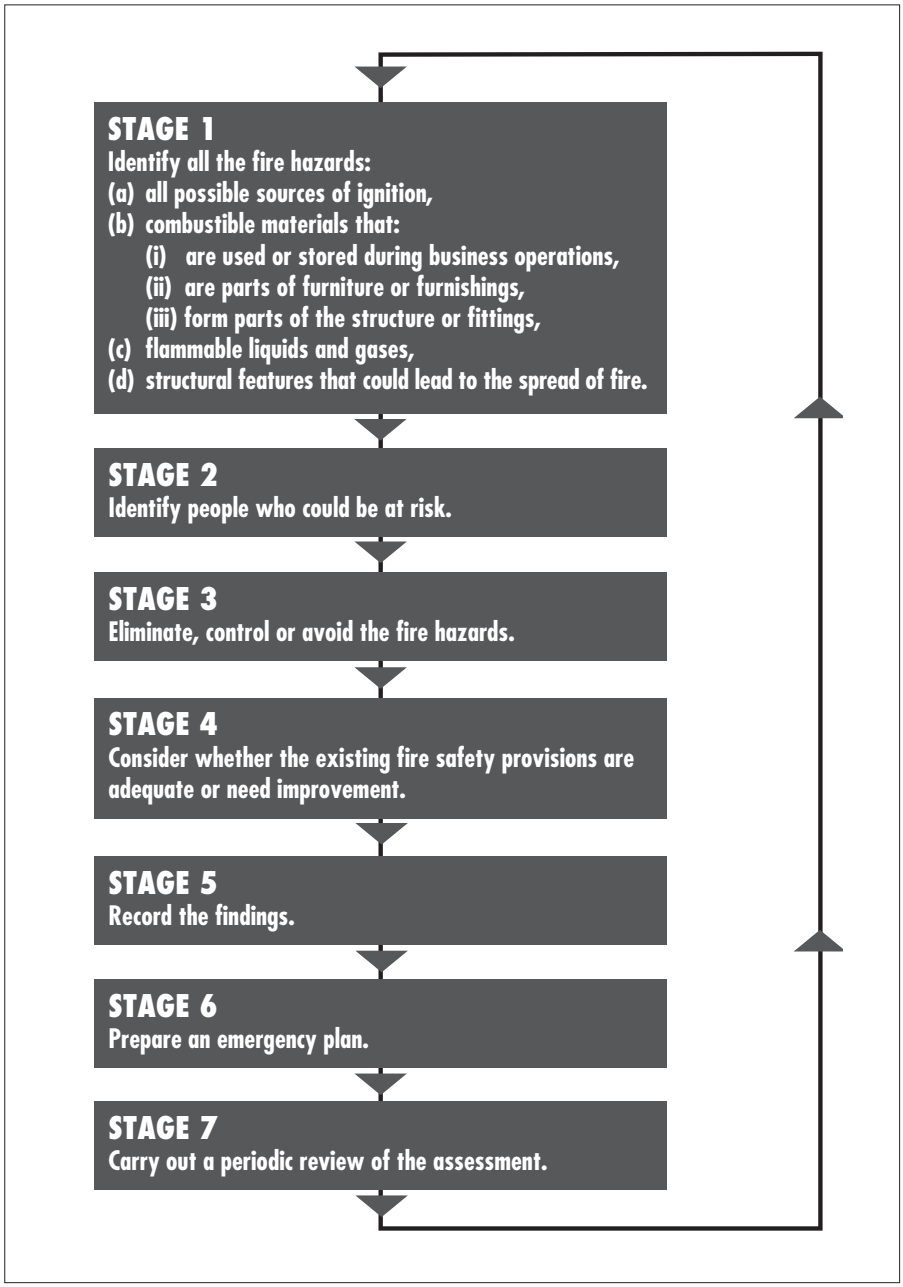


Figure A1: Seven-stage fire risk assessment

protection objectives and criteria will enable the achievement of cost-effective fire protection of the assets of the business. Designers should possess a broad view of how they may contribute to a risk assessment for property protection purposes.

It is necessary to acknowledge that, as mentioned above, a property protection risk assessment is more wide ranging than one carried out to establish the life safety and means of escape requirements to satisfy national legislation. In addition to the direct financial losses arising from a fire, the effect on the profitability of the business needs to be assessed. (The FPA's book, *Fire risk management in the workplace,* is an excellent introduction to the topic.)

It follows, therefore, that higher standards of fire protection will often be necessary to achieve acceptable property protection criteria and objectives than would be required to satisfy national building regulations.

Methods for risk assessing specific categories of building are explained in sector guides. Sector guides also contain tables describing the fire resistance standard of compartmentation in different situations.

Figure A1 outlines a method for the risk assessment of the acceptability of compartmentation in terms of its integration into the whole building.

Appendix B: The building as an entity

B1. Assessing the effects of a fire on compartmentation

The following should be considered when carrying out an appraisal of the behaviour of the structure under fire exposure:

- structural deflections are primarily thermally induced;
- changes in load do not significantly affect thermal deflections;
- deflections can cause significant problems when there is a need to ensure compatibility of movement between adjacent members;
- deflections can cause adjacent non-heated members to be damaged or collapse, and may cause gaps to occur between elements. These gaps will cause an integrity failure and assist in fire and smoke spread if they are not anticipated and accommodated at the design stage;
- unprotected steelwork, whether or not forming the structural frame part of a separating element, will deflect to a greater extent than protected steelwork;
- deflections should be designed out of the system by using suitable levels of restraint so they do not occur; and
- if the previous point is not possible, then the magnitude of the deflections should be calculated or estimated and then the structure should be designed to accommodate these deflections.

These principles give the appraiser guidance on issues relating to maintenance of compartmentation during a fire which need to be considered when assessing the likely damage in a building. There are other issues, relating to the performance of windows, ducts and other penetrations, and possible disruption thereof as a result of thermally induced movement, which should also feature in the appraisal.

The behaviour and support requirements for such elements of construction are also discussed in the appropriate places in the series of related date sheets which are to be found on the design guide section of the FPA's website, *www.thefpa.co.uk/Resources/Design+Guide.*

B2. The design process

The only way that the performance of a building in its entirety can be guaranteed is if each individual element is guaranteed to work in its environment. To establish this, it is necessary to carry out a brief analysis of each element when considering its performance in the context of the elements bounding it. This is achieved by considering each edge of a separating element in turn to see if it can retain the fire integrity along that edge. In the case of a non-separating element, the behaviour at each end should be considered in turn to ensure that any movement does not reduce the integrity at or near the junction, nor produce any significant change in the restraint conditions. A decision tree approach, as given below, is recommended.

B3. The decision tree approach

A decision tree has been established to assist in appraising the acceptability of a compartment wall. The following comments relate to this decision tree (Figure B1):

- if it is possible to follow the flow diagram straight down the left-hand side to the end point then the construction as tested is suitable without the need for any design or construction changes; and
- if the design needs to be changed, as a result of a 'yes' decision, indicating that the performance would be adversely affected by the movement, then the decision will need to be made either to prevent the deflection or to accommodate it.

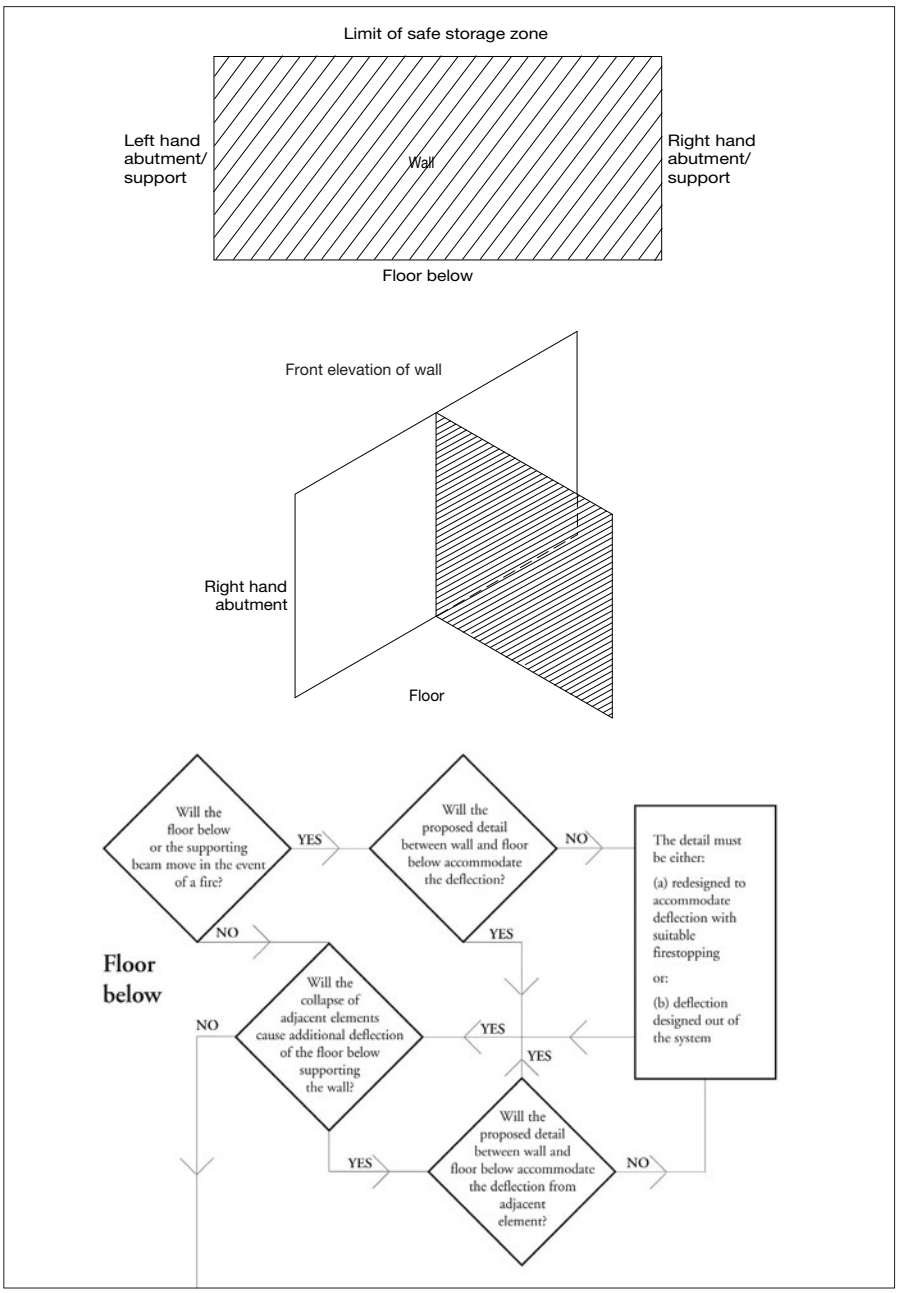
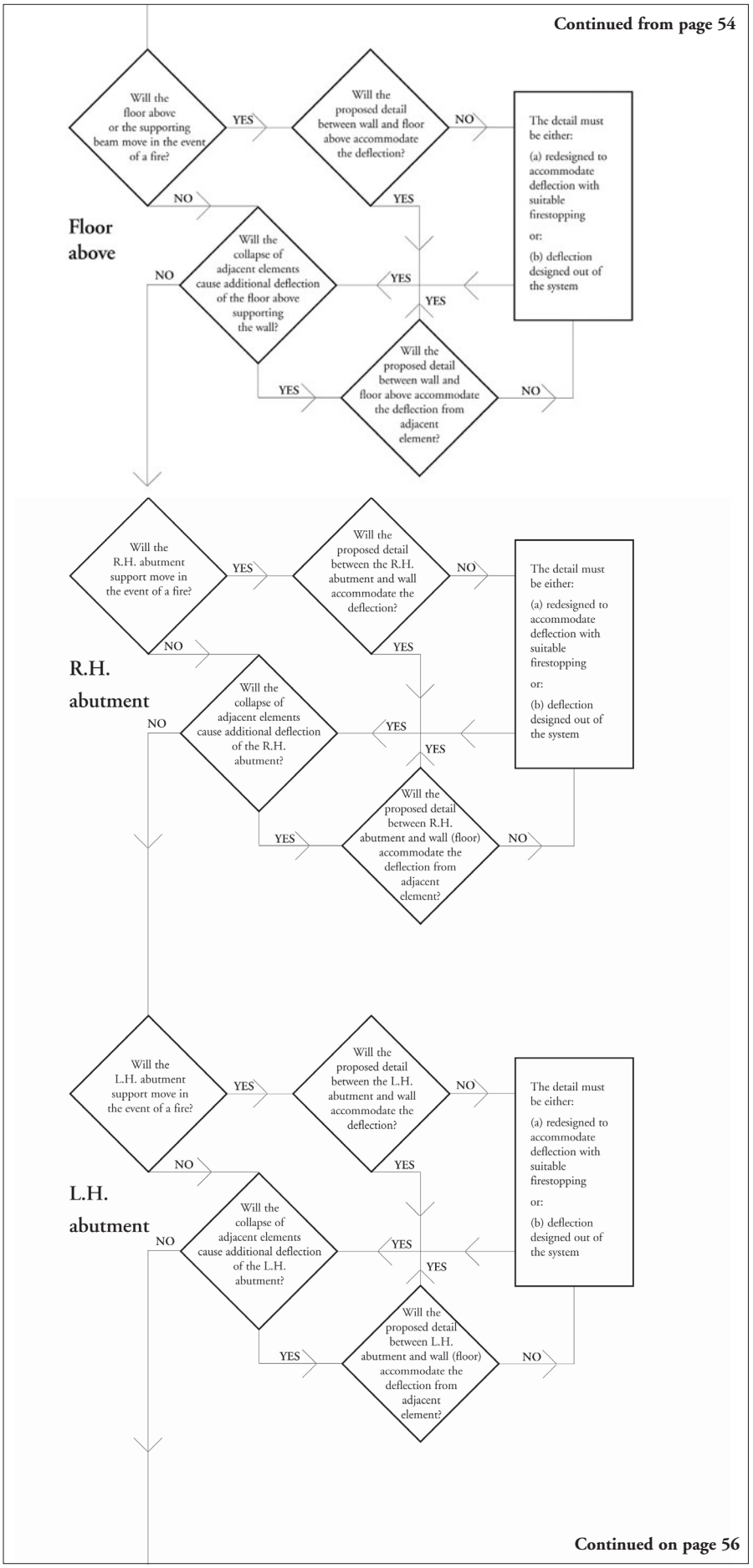
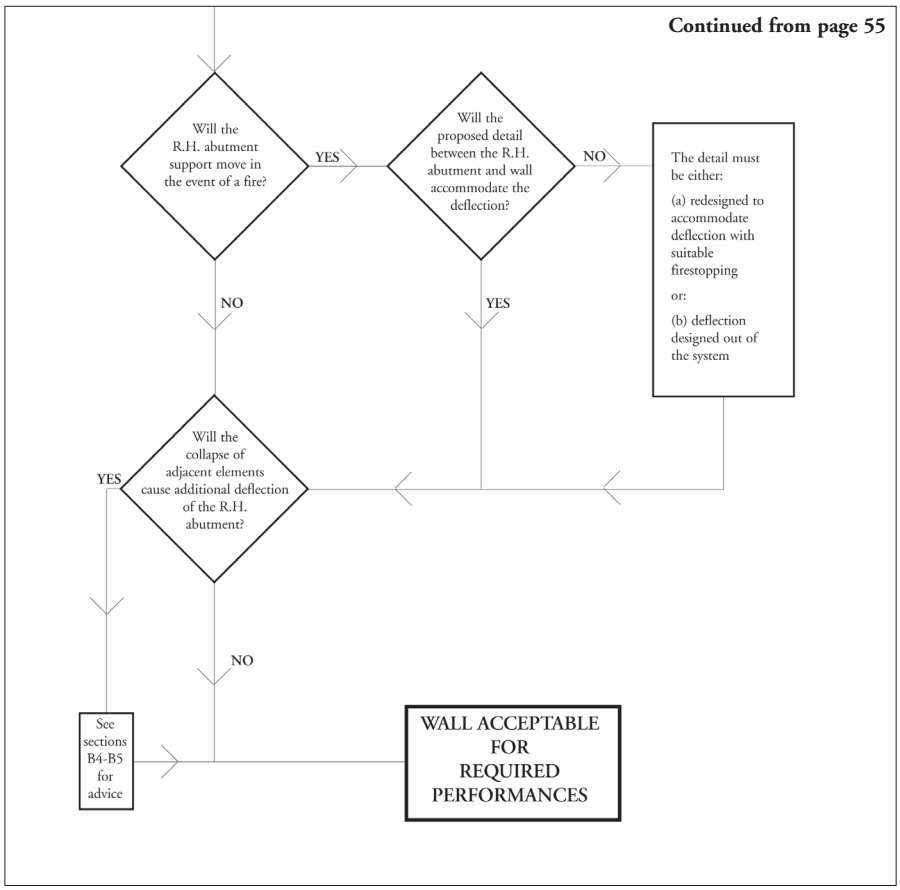


Figure B1: To establish the acceptability of a compartment wall by reference to a decision tree (continued on following two pages)

Continued from page 54



Continued on page 56



B4. Designing out the distortion

Should the appraisal indicate that the anticipated distortion cannot be accommodated by either the elements bounding the wall or floor under consideration, then the distortion should be restricted. There are a number of ways that this can be done dependent upon the practicality, cost or effectiveness of the various methods. A list of the possible options is given below:

- apply protection to the distorting element in excess of any protection required for it to satisfy the fire resistance test (Note: according to BS 476-21, the loadbearing capacity criteria for any element can be satisfied and yet it may still exhibit large resultant deflections. A floor with a span of 4m is able to deflect 133mm and still comply with the requirements of the Standard. A non-loadbearing element has no limit on its deflection as long as the distortion does not cause gaps to develop within the structure of the element.);
- use a construction that has a greater cross-section than is needed to satisfy the loadbearing or stability requirement for the element. This will mean that the element will be subjected to lower stress levels and will have a greater stiffness, remain cooler because of increased thermal inertia and hence reduce its tendency to bow. In a situation where fire attack could be from either direction, this will, in practice, mean that extra thickness is required on both sides;
- increase the restraint on vertical elements either by:
- restraining it on the cool, protected side of the construction; or
- adding protection to adjacent elements on the hot face, including any

bracing, so that they may provide additional restraint of the deflecting element;

- in the case of horizontal elements, additional protected supports may be provided;
- when collapse is inevitable, the structural joints should be designed so that the collapse takes place in a predicted manner, away from the critical location, allowing the members or elements immediately adjacent to the wall or floor to remain plane. An example is shown in Figure 7.8 and described in the accompanying text.

The analysis and the subsequent selection of a suitable system for controlling the deflection may well require input from a suitably qualified fire safety engineer or a structural engineer fully conversant with the fire engineered construction.

B5. Accommodating the distortion

Should the appraisal indicate that the distortion cannot be prevented by design, it is important that the structure can accommodate the anticipated distortion. It may be possible to incorporate this into the basic design. For example, where two adjacent elements are predicted to bow, then the size of the gap can be restricted if – in the case of two dissimilar elements – the stiffer of the two passes over the end of the less stiff element, rather than the other way round. Frequently, the gap will need to be sealed with a linear gap sealing system that is able to meet both the cold performance requirements and maintain the fire and smoke resistance in the 'hot' condition.

B6. Selecting a joint sealing system

Where the thermal distortion cannot be prevented by restraint, then the sealing system between the elements should be able to accommodate the maximum predicted deflection resulting from non-sympathetic distortions.

In the case of a joint between two vertical elements, the gap will probably increase as the fire duration increases. With the joint between a vertical element and a horizontal element where a seal is put in place to accommodate the vertical movement of the floor, the gap will reduce as the fire duration increases. At this maximum gap width, the flexible seal is required to maintain the integrity, with respect to the cotton pad criterion of BS 476-20: 1987, and insulation of the compartment for the designated durations, see 1.1. Generally, the seal will need to become more effective as the environment heats up, rather than less effective. This would tend to indicate that intumescent sealing systems are better than inert seals, especially where the gap is opening up.

Where sealing the gap between elements which separate different occupancies, the seal should also resist the spread of both hot and cold smoke. It is unlikely that a mineral fibre seal, which will lose its binder during the heating process, will have the necessary impermeability to restrict the flow of smoke unless it is subsequently coated with a high-temperature sealing material. Where there is anticipated movement between the elements in normal service, the seal chosen should be capable of accommodating that service movement.

Where the materials are different in nature – for example, timber and concrete – the seal should be supported by evidence of performance, or a field of application, that covers the following:

- duration of fire resistance;
- the maximum anticipated gap width; and
- the materials forming the gap.

The design of a detail capable of accommodating the deflection will depend on the system being installed and will therefore be particular to the element being appraised. The detail should be capable of tolerating the deflection without a premature reduction in the insulation or integrity at the joint. The system detail should be assessed by a suitably qualified fire safety engineer to sanction its choice if the application is not covered by the direct field of application for the seal.

If fire stopping is to be used and is to be located between walls (or walls and floors) of different material types, then the fire-stopping material should have been tested with the different material types being used as the substrate. Further information on the selection of fire-stopping and/or linear gap-sealing systems and materials is given in section 14 of the *FPA Design guide: Protection of openings and service penetrations from fire*.

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for the Fire Protection of Buildings

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