Sheet No: 6.1.1

6.1 Structural frames

Main application in respect to this *Design Guide:*

1. Providing a robust framework through which all relevant building forces and imposed loads are transmitted to ground.
2. Providing a load-bearing infrastructure to support other building components and fire safety provisions, e.g. compartment floors.

FUNCTION OF STRUCTURAL FRAMES

- To maintain a load-bearing capacity under fire conditions for the duration defined in Table 2.1 and 2.2 of the *Design Guide*, thus ensuring that the building structure retains its stability for a reasonable period.
- To maintain a load-bearing capacity for the duration defined in Tables 2.1/2.2 of the *Design Guide*, thus ensuring that all other fire safety systems exist within a robust infrastructure such that they can remain functional.
- Not to contribute unduly to the growth and development of fire within the building.
- To withstand the loading and deflection to be experienced in use and during fire exposure whilst maintaining the requirements above.
- To maintain the load-bearing performance over the lifetime of the building, in respect of realistic impact and/or ambient conditions.

EVIDENCE OF FIRE PERFORMANCE

The evidence of performance should cover the following;

- **Fire resistance performance (load-bearing capacity).** The ability of the structural frame (or its constituent components in combination) to maintain the requisite load-bearing capacity and resist undue deflection, deformation and collapse. This shall be verified by evidence of performance in accordance with BS 476: Part 21[1g], EN 1365 Part 3 (beams)[27c], or Part 4 (columns)[27d] under conditions appropriate to the final construction use of the frame. The large sizes of structural frames are typically incompatible with the sizes of fire resistance test furnaces. Fire performance is determined on the basis of fire resistance tests in accordance with BS 476: Part 21[1g], EN 1365 Part 3 (beams)[27c], or Part 4 (columns)[27d] on the individual components of the frame. Careful interpretation of these fire test results or engineered assessment is necessary to permit their application in the context of a frame assembly. A detailed and considered Engineering Assessment or Field of Application Report is essential. Connection details, interactions, boundary conditions and restrictions in use all need to be evaluated by a competent person.

BEFORE READING THIS DATA SHEET PLEASE REFER TO THE INTRODUCTION

IMPORTANT

THESE DATA SHEETS ARE ONLY INTENDED TO GIVE GENERIC INFORMATION.

DATA ON PROPRIETARY PRODUCTS MUST BE OBTAINED FROM THE MANUFACTURERS

Suitable fire resisting load-bearing capacity performance may also be verified by appropriate structural fire engineering design in accordance with accepted engineering principles as detailed in various British Standard design codes. Evidence should be requested to ensure that the design both complies with the recommendations, and that the design has been checked and assessed by a competent person.

- Structural frames are often required only to support the roof of a building. Whilst, it is generally not required that the stability of the roof be assured for the full duration described in Table 2.1 of this *Design Guide*, consideration must be given to the consequences of roof collapse on the overall stability of the building. In particular, attention should be paid to the stability of those structural members which rely on the roof members for stiffness and support. The effect of roof collapse on the load paths within the structural frame also need to be considered. It is likely that collapse of the roof will transmit additional loads (including overturning moments) to the structural frame. The structural frame needs to be capable of withstanding these additional forces for the required period of fire exposure. Otherwise the roof structure itself may need to be protected from the effects of fire.
- **Contribution to fire growth.** When the exposed surfaces of the structural frame are integral with a wall or a ceiling, whose surfaces are required to achieve a surface spread of flame characteristics, the frame surfaces shall not reduce or negate the surface characteristic.
- In some instances, the orientation, topography and surface properties of the frame may be such that an inherent resistance to the spread of flame is assured to the satisfaction of a competent person. Otherwise, the frame surfaces shall achieve a surface spread of flame classification of Class 1 as defined in BS 476: Part 7[1d] appropriate to the surface they form part of. The same surface shall also achieve a fire propagation Index (I) of not more than 12 and a sub-index (i) of not more than 6 when tested to BS 476: Part 6[1c]. Note that the combination of these various performance parameters is described as being Class 0 in the Approved Document B of the Building Regulations 1991 England and Wales[29]. Alternatively, the exposed surface of the frame may be designated as being of limited combustibility, as defined by BS 476: Part 11[1e]. The frame materials shall not add to the fire load within the building.
- **Loading and deflection.** The structural frame shall be so constructed such that the occurrence of a deflection of span/30 during fire conditions shall not cause the opening of gaps or undue cracks which could permit fire spread. Frames shall not suffer distortions such as to cause transfer of loads (direct or thermally induced) from the frame to adjacent non-loadbearing members such as partitions and walls. The thermal expansion of structural frames shall not impose lateral thrusts on walls such as could cause their collapse. Compliance with the requirement shall be demonstrated through a combination of an engineering awareness of load paths and fire test evidence in accordance with BS 476: Part 21[1g], EN 1365 Parts 3 (beams)[27c] or 4 (columns)[27d] together with an associated Field of Application Report.

- **Durability.** Evidence shall be available to verify that the materials used in the construction of the structural frame are not going to be adversely affected by ambient conditions and, if appropriate, abuse (e.g. low energy impacts) during the anticipated life of the building.

OVERVIEW OF STRUCTURAL FRAMES

Structural frames provide the load-bearing skeleton for a building. Many other building elements such as walls, floors and roofs achieve their stiffness and stability either directly or indirectly from the structural frame. In general terms, structural frames may be categorised as follows;

1. Assemblies of columns and beams
2. Trussed assemblies
3. Monolithic rigid frames (pitched roof portals)

Structural frames are constructed using steelwork, reinforced concrete or timber. The fire performance of the structural frame is a function of both its structural form and the construction material used.

1. ASSEMBLIES OF BEAMS AND COLUMNS

The fire performance of structural frames, which are assemblies of beams and columns, is a function of the fire resistance of the individual beams and columns as well as the nature of the fixings connecting them.

The load-bearing fire resisting performance of individual beams and columns is measured in BS 476: Part 21[1g], EN 1365 Part 3 (beams)[27c] or Part 4 (columns)[27d]. Fire tests are conducted on representative structural members under conditions of applied load. The end conditions of the test specimen, in terms of the degree of fixity present, are usually less rigid than those end conditions likely to be encountered by such members within a structural framework. Accordingly, fire tests predict levels of fire performance, which may be viewed as conservative. The application of individual fire test results to a full frame needs to carefully consider the end fixing.

Simple (or pinned) joints between the beams and columns are only capable of resisting shear and axial loads. They are unable to resist applied moments and lateral forces, e.g. wind. Such forces need to be resisted by horizontal bracing members. Frames containing simply connected members cannot utilise the moment resistance of the joints to increase the fire resistance rating of the frame beyond the fire resistance ratings of the individual beams and columns.

Beams and columns connected by a series of rigid joints are capable of withstanding shear, axial load and applied moments. Such rigid frames can utilise load-shedding and moment redistribution to achieve higher fire resistance ratings than those ratings achieved by individual beams or columns.

This data sheet considers the following:

1.1 Structural steelwork
1.2 Reinforced concrete: cast in-situ
1.3 Reinforced concrete: precast
1.4 Reinforced concrete: pre-stressed
1.5 Timber

1.1 Structural steelwork

The fire performance of structural steelwork frames constituted of individual beams and columns connected together is a function of the fire resistance of the individual beams and columns as well as the nature of the fixing connection between them.

The load-bearing fire resisting performance of individual steel beams and columns is measured in BS 476: Part 21[1g], EN 1365 Part 3 (beams)[27c] or Part 4 (columns)[27d]. Fire tests are conducted on representative steel members under conditions of applied load. As steel loses its strength at elevated temperatures, structural steelwork is typically afforded insulation from the effects of fire through application of a protective material or coating.

In terms of fire performance, typical bolted connections between steelwork beams and columns can be considered as semi-rigid connections, which are capable of resisting moments to a limited extent.

To be considered as a fully rigid frame, beams and columns need to be connected by welded joints. Alternatively joints constructed by bolted connections using thick end plates and local stiffeners can be considered as fully rigid. Fully rigid frames or monolithic frames are discussed in their own right elsewhere in this *Design Guide*.

Fire performance data

- **Load-bearing capacity.** Typically steelwork frames will be protected from the effects of fire. The degree of protection required will be deduced from fire tests on individual beams and columns to BS 476: Part 21[1g], EN 1365 Part 3 (beams)[27c] or Part 4 (columns)[27d], or by reference to the ASFPCM Yellow Book[32] if the section size and duration are known, albeit this gives a pessimistic view of the protection needed in practice. Unprotected structural steelwork frames consisting of rigid connections can achieve fire resistance ratings of up to 60min. Such performance needs to be carefully validated by a competent person and specialist computer software is usually necessary. (☆☆☆)
- **Contribution to fire growth.** Class 0 and non-combustible. (☆☆☆☆☆)
- **Contribution to fire load within building.** Steelwork is not combustible and does not add to the fire load within the building. (☆☆☆☆☆)
- **Loading and deflection**. Steelwork expands on heating and careful consideration should be given to the resulting thermal movements. Special joints may be necessary to accommodate thermal movements or alternatively insulation protection provided. (☆☆☆)
- **Durability.** Resistant to substantial impacts and when decorated it is resistant to atmospheric degradation. (☆☆☆☆☆)

1.2 Reinforced concrete: Cast in-situ

Assemblies of cast in-situ concrete beams and columns are generally provided with reinforced connections and such frames can be considered as rigid in the context of fire performance. Therefore the dominant parameters influencing the fire performance of a concrete frame are the size of the frame (its spans) and the thickness of cover afforded to the reinforcing steel.

Fire performance data

- **Load-bearing capacity.** The fire resistance of the frame will largely be a function of the thickness of cover afforded to the reinforcing steel. In broad terms, concrete frames with cover depths of 20mm will achieve at least one hours fire resistance, whilst frames with 50mm cover will achieve two hours fire resistance. (☆☆☆☆)
- **Contribution to fire growth.** Class 0 and non-combustible. (☆☆☆☆☆)
- **Contribution to fire load within building.** Concrete is not combustible and does not add to the fire load within the building. (☆☆☆☆☆)
- **Loading and deflection**. Concrete has a relatively low coefficient of thermal expansion. Further, it has poor conductivity which means that it is slow to heat up. Concrete frames, therefore, suffer only minimal thermal movements. (☆☆☆☆☆)
- **Durability.** Resistant to the most substantial impacts and durable in use. (☆☆☆☆☆)

1.3 Reinforced concrete - Precast

The fire resistance of individual precast beams and columns will be similar to their cast in-situ equivalent. However, precast concrete frames may have a lesser degree of joint fixity, continuity and rigidity.

Fire performance data

- **Load-bearing capacity.** The fire resistance of the frame will largely be a function of the thickness of cover afforded to the reinforcing steel. In broad terms, concrete frames with cover depths of 30mm will achieve at least one hours fire resistance, whilst frames with 60mm cover will achieve two hours fire resistance. (☆☆☆)
- **Contribution to fire growth.** Class 0 and non-combustible. (☆☆☆☆☆)
- **Contribution to fire load within building.** Concrete is not combustible and does not add to the fire load within the building. (☆☆☆☆☆)
- **Loading and deflection**. Concrete has a relatively low coefficient of thermal expansion. Further, its poor conductivity means that it is slow to heat up. Concrete frames, therefore, suffer only minimal thermal movements. (☆☆☆☆☆)
- **Durability.** Resistant to the most substantial impacts and durable in use. (☆☆☆☆☆)

1.4 Reinforced concrete - Pre-stressed

Pre-stressed concrete members rely on the retention of stress within their steel tendons to deliver the required load and moment carrying capacity. In basic terms pre-stressed members may be treated similarly to ordinary reinforced concrete, with the depth of cover being the primary influence on behaviour. However, the performance of pre-stressed members needs to be assured as their failure under fire conditions will be sudden, unlike ordinary reinforced concrete which will fail in a ductile manner. Fire resistance ratings should be determined through testing to BS476: Part 21[1g].

It should be noted that pre-stressed members will not regain their strength on cooling after exposure to fire conditions and expert advice should be sought regarding their re-instatement past fire.

Fire performance data

- **Load-bearing capacity.** The fire resistance of the frame will largely be a function of the thickness of cover afforded to the reinforcing steel. (✫✫)
- **Contribution to fire growth.** Class 0 and non-combustible. (✫✫✫✫✫)
- **Contribution to fire load within building.** Concrete is not combustible and does not add to the fire load within the building. (✫✫✫✫✫).
- **Loading and deflection**. Concrete has a relatively low coefficient of thermal expansion. Further, its poor conductivity means that it is slow to heat up. Concrete frames, therefore, suffer only minimal thermal movements, subject to the steel tendons being suitably protected. (✫✫✫✫)
- **Durability.** Resistant to the most substantial impacts and durable in use. (✫✫✫✫✫)

1.5 Timber

The fire performance of timber structural members within a frame is dominantly a function of two variables; timber density and the cross-sectional size of the timber member.

Timber beams and columns should be of sufficient size to enable them to retain their structural stability during the fire period. Allowance shall be made for the reduction in cross-sectional area of the members which will result from pyrolysis and charring of the members.

Unless information to the contrary is available timber beams should be assumed as being of ordinary density (softwood) and taken to char at a rate of 0.66mm per minute of exposure to fire test conditions. Hardwood timber beams, i.e. higher density timbers (650kg/m^3), can be taken to char at a lesser rate of 0.5mm per minute. Timber columns should be assumed to char at a rate some 25% higher than timber beams. Fire performance shall be demonstrated through appropriate structural design calculations to BS 5268: Part 4: Section 4.1[5a] or through satisfaction of the load-bearing criteria during test to BS 476: Part 21[1g], EN 1365 Parts 3 (beams)[27c] or 4 (columns)[27d] for the duration specified in Tables 2.1/2.2 of this *Design Guide*.

The joints between beams and columns will suffer deterioration at elevated temperatures. In addition to basic pyrolysis of the timber, mechanically fixed joints can suffer loss of material strength, increased conduction of heat into the timber with associated charring and loss of bond between the charred timber and the mechanical fixing. In order to be assumed rigid, the above mechanisms need to be taken into account and the joint details need to be verified by a competent person.

Fire performance data

- **Fire resistance performance (load-bearing capacity)**. Although timber is combustible, it burns at a relatively slow and determinate rate. It is possible to ascertain the load-bearing capacity of the charring section after a period of exposure to fire. Detailed calculations are described in BS 5268: Part 4: Section 4.1: 1978[5a]. Alternatively, beams and column whose fire resisting load-bearing capacity has been verified through testing to BS 476: Part 21[1g], EN 1365 Part 3 (beams)[27c] or Part 4 (columns)[27d] may be assembled as a frame, subject to the use of suitable jointing details and compliance with the test assessment or Field of Application report. (☆☆☆☆)
- **Contribution to fire growth.** Timber members achieve a Class 3 surface spread of flame rating and are combustible, unless treated chemically or physically coated. Verification of performance of the treated timbers shall be confirmed through testing, together with due consideration of long term durability of said treatments. Alternatively, the spread of flame on surfaces of the beams/columns adjacent to ceilings/walls can be restricted through suitable engineering detailing. Certain treatments have been accredited with causing a loss of strength. (☆☆)
- **Contribution to fire load within building.** Timbers of sufficient size to constitute a structural frame are not readily ignitable. The ratio between such timber's surface area and its volume will greatly restrict its burning rate. The structural timber frame, although combustible, will only slightly increase the fire load within the building. (☆☆☆☆)
- **Loading and deflection**. Timber shrinks on exposure to heat and accordingly will not impose thermally induced thrusts on the adjacent structure. The potential for openings and shrinkage cracks needs to be considered. (☆☆☆)
- **Durability.** Resistant to substantial impacts and durable in heated and ventilated internal conditions. (☆☆☆☆)

2. Trussed assemblies

Truss structures are capable of carrying higher levels of loading per unit span per unit self-weight than traditional beams and columns. Trusses achieve this saving in unit weight because they are made up of many smaller members connected together. As a result, however, the thermal inertia of a typical truss is significantly lower than would be expected of a beam with similar load carrying capabilities. However, their lower thermal inertia make trusses particularly vulnerable to fire attack.

Trussed assemblies may be used in lieu of either beams or columns or both. For example, trussed beams may be used in conjunction with traditional column.

2.1 Steelwork trussed assemblies
2.2 Concrete trussed assemblies
2.3 Timber trussed assemblies

2.1 Steelwork trussed assemblies

The majority of truss frame construction is steelwork. Prefabricated trusses may be assumed to have rigid connections, for the purposes of fire safety design. The low thermal inertia of the truss's constituent members means that unprotected steel trusses are likely to heat up quickly on exposure to fire conditions. This limits the fire resisting performance that can be achieved without application of protection to insulate the truss against the effects of heat. The high number of members constituting a truss, together with their small sectional size means that application of protective materials to steel trusses is difficult in practice. Surface coatings are more popular than boarded protection.

Fire performance data

- **Load-bearing capacity.** Unprotected steel trusses will heat up quickly on exposure to those conditions prescribed in BS 476: Part 21[1g], pr EN 1365 Part 3 (beams)[27c] or Part 4 (columns)[27d] Although, under such conditions, trusses have reserves of strength available as a result of their high stiffness (and an associated capacity for moment redistribution), their fire performance is limited. Additional fire protection is usually required before steel trusses can achieve higher fire resistance ratings. (☆☆)
- **Contribution to fire growth.** Class 0 and non-combustible. (☆☆☆☆☆)
- **Contribution to fire load within building.** Steelwork does not add to the fire load within the building. (☆☆☆☆☆)
- **Loading and deflection**. Steelwork expands on heating and careful consideration should be given to the lateral thermal thrusts expected at the bearing points of a truss. Special joints may be necessary to accommodate thermal movements or alternatively such movement prevented by providing insulation against the effects of heat. (☆☆☆)
- **Durability.** Resistant to substantial impacts. (☆☆☆☆☆)

2.2 Concrete trussed assemblies

The fire performance of prefabricated concrete trusses is governed by the depth of concrete cover provided to the reinforcing steel. The small section sizes encountered make concrete trusses particularly susceptible to destructive spalling on exposure to fire, with a resulting loss in cross-sectional area and stability. The fire resisting properties of concrete trusses should ideally be established through fire testing and engineering assessment to BS 476: Part 21[1g], EN 1365 Part 3 (beams)[27c] or Part 4 (columns)[27d].

Fire performance data

- **Load-bearing capacity.** Given the absence of destructive spalling, concrete trusses can achieve reasonable fire resistance ratings. (☆☆☆☆)
- **Contribution to fire growth.** Class 0 and non-combustible. (☆☆☆☆☆)
- **Contribution to fire load within building.** Concrete does not add to the fire load within the building. (☆☆☆☆☆)

- **Loading and deflection**. Concrete has a relatively low coefficient of thermal expansion. Further, its poor conductivity means that it is slow to heat up. Concrete trusses, therefore, suffer only minimal thermal movements. (☆☆☆☆☆)
- **Durability.** Resistant to substantial impacts. (☆☆☆☆☆)

2.3 TIMBER TRUSSED ASSEMBLIES

Timber trusses members need to be sufficiently sized to allow for the reduction in their cross-sectional area which will result from their pyrolysis and charring on exposure to fire conditions.

Fire performance shall be demonstrated through appropriate structural design calculations to BS 5268: Part 4: Section 4.1[5a] or through satisfaction of the load-bearing criteria during test to BS 476: Part 21[1g], EN 1365 Part 3 (beams)[27c] or Part 4 (columns)[27d] for the duration specified in Tables 2.1/2.2 of this *Design Guide*.

Timber trusses are particularly reliant on the integrity of the joints between individual members. Steel plated mechanically fixed joints suffer a loss of material strength at elevated temperatures and also conduct heat into the timber members, leading to higher rates of charring local to the connection. This can hasten loss of connection between the charred timber and the mechanical fixing. Timber truss joint details need to be verified by conducting a fire test or alternatively by the undertaking of an engineering assessment by a competent person.

FIRE PERFORMANCE DATA

- **Fire resistance performance (load-bearing capacity)**. Although timber is combustible, it burns at a relatively slow and determinate rate. It is possible to ascertain the load-bearing capacity of the individual charred sections of a truss after a period of exposure to fire. Detailed calculations are described in BS 5268: Part 4: Section 4.1: 1978[5a]. Timber trusses may have their fire resisting load-bearing capacity determined by test to BS 476: Part 21[1g], EN 1365 Part 3 (beams)[27c] or Part 4 (columns)[27d]. Particular attention should be given to the fire behaviour of the joints and a detailed Engineering Assessment or Field of Application report is necessary. (☆☆☆)
- **Contribution to fire growth.** Timber members achieve a Class 3 surface spread of flame rating and are combustible, unless treated chemically or physically coated. Verification of performance of the treated timbers shall be confirmed through testing, together with due consideration of long term durability of such treatments. Alternatively, the spread of flame on the surface of a truss can be restricted through suitable engineering detail. (☆☆)
- **Contribution to fire load within building.** Timber trusses are combustible and will modestly increase the fire load within a building. (☆☆)
- **Loading and deflection**. Timber shrinks on exposure to heat and accordingly will not impose thermally induced thrusts on the adjacent structure. The potential for openings and shrinkage cracks needs to be considered. (☆☆☆)
- **Durability.** Resistant to substantial impacts. (☆☆☆☆☆)

3. Monolithic rigid frames

Monolithic frames are those where the beam/column interface may be assumed fully rigid. Such frames include concrete frames (cast monolithically) and steel or timber portal frames, with rigid connections between columns and beams. In monolithic frames, the floor slab is also often integral to the structural frame, providing it with increased stiffness.

3.1 Reinforced concrete monolithic rigid frames
3.2 Steelwork monolithic rigid frames
3.3 Timber monolithic rigid frames

3.1 Reinforced concrete monolithic rigid frames

As it is impractical to subject full size frames to fire testing, an understanding of frame behaviour is derived principally from theoretical models. Although, such models are extremely sensitive to the material models chosen, they confirm the formation of plastic hinges at the mid-span of the heated beams, when their reinforcing steel reaches a sufficient temperature. Redistribution of moments towards the supports then occurs. Final failure only takes place when excessive temperatures are reached in the steel reinforcement at the supports, which is generally on the upper (and cooler) surface. Accordingly, monolithic concrete frames can resist collapse despite very long periods of exposure to fire conditions.

Fire performance data

- **Load-bearing capacity.** Excellent resistance to collapse and deflection for substantial periods of exposure to fire conditions. (☆☆☆☆☆)
- **Contribution to fire growth.** Class 0 and non-combustible. (☆☆☆☆☆)
- **Contribution to fire load within building.** Concrete does not add to the fire load within the building. (☆☆☆☆☆)
- **Loading and deflection**. Concrete has a relatively low coefficient of thermal expansion. Further, its poor conductivity means that it is slow to heat up. Concrete frames, therefore, suffer only minimal thermal movements. (☆☆☆☆☆)
- **Durability.** Resistant to substantial impacts. (☆☆☆☆☆)

3.2 Steelwork monolithic rigid frames

In fire safety terms, steel portal frames are unusual in that the structural columns very often only support the roof beams. (See Figure 1). As there is no requirement for roofs to have a fire resisting capability, other than within the protected zone, portal frames only need to achieve a fire performance in those instances where the collapse of the columns could lead to failure of walls or floors and the potential spread of fire either within the building or externally to adjacent properties.

The rafters of a single-storey portal frame are generally unprotected and quickly lose their strength on exposure to fire. Under such conditions, the roof members could no longer sustain the loads acting upon them nor continue to act as a prop for the columns. The roof members will deflect downwards, pushing the column members outwards. Steel portals must be designed to ensure that this outward thrust is not sufficient to cause the columns to fail outwards.

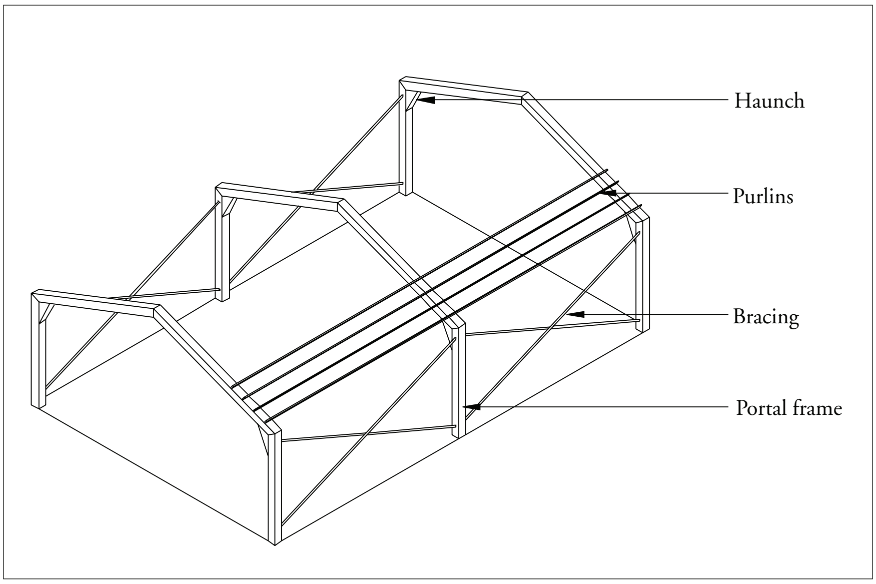

Figure 1. Typical portal frame construction.

Further, the rigidity of the beam/column connection within the portal frame, is such that the downwards movement of the roof beams will impose a significant overturning moment on the columns. Columns must be designed to resist this imposed moment for a sufficient duration. Whilst at ambient conditions the base of portal frames are designed as simple pinned connections, under fire conditions these connections must be designed to resist the overturning moment caused by roof failure.

Fire performance data

- **Load-bearing capacity.** The fire resisting load-bearing capacity of steel portal frames when exposed to the heating conditions defined in BS 476: Part 20[1f] should be confirmed through appropriate fire engineering design to BS 5950: Part 8[9]. (☆☆☆)
- **Contribution to fire growth.** Class 0 and non-combustible. (☆☆☆☆☆)
- **Contribution to fire load within building.** Steelwork does not add to the fire load within the building. (☆☆☆☆☆)
- **Loading and deflection**. Steelwork expands on heating and careful consideration should be given to the resulting thermal movements, particularly at the column heads. The column needs to be sufficiently sized to cope with the lateral thrust from the roof members. (☆☆)
- **Durability.** Resistant to substantial impacts. (☆☆☆☆☆)

3.3 Timber monolithic rigid frames

The timber beam and column members within portal frames need to be sufficiently sized to allow for the reduction in their cross-sectional area which will result from their pyrolysis and charring on exposure to fire conditions. Where roof timbers are smaller than column timbers, there is a potential that the roof may collapse before the columns. It is important that the load-bearing capacity of the columns is such that they are able to carry any additional loads or moments created by failure of the roof members.

Fire performance shall be demonstrated through appropriate structural design calculations to BS 5268: Part 4: Section 4.1[5a] or through satisfaction of the load-bearing criteria during test to BS 476: Part 21[1g], EN 1365 Part 3 (beams)[27c] or Part 4 (columns)[27d] for the duration specified in Tables 2.1/2.2 of this *Design Guide*.

If the continuity of the beams/columns is important to structural performance, the beam/column joint must be adequately protected from the effects of fire. Often this can be achieved simply by increasing timber sizes at the joint, allowing for some sacrificial burning. Steel plated mechanically fixed joints suffer a loss of material strength at elevated temperatures and also conduct heat into the timber members, leading to higher rates of charring local to the connector. This can hasten loss of connection between the charred timber and the mechanical fixing. Timber joint details need to be verified by conducting a fire test or alternatively by the undertaking of an engineering assessment by a competent person.

Fire performance data

- **Fire resistance performance (load-bearing capacity)**. Although timber is combustible, it burns at a relatively slow and determinate rate. It is possible to ascertain the load-bearing capacity of the charred section after a period of exposure to fire. Detailed calculations are described in BS 5268: Part 4[5a]. Timber portal frames are typically too large to have their fire resisting load-bearing capacity determined by to BS 476: Part 21[1g], EN 1365, Part 3 (beams)[27c] or Part 4 (columns)[27d] although the results from such a test may be integrated within engineering calculations to confirm fire performance. Particular attention should be given to the fire behaviour of joints and an Engineering Assessment or Field of Application report is necessary. (☆☆☆)
- **Contribution to fire growth.** Timber members achieve a Class 3 surface spread of flame rating and are combustible, unless treated chemically or physically coated. Verification of performance of the treated timbers shall be confirmed through testing, together with due consideration of long term durability of said treatments. Alternatively, the spread of flame on element surfaces can be restricted through suitable engineering detail. (☆☆)
- **Contribution to fire load within building.** Timbers of sufficient size to constitute a structural frame are not readily ignitable nor predisposed to rapid burning. Structural timber frames modestly increase the fire load within the building. (☆☆☆☆)
- **Loading and deflection**. Timber shrinks on exposure to heat. Nonetheless vertical displacement of the roof members will impose a lateral thrust on the columns and this needs to be taken into account in design. (☆☆☆)
- **Durability.** Resistant to substantial impacts. (☆☆☆☆☆)

Installation

The installation of structural frames should be executed and completed by a suitably qualified person to the required standard appropriate to the system used. It is advisable that where fire performance is required then an inspection by an independent body may be carried out on the completed work.

Summary of performance data

Type of structural frame	Load bearing capacity	Contribution to fire growth	Contribution to fire load within building	Load and deflection	Durability
1. Assemblies of beams and columns					
1.1 Structural steelwork	☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆	☆☆☆☆☆
1.2 Reinforced concrete cast in-situ)	☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆
1.3 Reinforced concrete precast	☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆
1.4 Reinforced concrete pre-stressed	☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆	☆☆☆☆☆
1.5 Timber	☆☆☆☆	☆☆	☆☆☆☆	☆☆☆	☆☆☆☆
2. Trussed assemblies					
2.1 Steelwork	☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆	☆☆☆☆☆
2.2 Concrete	☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆
2.3 Timber	☆☆☆	☆☆	☆☆	☆☆☆	☆☆☆☆☆
3. Monolithic rigid frames					
3.1 Reinforced concrete	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆☆
3.2 Steelwork	☆☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆	☆☆☆☆☆
3.3 Timber	☆☆☆	☆☆	☆☆☆☆	☆☆☆	☆☆☆☆☆