FIRE SERVICES EXAMINATIONS BOARD

STUDY NOTE

EXAMINATION	STATION OFFICERS' EXAMINATION
PAPER	FIRE SAFETY, EDUCATION AND ENFORCEMENT
SUBJECT	FIRE SAFETY RISK ASSESSMENT
ITEM	BUILDING DESIGN AND STRUCTURAL FIRE PRECAUTIONS
STUDY NOTE No.	3209

INTRODUCTION TO THE STUDY NOTE

This study note has been prepared as the basis of study in connection with the qualifying examinations for promotion.

Candidates will be expected to demonstrate knowledge of the information contained in the study note and understand how it should be applied:

The 'References' made at the end of the Study Note are included for information only and candidates will not be expected to study these as part of the bibliography.

BUILDING DESIGN AND STRUCTURAL FIRE PRECAUTIONS

PART 1 BUILDING MATERIALS

1. Introduction

The majority of materials used in the construction industry are subject to tests as to their suitability for particular usage.

A British Standard indicates that a material has passed a particular fire related test. The tests cover a wide variety of situations and are the principal criteria for assessing the fire properties of building materials and elements of structure. Examples of such tests include: ignitability; ease of extinction; flame spread; heat release; smoke obscuration; and tests for toxic potency.

All British standards either already have European or International equivalent standards or will in the future. The Fire Service can expect to find an increasing number of dual standards quoting ISO (International Standards Organisation) and CEN (Committee on European Norms) numbers together with their British equivalents.

Fire testing, if correctly designed and carried out, may, in some cases, be the only available and reliable indication of a material's behaviour in a given fire situation. It can thus be a vital factor in giving detailed answers to questions put in identifying and assessing fire hazards.

It must be remembered that fire behaves in a complex manner and any information gleaned from a particular fire test must not be over-estimated or taken as a prediction of a probable course of an actual fire. It can only predict the behaviour of the test material in the restricted situation of the test itself. A fire test result that shows an acceptable performance by the tested material can never be taken to guarantee a safe situation.

Notwithstanding legislation controls etc, each building is a conglomeration of materials put together in a particular and, almost always, unique way. Therefore, that building's reaction to a fire, or explosion, can never be accurately forecast.

2. Building Materials

An architect will usually design a building using those materials which together with the client agree will suit the required endurance, probable use and relevant building controls and, of course, come within the economic parameters set down.

The building controls include certain standards required to ensure that the behaviour of a building, in a fire situation, is satisfactory.

The point must be made here that fire tests are usually carried out in test rigs which attempt to simulate, as accurately as possible, the kind of situations the material under test could be involved in at a fire. Unfortunately, there are an almost infinite variety of different fire situations, which could involve any material, and it is impossible to simulate them all. In a real fire situation such factors as:

(a) The severity of the fire;

(b) How long the material has been involved;

(c) The position of the material eg wall, floor, ceiling, cladding;

(d) How the material is fixed to adjoining material;

(e) Reaction between the adjoining materials;

(f) The reaction of the material to the extinguishing medium used; and

(g) The standard of the construction and the workmanship etc

all have a bearing on its behaviour.

Primarily it is the contents of a building that give rise to the danger of fire and any system of tests is designed to try and control the level of the fire risk down to an acceptable standard. The fact that materials used in construction have satisfactorily attained a test requirement will not abolish the risk of fire or prevent it but should have a mitigating affect on fire development.

3. The Character and Use of Building Materials

General

This section is based on a list of the materials in general use for the construction of buildings and their contents and some of the dangers, if any, that they can present in the course of firefighting operations.

One point of importance in the fire testing of materials deserves mention at this introductory stage. This is the difference between materials which possess their fire resistant qualities inherently, and those where the qualities are added to them at some stage.

By 'inherently' it is meant that the quality or qualities reside in the physical and chemical composition of the material itself, so that the material will always possess them while it continues to be that material. On the other hand, various forms of treatment are available for different materials, which will improve their fire resistant qualities: sometimes this involves surface application, sometimes impregnation.

In the case of some plastic materials particularly, there are techniques of adding substances at some stage in manufacture; one might think that this would produce 'inherent' qualities in the finished material, but this is not necessarily so.

Any process which might result in an uneven distribution of the additive through the material must be regarded with some reserve.

It is common to find that regulating or purchasing authorities tend to distinguish between materials with an inherent fire resistant quality and those of applied quality in favour of the former. This is due to various factors, the most important of which is uncertainty as to whether the quality is permanent after it has been added and, if not, whether it will last the life of the material in the given situation.

(a) Timber

Wood is a combustible material, which consists essentially of cellulose, hemicellulose and lignin. It is a non-homogeneous and variable material, and even for a given species the properties (particularly structural properties) are dependent upon the grain direction and the size and nature of discontinuities such as knots, shakes etc.

It is common to find solid timber sections employed in the construction of beams for floors, columns and framed walls for use in domestic buildings, offices, schools etc. With few exceptions, these constructions use timber sections in conjunction with various lining materials. Timber floors and timber stud walls are therefore examples of composite constructions in which the combined behaviour of timber and the associated materials determines structural behaviour in fire.

Wood burns, but because it burns at a regular, measurable rate it is possible to deliberately oversize timbers, so that they can be used as structural elements. Such oversizing is often described as 'sacrificial timber'.

The surface degradation of the wood is normally in the form of charring, and the flaming will occur only with temperatures at the surface in excess of 350°C and the presence of a pilot ignition source.

As the outer surfaces of a timber member char, they tend to stay in place and the inner core of the wood remains relatively unaffected and can retain its stability and integrity.

Laminates may actually perform better as they will not be so prone to knots or other deformations of the timber. The use of flame-retardant treatments will not normally slow down the charring rate. It is, of course, possible to protect timber by the use of insulation materials, but as the choice of timber has probably been made because the designer wishes it to be exposed, this is an unattractive option in new buildings. However, it may be necessary when improving the fire safety of existing timber structures to consider the cladding of timber elements with insulating materials.

The great advantage of timber to the designer is that failure is predictable and will occur slowly, the great disadvantage is the dramatic increase in cost of timber elements which have had to be deliberately oversized.

Loadbearing timber walls are usually found in low rise buildings intended for domestic or office accommodation Consequently the fire resistance requirements are for 30 or 60 minutes depending upon the use of the wall. Such walls are an essential component of timber-framed housing where the walls consist essentially of a timber stud framework of storey height, 2.8m or so, in which the uprights are held in place by timber plates at the top and bottom with one or more stiffeners or noggins.

Although there exist examples of timber-framed houses dating back to Tudor times it would be fair to say that the vast majority of houses constructed in timber in this country have been built since 1964-65. Because this form of construction enables a wide range of claddings to be used (eg brick outer skins, tile hanging or cement rendering on metal laths, in addition to timber which itself can be fixed to otherwise traditional brick houses), it is not always obvious whether or not a house is timber-framed.

As one would expect, timber is combustible and there are various flame retardant treatments that can assist in making wood more difficult to ignite. There are two types of flame retardant treatments for timber:

(i) Surface coatings - painted onto the timber surface with little or no penetration into the wood. Some doubt exists as to the permanency over a period of time.

(ii) Impregnation - using a combination of pressure and vacuum this process 'drives' the liquid into the timber. This is a type of permanent treatment but it may affect the cosmetic appearance of the timber in moist atmospheres.

However, the performance of timber in real fires is frequently far superior to unprotected, non-combustible materials such as steel and aluminium for the following reasons:

(i) Timber does not expand significantly under the influence of heat (in fact, it may shrink slightly) and buildings reliant upon timber for structural purposes are not likely to suffer sudden collapse brought about by 'unrestrained' expansion.

(ii) British Standards 476: Part 5 comes to the conclusion that timber in sizes normally used for construction purposes is defined as '...not easily ignitable'.

(iii) Timber has the inherent ability to protect itself; the build-up of charcoal on the surface of burning timber limits the availability of oxygen thereby insulating the remainder of the section.

(iv) It has been established that the burning or charring rate is predictable and varies only slightly with species of timber and not on the severity of the fire. 'Sacrificial' timber built into the construction may be consumed by a fire before the structural core is attacked.

It may also be argued that timber has two further advantages over steel, aluminium, etc these being:

(i) Structural members of timber are less likely to enable the spread of fire from one compartment to another due to thermal conductivity.

(ii) Failure of structural members of timber due to sagging, twisting, softening is less likely.

Laminated timber has become popular in Britain and has been used for decades in Scandinavian countries, as well as France and Germany. This type of timber keeps its structural integrity and its cosmetic appearance is one of its attributes. Spectacular spans of over 150 metres can be achieved thereby reducing the requirement for connectors, which can represent a weak link in any structure.

(b) Stone

Natural stone used for building construction falls within the following general classes:

(i) Igneous rocks - these result from a molten material, which has subsequently solidified. One of the most common in this group is granite;

(ii) Sedimentary rocks - these result from a breakdown of igneous rock into small particles by the changing climatic conditions. The particles fall into low-lying areas to form layers, which over very many years become hardened by pressure. Among this group is sandstone and Portland stone;

(iii) Metamorphic rocks - these result from igneous and sedimentary rock which have undergone a natural change by pressure or heat, and in some cases, both. Amongst this group is marble.

The types of stone principally employed in building are granite, sandstone and limestone. Igneous rocks, such as granite, contain free quartz, which has the peculiar property of expanding very rapidly at 575°C and completely shattering the rock. Considerable spalling at the surface may occur in a fire and thin sections of stone may disintegrate entirely. Limestones are composed principally of calcium carbonate, which decomposes at about 800°C into free lime and carbon dioxide. The change is gradual with little alteration in volume, and as heat is absorbed in the process, the interior of a block of limestone may be protected by the outer skin. Water used in fire fighting will slake away the quicklime so formed and will cause the outer skin to fall away.

Sandstone generally comes between granite and limestone in fire behaviour and may shrink and crack in a fire.

Stone is, in general, a good heat insulator, but is inferior to brick when subjected to continuous heat, because of its tendency to spall or split into pieces, especially when water is suddenly applied. Stonework should always be carefully watched for signs of cracking when it is necessary to work beneath or near it.

Stone and granite is now normally used for facings and decoration and its failure in the event of a fire is unlikely to affect the stability of the structure.

(c) Masonry

Masonry materials have been used for fire resisting constructions ever since the need for fire protection in buildings became apparent. Masonry includes bricks and blocks of clay or concrete covering a wide variety of shapes and densities.

The most common use of masonry is in the construction of walls, of factories; storage buildings; offices and high rise blocks. It can be used in conjunction with concrete, steel or wood structures. Masonry constructions are usually able to withstand exposure to fire without much distress.

Brickwork is generally a very good fire-resisting material. It is quite possible to achieve periods of resistance of up to four hours, the stability of the material being due to the high temperatures to which it has already been subjected during manufacture. However, there may be problems with large panels (over 4 metres) of brickwork due to differential expansion and movement. In these instances, the restraints being applied to the edges of the panels become critical eg brick panels in concrete frame buildings.

The behaviour of solid concrete blocks is similar to that of concrete walls as their properties are similar, but the presence of mortar joints allows improved capacity to compensate for unequal expansion on the section when one face is exposed to heating. Both hollow and solid blocks are not susceptible to damage by spalling. Aerated concrete blocks, owing to the thermal properties of the product, provide good fire resistance as loadbearing and non-loadbearing systems.

(d) Cement

Cement is a fine powder - usually made with various types of Portland cement - which forms part of a combination of materials to make concrete. It reacts chemically with water and the longer the drying process the more strength is developed.

Glass Reinforced Cement (GRC), with its rapidly increasing applications in construction, is a composite material consisting of cement and a small proportion of glass fibres.

The addition of GRC reinforcement enhances the strength and toughness of the cement; however, there is some doubt as to the long-term durability of GRC.

Two particular characteristics of cement can be changed by the addition of small proportions of other materials. For example, cement is inherently fire resistant but the addition of pulverised fuel ash can increase that fire resistance. Cement is also known to shrink considerably when drying and a small amount of sand added to the GRC ensures that this does not happen.

(e) Concrete

Concrete is a cementious material produced by a chemical reaction of Portland cement and water to which inert materials called aggregates such as sand, gravel or crushed stone, are added.

A common error is the use of the term 'cement' when 'concrete' is the proper term; cement is a component of concrete.

Shortly after it is mixed, concrete sets into a solid, rock like mass, but it continues to cure indefinitely.

Whilst curing, concrete generates heat of hydration. During its initial curing, concrete must be protected from freezing as low temperatures retard the curing and freezing is harmful to the material.

Concrete is very weak in tensile strength and has poor shear resistance. Its compressive strength is good, particularly when compared to the cost of steel to resist the same load.

Concrete is inherently non-combustible, it may have been fabricated to meet a specific fire resistance standard. Unfortunately there is often confusion over non-combustibility with fire resistance. Neither is synonymous with fire safety. Concrete can be produced having a wide range of properties such as high compressive strength, durability, thermal insulation and fire protection. All these qualities largely depend on the materials and the proportions used in the mix. When concrete is heated, it expands due to thermal expansion of the materials, but the hardened cement paste also shrinks as a result of loss of moisture by drying out. As a result the overall change is not easily predicted and internal stresses can be set up within the concrete.

In a severe fire, spalling of the surface material occurs and is aggravated if the hot concrete is suddenly chilled, for example with a jet of water. Concrete made with limestones or lightweight aggregates, are very much less susceptible to spalling than those made with more dense aggregates, hence the fire resistance of structural concrete is classified differently according to the type of aggregate used.

It is possible to achieve very high levels of fire resistance with reinforced concrete, up to four hours is easily achieved. However, as reinforced concrete depends for its tensile strength on the steel reinforcement, it is critical that in the design of the elements sufficient protection is provided to the steelwork. Simply increasing the thickness of the concrete cover to the reinforcement does not necessarily give the corresponding increase in safety because of the tendency of concrete to spall (break off) in a fire. This can reduce the cover and it may be necessary to provide supplementary reinforcement to counteract this danger if the cover is thicker than 40mm.

One of the critical issues in the fire resistance of concrete is the nature of the aggregate, which is being used, certain aggregates being more resistant to spalling and having a lower thermal conductivity. The issue of thermal conductivity is particularly important when the assembly is also providing a subdivision and it is necessary to limit heat transfer. Also critical can be the use of permanent steel shuttering when it is necessary to design concrete slabs to be able to withstand the failure of the steel.

There are two basic types of concrete construction:

1. Cast-in-place, which includes plain concrete, reinforced concrete and post-tensioned concrete; and

2. Pre-cast, which includes plain concrete, reinforced concrete and pre-tensioned concrete.

Within the types of concrete construction, certain definitions are used, they include:

Aggregate - this material is mixed with cement to make the concrete. Common aggregates are both fine and coarse. Fine aggregate is usually sand. Coarse aggregate may depend on the desired characteristics of the finished product and include crushed stone, gravel, shale, slate or clay.

Cast-in-place concrete - this concrete is moulded in the location in which it is expected to remain.

Casting - the process of placing fluid concrete into moulds, generally called forms, in which the concrete is permitted to harden to a certain shape.

Plain concrete - this term refers to concrete that has no reinforcement.

Pre-tensioning and post-tensioning - these are processes by which steel rods or tendons are placed under tension drawing the anchors together. The tensioned steel places the concrete in compression.

Pre-cast concrete - this concrete has been cast at a location other than the place where it is to remain.

Pre-stressed concrete - pre-stressing places engineered stresses in architectural and structural concrete to offset the stresses, which occur in the concrete when it is placed under load.

Reinforced concrete - this is a composite material made of steel and concrete. Steel provides the tensile strength that concrete lacks.

Spalling - this term describes the loss of surface material when concrete (or stone) is subjected to heat. Some concrete and certain aggregates are more subject to spalling than others.

Concrete may be in one of the following forms:

(i) Reinforced concrete

Except for concrete bricks and blocks, concrete is rarely used for structural purposes without being reinforced because it is relatively weak in tension and prone to crack. High tensile steel - hot rolled bars or cold-worked bars of different types - have been introduced over the years as the reinforcement agent. In reinforced concrete, the steel is not stressed until loads are imposed on the structural member.

(ii) Pre-stressed concrete

Pre-stressed concrete is a form of structural concrete in which tensile steel tendons are stressed against the length of concrete, which is thus put into compression, before imposed loads are applied. Pre-stressed concrete is sub-divided into pre-tensioned and post-tensioned systems.

(iii) Pre-tensioned concrete

This has the tendons stretched and anchored independently of the concrete before the concrete is cast around them and allowed to harden. The tendons are then released from their anchorage but, because they are now bonded to the hardened concrete, they are anchored by the concrete and put it into compression.

(iv) Post-tensioned concrete

This is cast with ducts through which the tendons are threaded and then stressed after it has hardened, each tendon being anchored against the concrete. The tendons may remain unbonded, but often the space between the tendons and the ducts is grouted so that the tendons become effectively bonded to the concrete and at the same time are protected against corrosion.

No distinction is drawn between the different forms of pre-stressed concrete in assessing their fire resistance.

The fire resistance of concrete itself is determined by the aggregate used in its make-up. However, the fire resistance of structural concrete, whether reinforced or pre-stressed, is determined primarily by the protection of the steel against an excessive rise in the temperature. This is afforded by the concrete cover, i.e. the concrete between the surface of the member and the nearest surface of the embedded steel.

Generally, the greater the amount of cover, the longer the period of fire resistance.

In a fire, structural concrete does not normally collapse suddenly - it may deflect considerably under load, and floors may suffer local break down, but even after a severe fire most concrete structures are safe enough to be reinstated to perform their original functions.

(f) Metals

Whilst a number of different metals are used to some extent in building, only **iron and steel** are normally used for those parts which have to carry any load. **Cast iron** possesses relatively little strength in tension, but is capable of sustaining a considerable load in compression. Cast iron was very widely used in the 19th century for beams and columns, and even now, there are many buildings in use which are supported by cast iron columns and beams.

Iron and steel used in the construction of a building are not combustible and present no risk of fire spread from direct burning.

Unprotected metal surfaces may, none the less, constitute a serious risk in a fire because all metals heat up and expand when exposed to fire and are also a potential cause of fire spread by conduction. Unprotected metal, which is used to carry a load also, presents the even more serious danger of rapid collapse when excessively heated.

Structural steel, for example, loses two-thirds of its strength at 593°C and, in proportion to the amount and direction of the load to which it is subjected, begins to sag and twist. This is by no means an abnormal temperature in even a moderate fire - the danger of the failure of unprotected load-bearing metal work cannot be over-emphasised.

A 10 metres steel joist, for example, will expand 60mm for a 500°C rise of temperature, and where it is built into a load bearing wall, such expansion may cause collapse.

In a framed building, the failure of a single beam or column is unlikely to cause more than a local collapse. It is clear then that all structural steel must be protected either by solid or hollow protection.

Because it is prone to rapid corrosion, **stainless steel** is invariably coated, normally with a protective metal coating in the first place, and, outside this, frequently with some form of mineral and resin mixture.

This is liable to produce the anomaly that, whereas steel itself is non-combustible, a protected steel sheet of the type described may well have a surface spread of flame classification.

Increasing use is being made of **aluminium** and its alloys for structural and cladding members and this has created new fire problems.

The advantages of using aluminium alloy in buildings are:

(i) A reduction in the weight of the structure;

(ii) Resistance to corrosion;

(iii) Ease of handling and working; and

(iv) The high strength to weight ratio.

The disadvantages are:

(i) The vary rapid loss of strength in fire (stability is affected at 100°C to 225°C).

(ii) The high expansion rate (approximately twice that of steel).

(iii) Its very low melting point (pure aluminium melts at 660°C).

Lead is principally employed for flashings and roof coverings. It melts at 327°C and precautions should therefore be taken against injury from molten metal when working beneath a lead roof at a fire in older buildings. **Copper** and **zinc** are also used for roof coverings but their melting points are much higher and the metal usually oxidises away under the influence of the fire so that there is rarely much danger from falling molten material. **Bronze** has a melting point about 1000°C, but is normally only used for decorative grilles, handrails, etc and occasionally for window frames.

(g) Glass

Glass is non-combustible and will not, therefore, contribute fuel to a fire or directly assist a fire to spread. At one time, glass would have constituted a major weakness in a wall, door or screen because it would break and fallout. Fire resisting glazing not only provides an effective barrier to the spread of smoke and flames, it can also provide protection against radiant heat in a fire.

Architects and designers are no longer restricted by solid materials such as timber and metals. Today in its various fire safety forms, glass offers new dimensions and designers can create the feeling of more light and space with glass. In high security areas such as Banks and Building Societies, the glass may be specially toughened to resist vandal attacks.

Until recently, limitations were placed on the use of glass as an element of building construction in fire resisting applications. This was due to the natural property of glass to directly transmit radiation. When a fire is fully developed, high levels of transmitted radiation through glass may present a hazard to people escaping or possibly cause the ignition of combustible materials resulting in fire spread. Thus, a window in a compartment wall could be a weak link.

However, clear vision through a wall or door can also provide safety benefits in the event of a fire, enabling the location and safe evacuation of occupants from burning buildings. This is particularly true in fire doors and has led to the extensive use of wired glass in these locations.

Normal glass has very little fire resistance, offering little insulation and being liable to lose its integrity and stability as it shatters under fire conditions. However, there are three types of glass now available which offer some degree of fire resistance.

The familiar **Georgian-wired** glass can solve the problem of stability and integrity by holding the glass in place, but this still does not offer any insulation and radiant heat can still pass through the material. Wired glass permits the transmission of heat radiation from the fire, yet provides specific resistance to the passage of flames and smoke; it is a non-insulating glass. Other non-insulating, non-wired glass products with similar properties have also become available in recent years owing to improvements in glass processing technology.

Toughened glasses are now available which achieve the same integrity and stability as the wired glass without the unattractive appearance of the wires, yet these also fail to provide any insulation.

The one type of glass which does offer insulating properties is **laminated** glass. These incorporate a completely translucent and transparent intumescent layer, which, on the application of heat expands to form an insulating barrier. These glass products have the ability therefore, to resist fire radiation transmission, by becoming opaque when subjected to heat above 120° Celsius. Such fire insulating glass products enable glass to be used in larger sizes and in locations, which were previously served by traditional opaque fire compartment materials, such as brick or concrete.

The disadvantages of such laminated glass lie in its weight, cost and limitations on external use.

With all three types of glass (wired, toughened and laminated), the design of the frame is as important as the choice of glazing material and it is essential that the frame will survive as long as the glass. It is crucial that the architect considers the fire resistance of the glazing assembly and not just the glazing material itself.

The performance characteristics of glass therefore will vary with its composition. In order to achieve levels of fire resistance from glass, it is necessary to ensure that it is glazed and framed in ways that are specified for that particular product.

Normally, glass can be divided into the following categories:

(i) Non-insulating glass products

These are glass products able to resist the passage of smoke, flames and hot gases, but not able to satisfy the insulation criterion. Regulations may place limits on the location or areas of non-insulating glass that may be used.

There are basically two types of glass which are considered non-insulating:

1. Wired glass - Wired glass is generally 6mm thick and is manufactured by sandwiching an electronically welded steel mesh between two layers of molten glass in one continuous rolling process. On exposure to fire, the glass breaks due to thermal shock but the wire mesh within the glass maintains the integrity of the specimen by holding the fragmented pieces in place. Thus, the integrity and stability are retained in a fire, and the spread of smoke and flame is prevented even though the glass may be badly damaged.

2. Special composition glass - On exposure to fire, owing to its low coefficient of thermal expansion, the glass does not break and hence remains unbroken within its frame. The glass may also be thermally strengthened to minimise the effects of stress, thereby achieving a level of impact safety.

(ii) Partially Insulating Glass Products

These have fire resistance properties, which lie between the insulating and non-insulating glass products. They are usually multi-laminated panes incorporating one intumescent interlayer which becomes opaque on heating. As a result of this intumescent interlayer, they are able to resist the passage of smoke, flames and hot gases and meet the insulation criterion for up to 15 minutes. The temperature on the unexposed surface, after this time, then rises beyond the accepted criterion level, but less quickly than for non-insulating glass.

(iii) Insulating Glass Products

These are glass types, which are able to resist the passage of smoke, flames and hot gases and meet the insulating criterion for at least 30 minutes. National regulations generally require 30, 45 and 60 minutes compliance.

There are two types of insulating glass available. The first is intumescent laminated glass formed from multi-laminated layers of flat glass and clear intumescent interlayers. The fire resistance depends on the special composition of the interlayers, which react to high temperature by intumescing to produce an opaque shield that resists the transmission of radiant and conducted heat. On exposure to the fire the glass fractures, but remains bonded to the interlayer. The level of fire resistance achieved is directly related to the number of interlayers.

The second is gel interlayed glass formed from a clear, transparent gel located between sheets of toughened glass separated by metal spacer bars and sealed at the edges. The level of fire resistance achieved is related to the thickness of the gel interlayer. On exposure to fire, the gel forms a crust and the evaporating water from the interlayer absorbs the heat energy. This process continues until the gel has burnt through.

(iv) Multi-laminate glass

This relatively new fire-resisting glass is manufactured from multi-laminate panes of float glass with clear intumescent interlayers. On exposure to fire the intumescent layers expand to form an opaque shield which forms an effective barrier to smoke and flames and prevents the transfer of radiant and conductive heat.

(v) Heat treated fire glass

This type of glass is wire free and as such can be fractured early on in a fire if subjected to thermal shock. The important aspect here is the 'edge' of the glass. This must be protected from the full force of the fire. As with all windows, it is absolutely vital that the glass is installed properly to ensure that it performs correctly and does not fracture. Glass by itself is not fire resisting. The level of fire resistance achieved is that of the system - glass, beads, glazing materials, frame and frame restraint detail. The whole system is only as strong as its weakest component.

It is imperative however with fire resistant glass that the whole glazing system, including the frame and method of fixing must have fire resistance, not just the glass itself.

(h) Building Boards

Whatever the cause of a fire within a building, the surfaces of wall and ceilings will contribute to the fire if they are ignited. Ensuring that these surfaces are non-combustible or at least very difficult to ignite, means that, if a fire does start, its rate of growth will be reduced. It is also desirable to keep to a minimum the amount of smoke or toxic fumes given off from this type of surface if involved in a fire, particularly those lining escape routes.

A wide range of materials is used in the manufacture of sheets of varying sizes, thickness and fire resistance. They bear many different trade names but may be classified generally in one of the following groups:

(i) Fibre building boards

Fibre building boards are manufactured in a wide range of sheet materials, usually more than 1.5 mm thick. They are made from actual wood fibres or woody plants and derive their basic strength and cohesion by the felting together of the fibres themselves, and from their inherent adhesive properties. Bonding, impregnating or other agents, including fire retardants, may be added during or after manufacture to modify particular properties.

Fibre building boards fall into two major groups according to whether the board has been compressed in a hydraulic press during manufacture or not.

1. The non-compressed type is termed insulating board (softboard). This is used in sheet form and as tiles. Bitumen impregnated insulating board also comes within this category; it is used for sheathing timber-framed buildings and for roof lining, the bitumen content gives it a high resistance to moisture.

2. In the second group are medium boards of low or high density, from 6-13 mm thick, and hardboards. Standard hardboard is a dense sheet material 2-13 mm thick with one smooth face and a mesh pattern on the reverse. Tempered hardboard, 3-13 mm thick, has high strength and water resistance. It is made by impregnating standard hardboard with oils and resins, usually immediately after pressing, and then applying further heat treatment. Building boards of this group are not easily ignitable but all are combustible.

(ii) Plaster boards

Plaster boards for interior use are composed of a core of set gypsum or anhydrite plaster enclosed between, and firmly bonded to, two sheets of heavy paper to increase their tensile strength. In a fire the exposed paper face may burn away making it relatively easy to break up the non-combustible gypsum core, but until this happens, the plaster board will retard the spread of fire.

Vermiculite is a clay-mineral which expands to many times its original volume when subjected to high temperature. It is incorporated in plasterboards to give it a superior fire resistant rating than ordinary linings. Plasterboard and vermiculite can also be mixed with other products such as silicate which again is non-combustible and does not emit smoke when involved in fire.

(iii) Asbestos boards

It goes without saying that asbestos does not form a part of the composition of today's products but cement sheets or insulating or wallboards may still be found in older buildings. When subjected to fire, the amount of smoke given off is negligible.

(iv) Plywood boards

Plywood boards are made up of thin wood laminations laid in alternate directions to increase their strength. Their susceptibility to fire depends on the type of timber used and the overall thickness of the board. The type of bonding material may have some bearing on the development of a fire.

(v) Block boards

These are made from a core of separate wood blocks bonded together and finished externally with a veneer or plastic overlay to give the appearance of a homogenous board. They are produced in many grades and qualities and their behaviour in fire varies accordingly.

(vi) Plastic boards

Plastic boards are composed of organic materials, eg paper, linen, sawdust or woodchips, bonded together with synthetic resins and subjected to heat and pressure. Phenolic laminates are rigid boards made of sheets of special paper impregnated with phenol-formaldehyde and urea-formaldehyde. This type of board has good fire resisting properties and usually incorporates a flame-retardant substance in its manufacture. Resin-bonded sawdust (or woodchip) boards are sawdust and/or woodchips bonded with synthetic resins, and are man-made timbers; their behaviour in fire is dependent on their surface treatment.

`There are many other types of popular plastics available. One, which has increased in use, is expanded polystyrene, which is often used as wall and ceiling tiles because of its good thermal insulation qualities. Although this is available in flame retardant grades it is known to burn fairly rapidly and often softens and collapses. Foamed polyurethane in flexible and rigid forms are also excellent thermal insulators and are used in various applications as a weather resistant coating. Again this is available in flame retardant grades but generally burns rapidly producing thick dark smoke.

(vii) Sandwich panels

Sandwich panels are building elements, which comprise of an insulating core within an outer skin. They are used for both the outer envelope of lightweight buildings, or to create partitions within a building.

One of the largest users of such panels is the food industry for such premises as cold stores or meat processing. Here the outer skins are often coated to provide a food safe surface that can be frequently washed down with water sprays.

Although widely used in the food industry, sandwich panels can be found in a wide variety of situations. Sandwich panels present a particular hazard when involved in fire and the subject is dealt with in greater detail in Study Note 3106.

(i) Building slabs

Building slabs can come in a variety of sizes and are generally made out of long wood fibres mixed with Portland cement and compressed. They are combustible but the wood is chemically treated to provide fire resistance and often are water-resistant as well. Slabs are used for roof decking and provide sound and heat insulation.

(j) Building blocks

Building blocks, like bricks, are used for the construction of walls of all types, and they have become popular because of the savings resulting from the improved productivity when laying units larger than bricks. Blocks are generally made of concrete combined with various types of aggregates which give the block different load bearing qualities whilst others are designed purely for insulating qualities.

Hollow-fired clay blocks combine a clay aggregate to produce a particularly lightweight block. The hollow interior is filled with polyurethane foam to give it excellent thermal properties.

Their fire resisting qualities are generally better the greater their thickness and the smaller the proportion of voids.

In a fire, the face of the block exposed to the fire, whether used in a partition or a floor, may spall as a result of the unequal expansion of the material in the block as the temperature rises.

There are several types of concrete block, which are made in a variety of thickness from 50mm to over 100 mm thick. Their size and whether they are solid or hollow decide if they are to be used as load bearing walls or non-load bearing partitions. Most are moulded by special machines from concrete made with normal dense or lightweight aggregates.

A completely different process using cement and sand and/or pulverised-fuel ash or cement and lime makes aerated concrete. The addition of fine aluminium powder causes the formation of numerous small air cells. A large 'cake' is produced which is cut into pieces and autoclaved (high pressure steam curing).

For the purpose of determining fire resistance, machine-made blocks are divided into classes according to the type of aggregate used in their manufacture.

All types provide a high degree of fire resistance with little risk of collapse or deterioration and, therefore, give effective compartmentation

The fire resistance of block walls is improved if they are plastered on both sides and especially so if a lightweight plaster, such as vermiculite-gypsum plaster, is used.

(k) Insulating material

(i) Cavities

In order to reduce heat transmission in hollow spaces such as those between double partitions between an exterior wall and an internal lining, in a floor or in a roof, they are frequently filled with materials, which are of a loose fibrous nature and have a low conductivity. Many substances have been used for this purpose, including such combustible materials as cork, sawdust and peat. Modern research, however, has produced non-combustible substitutes such as rock or glass wool, foamed slag, vermiculite, etc.

Polystyrene is well known for its good thermal properties and comes in various forms such as rigid or flexible sheets, in granulated form or as a spray - it has the disadvantage however of having little fire resistance.

(ii) Spray-on insulation and intumescent seals

It is essential that the structure of a building is safe under fire conditions and retains its integrity long enough for the brigade to carry out its duties.

Since the advent of sprayed asbestos, new technology has developed a wide range of spray-on products like vermiculite-cement and sprayed mineral fibre, some of which are designed to withstand high intensity fires which might be experienced, for example, in the petro-chemical industry.

Intumescent strip seals and acrylic mastic have been developed to provide protection and maintain fire resistance in gaps and joints which are flexible enough for structural movement. These various types of internal and external insulation material not only help a building to reduce heat transmission or protect it in the event of fire; it also helps to reduce condensation and deaden sound.

(l) Paint

Paint is used both as a preservative and as a decoration principally for woodwork, steelwork and plaster, and is sometimes applied to brickwork. Paint consists of a pigment (normally a powdered solid) carried in a liquid which, by chemical action and evaporation, allows the film to harden. Almost all paints, with the exception of fire retardant paints mentioned later, are flammable, but the film is usually so thin that it has no appreciable effect on a fire, although under certain conditions it can foster surface spread. Sometimes, however, when many coats of paint have been applied over a number of years, the film may be sufficiently thick to become flammable and constitute a fire risk. The paint on steelwork, for instance, can ignite if heated sufficiently by a fire, eg the far side of a bulkhead in a ship fire. Where appearance is unimportant, tar or bituminous paint is sometimes used and the film may then be sufficiently thick to burn even though applied to steelwork with no other combustible material present.

Fire retardant paints are occasionally used to protect timber and are of two types. One type is a fairly heavy-based paint which will not inhibit combustion completely, but will do much to reduce flaming, whilst the other, which is termed 'intumescent paint', will, when subjected to heat, bubble up and form a layer of air cells which acts as an insulation between the heat of the fire and the timber underneath.

The development of intumescent coatings has proved to be a technological breakthrough. Originally, this type of paint was designed to retard flame spread but has now been developed to react chemically to heat exposure by undergoing a physical change. On reaching temperatures in excess of 200°C the paint develops into a thick insulating foam which can protect steel for long periods of time depending on the thickness of the coatings.

(m) Plastics

The term 'plastics' is a generic name for a group of materials based on synthetic or modified natural polymers which at some stage of manufacture can be formed to shape by flow, aided in many cases by heat and pressure. They can be **thermosetting**, ie they will not soften significantly on heating to a temperature below decomposition temperature, or **thermoplastic**, ie capable of being softened by the application of heat.

Plastic materials of different degrees of stiffness are described as rigid, semi-rigid and non-rigid plastics. Reinforced plastics consist essentially of polymer combined with fibrous material to enhance its mechanical strength. This term is most commonly used for thermosetting polyester resin with glass fibres. One of the uses of this material is as external cladding in the form of moulded panels in building systems. It can be formed to a wide variety of shapes, colours and textures; components made from it are light in weight and its mouldability allows the incorporation of detail that would be impossible to achieve with other materials.

Cellular plastics are made up of a mass of cells in which the matrix is a plastic material.

Foamed plastics are cellular plastics made mainly from liquid starting materials, eg polyurethane foam.

Expanded plastics are made by stamping or cutting plastics sheet and stretching to form open meshes, in the same way as expanded metal is formed.

The problems of tensile strength and compressive strengths of these materials for their possible use as structural elements have not yet been fully resolved and, except for small complete structures, they are not used for load bearing members.

A substantial amount of plastic material will, however, be encountered within buildings in the form of thermal insulation, service pipes, wall, floor and ceiling covering, furniture, furnishings and fitments. Translucent pvc sheeting is widely used for roof lighting and clear acrylic resins used for shaped lighting panels as in domes. Plastic materials cover such a wide range of substances that their properties and behaviour in fire can be described only in very broad terms. It depends upon the composition and method of manufacture, the free access to air and any support to combustion that may be available. The products of combustion of many plastic materials may be very toxic; again this is dependent on the type of plastic and the combustion of other materials that may be involved in the fire.

4. Statutory Requirements Relating to Building Construction

Building Controls

All building works, with a few exceptions, within the UK are controlled by legislation. The legislation covers all aspects of construction including structural fire precautions and some means of escape. The principle is to provide for the health, safety and welfare of people and is not, primarily, for safeguarding property or limiting economic loss. The requirements of regulations relating to fire can be put under the following headings:

- Means of escape
- Internal Fire Spread (Linings)
- Internal Fire Spread (Structure)
- External Fire Spread
- Access and Facilities for the Fire Service.

In Scotland the requirements of regulations can be put under similar headings:

- Fire resistance and non-combustibility
- Distance of sides of buildings from boundaries
- Means of escape from fire
- Internal fire spread
- Facilities for firefighting
- Means of warning of fire.

PART 2 ELEMENTS OF STRUCTURE

1. Fire Resistance of Structure

Premature failure of the structure can be prevented by provision for load bearing elements of structure to have a minimum standard of fire resistance, in terms of resistance to collapse or failure of load bearing capacity. The purpose is threefold:

(i) To minimise the risk to occupants, some of whom may have to remain in the building for some time whilst evacuation proceeds if the building is a large one.

(ii) To reduce the risk to firefighters who may be engaged on search or rescue operations.

(iii) To reduce the danger to people in the vicinity of the building who might be hurt by falling debris or as a result of the impact of the collapsing structure on other buildings.

2. Columns

The function of a column is to carry part of the weight of the building where an internal wall would interfere with the designed use or where a large open space is needed. A column is often designed to withstand only vertical loads and any eccentric loading greatly increases the stress and will overturn any column not rigidly fixed at its foot. Principal materials, which have been used for the construction of columns are: timber; brick; stone; reinforced and pre-stressed concrete; cast-iron and steel.

(a) Timber

At the beginning of the 19th century timber was normally used for columns in multi-storey factories and mills and some of these buildings still exist. Timber columns are usually found fitted with cast-iron caps, which accommodate the ends of the wooden beams. When these columns are located one above the other, on various floors, a cast-iron pintle (a bar of round section) runs through the beam in line with the column and transmits the load. This avoids the undue crushing force on the intervening timberwork.

(b) Laminated timber

Techniques for laminating sections of timber are well established and usually replace the more costly baulks of timber. The sections are described as "glulam" and their designed load-carrying capacity can be accurately calculated as well as their fire resistance.

(c) Brick

Brick columns are usually found in basements supporting beams which, in turn, take the load of the building above. Developments of brick columns in buildings are post-tensioned columns. These are stressed in a similar way to post-tensioned concrete and resist forces, which would tend to overturn the column, by compressing the column lengthways. These can be found in all areas of a building.

(d) Stone

Stone columns in old buildings, even if particularly massive in appearance may not be as solid as they look. Some will have been constructed with facing stones filled behind with rubble and mortar. This rubble could have settled leaving the column load carried by the facing stones only. More modern columns may, or may not, be load bearing but where they are they will most probably conceal steel stanchions behind a stone face. Firefighters should also be aware of the trend nowadays of erecting "stone" columns, which are made of tough plastic or fibreglass covering a steel girder.

(e) Reinforced concrete

The reinforcing steelwork in structural concrete has developed to a very high standard. Pre-cast factory constructed units are probably more in use on sites using modular building methods but a lot of steel fabrication is done on site and the concrete poured into form work around the steel reinforcement. The fire resistance of a concrete column depends on:

(i) The applied load.

(ii) The type and strength of the concrete.

(iii) The dimensions of the column.

(iv) The method of reinforcement.

(v) Its resistance to collapse.

A column should have at least the fire resistance of the elements of structure which it supports or carries and this, under the Building Regulations or Standards, depends on what type of structure they are a part. Obviously a higher standard of fire resistance will require greater dimensions and adequate protection of the steelwork.

(f) Cast-iron

Although seldom used in modern buildings, cast iron columns will be found in many old buildings and especially manufactories. There are numerous shapes and fittings and often different types will be found in the same building where extensions have been carried out. A common type is a circular tube with a rectangular capping which carries the ends of the beams. The height of the column is the same as that of the floor and can vary from 2.7m to 6m whilst diameters can be 450mm on the lowest floor of a large building to 150mm on the top floor of a small building. The bases of the columns on each floor fit into the caps of the columns below but are not, usually, bolted to them. Quite often a central spigot fits into a socket and these can be either of wood or metal

It is not unusual to find cast-iron columns still standing after a fierce fire when the remainder of the building has collapsed.

(g) Structural steel

Steel columns are usually H section rolled as a single piece. Occasionally, where necessary they may be strengthened by flat plates riveted to the flanges and they can run up through more than one floor. The horizontal joists carrying the various floors would then be bolted or riveted to the column. Structural steelwork has the disadvantage of being unable to withstand the high temperatures generated under fire conditions and it will quickly loose its strength, buckle and fail. It must, therefore, usually be protected where fire resistance is required and the type of protection can be either "solid" or "hollow".

(i) Solid protection

This is achieved by:

1. concrete encasement;

2. spraying with different types of mineral fibre vermiculite cements; or

3. application, either by spray or brush, of intumescent paints.

The degree of fire resistance required in the case of the first and second method will depend on the density of the application and its thickness. The same applies in part to the third method although the chemical ingredients will dictate the amount of intumescing that takes place and also the protection afforded by the carbonaceous char.

(ii) Hollow protection

This is the encasement of steelwork by fire resistant boards. Again the materials from which the boards are made vary from manufacturer to manufacturer. Vermiculite is often used, sometimes combined with gypsum, but there are other ingredients.

Further methods use covered mesh protection, which combines fire resistant compounds sprayed onto a fire resisting metal mesh surrounding the steelwork. An even further method is to fill in the hollow protection with additional thermal protection - mineral fibre, fibreglass, rock wool, foamed slag etc. All of which will add to the fire resistance of the steel. Needless to say most of these coverings should be finished off very carefully at joints, especially at floors and walls, to ensure that the whole is up to the required standard.

The fire resistance of the various methods of protection must be at least that laid down by Building Regulations and Standards for that particular type of occupancy. In addition any column must have the fire resistance of not less than the period required for any element which it carries and, if it forms part of more than one building or compartment, must comply with the maximum fire resistance for those buildings or compartments. Heavy steel columns fail less readily than light ones as the thermal capacity (ie the ability to absorb heat) of the heavy column is greater for the same temperature rise. Consequently, a light steel column will require probably more protection than a heavy one.

3. Beams

The primary function of a structural beam is to support an applied load. A simple beam is one of short span supported at each end. A continuous beam is one used in longer spans and supported on a series of columns. In this way a greater load can be carried than by using a series of simple beams. When a load is applied to a beam it bends slightly ie deflects the upper section being compressed and the lower section tending to stretch, ie be put under tension.

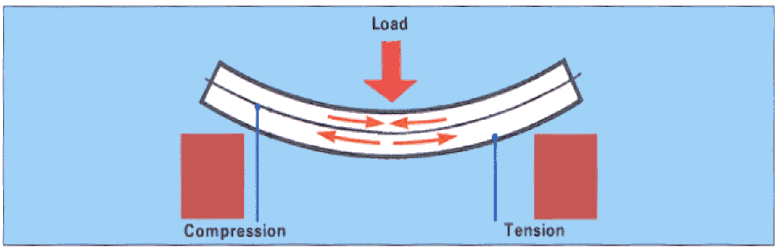


Diagram showing the effect of deflection on a beam. The curvature shown is greatly exaggerated

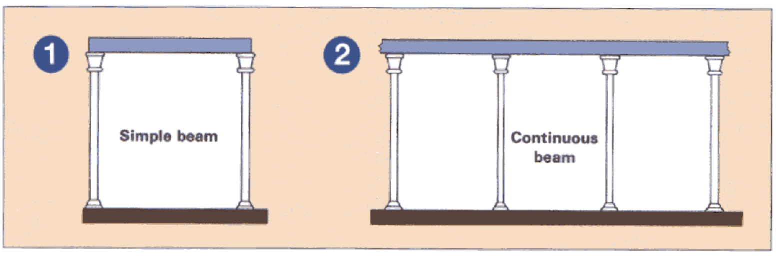


Diagram showing the two types of beam: (1) a simple beam, (2) a continuous beam

(a) Timber

Except in houses, solid timber is very seldom used in structural framing but could be found in the older industrial buildings.

The use of laminated timber for public buildings is however common. The structural integrity is good.

(b) Reinforced concrete

To compensate for its lack of tensile strength concrete beams are reinforced by high tensile steel rods. These are usually held in place by a designed system of steel latticework according to the type of construction strength required and then encased in concrete.

Steel is used for reinforcement for 3 reasons:

(i) It can withstand high tensile stresses;

(ii) The expansion rates of steel and concrete are almost the same; and

(iii) The adhesion between the 2 surfaces in contact results in efficient bonding of the 2 materials.

These beams are inherently non-combustible but the fire resistance is dependent on the cross-sectional area of the beam and the amount of concrete cover provided for the reinforcement. Although reinforced concrete is a good structural material, being very strong and capable of almost limitless fabrication and flexibility in design, it has 2 main problems:

(i) The heavy dead load of the material results in limited effective spans of floors and beams unless specialist techniques are used.

(ii) Due to the low elasticity of concrete and the high elasticity of steel, soffits of floors and beams may crack on overload and the steel, if not properly protected, may be attacked by the capillary action of moisture etc.

This is one of the reasons why, in order to overcome these problems, a system of pre-stressing concrete was introduced.

(c) Pre-stressed concrete

This method depends on the reliability of control of the aggregate and mix proportions, the placing of the concrete, the quality of the steel reinforcing and the application of the precise degree of stress to the cables.

There are 2 methods of pre-stressing concrete:

(i) Pre-tensioning

Here the cables are stretched between the anchor blocks fixed to the pre-stressing bed. The framework is then arranged around the cables and concrete case. When the concrete has matured sufficiently, the cables are released and, in trying to return to their own lengths, they compress the concrete

(ii) Post-tensioning

The method used here is that the cables are stressed after the concrete is set and has reached an adequate strength. The cables, or bars, are anchored at one end of the members and, using a special jack, are stretched until the right stress is reached and then anchored at the other end. The whole idea is to induce the concrete in the "tensile region" to be in compression. When a load is applied there remains, in the normally "tensile zone", sufficient compressive strength to neutralise the tension.

(d) Cast-iron

Although beams are no longer made of cast-iron there are many which still exist. A feature of all cast-iron beams is a large bottom flange the top flange being smaller or, occasionally, omitted altogether. Stiffeners are cast on the web and the ends shaped to fit the head of the cast-iron column to which they are bolted.

(e) Steel

Beams of structural steel are usually referred to by the function they are required to perform eg main beam, tie beam, joist. The term "universal beam" is used to denote one of a range of sections usually of the same type but varying in size and mass per kilogram per metre run. Most beams are of a rolled "H" section with, if necessary, additional flat plates riveted to the top and bottom flanges to give it added strength. Where fire resistance is required the same methods as specified for columns apply.

(f) Steel lattice

This type of beam consists of cold-rolled steel bars or tubes welded to top and bottom plates most of which are profiled for a particular reason which can be used as permanent shuttering for a reinforced concrete slab. These beams are light but strong, easily erected and ideal for lightweight roofs or floors and are found in large single and two-storey industrial storage and commercial buildings.

(g) Open-web - castella type

This type can be used as permanent shuttering for a reinforced concrete slab. These beams are light but strong, easily erected and ideal for lightweight roofs or floors and are found in large single and two-storey industrial storage and commercial buildings.

This type of beam has been cut along a castellated line and then welded back together again. This increases the depth of the beam one and half times and reduces the deflection under load. Both steel lattice joists and castellated beams are often used to support ceilings as their design allows all types of services to be run through the beams.

4. Walls (load-bearing)

As with steel beams, walls are usually referred to by the function they perform eg external, compartment, separating and load bearing.

In the following paragraphs some of the types of load bearing walls are described.

(a) Solid brick

The commonest type of load bearing wall, and one which is also widely used as a non-load bearing panel wall in a framed building, is made of brick. The thickness of a brick wall is measured in multiples of a half-brick.

The bricks are bedded in mortar which may consist of a mixture of lime and sand with water (lime-mortar) or a lime mortar to which has been added a proportion of cement (lime cement mortar or "compo") or of a mortar consisting of cement, sand and water.

Lime mortar is relatively soft and may be protected on the outside of the building by "pointing" the joint with a stronger mortar.

Bricks are arranged in a wall so that the vertical joints of one layer or "course", do not coincide with the joints of the course below. This is known as "bonding" and a number of different arrangements or "bonds" are in general use.

(b) Cavity brick

Cavity walls are used mainly as external walls in buildings particularly exposed to weather. The object of the cavity is to prevent rain penetrating to the inside face of the wall. The usual type of cavity wall found in domestic buildings consists of two half-brick walls held together by metal ties and separated by a 50mm cavity. Sometimes the internal wall is only 76mm thick in modern buildings and is built either of bricks laid on edge or concrete slabs. Whatever method is used the weight of the upper floors, and sometimes the roof, is carried on this internal wall.

The cavity may, or may not, be ventilated to the outside air by airbricks at the top and bottom. In practice the cavity is filled with an inert material giving additional thermal insulation to the building.

Another type of construction, which uses brick as the "outer skin" is the timber-framed construction. Here the main structure is of timber with the frame clad internally and externally with building board usually of an insulating type. On the outside of this, with a small gap, is laid a conventional brick "skin". A membrane of either plastic or bitumenized paper is placed between the inner and outer skins. In order to prevent fire spread in the cavity a system of fire stopping is placed at appropriate spots in the cavity.

Even if construction is carried out to a good standard, firefighters may have to penetrate the inner skin to locate, and extinguish, a fire in the cavity. This type of construction is not limited to houses but may also be found in two-storey residential homes, hotels, schools etc.

(c) Timber-framed

It must be stressed that this type of timber framing is very different to that in the preceding paragraph, and is usually only found on very old buildings. The timbers here are infilled with brickwork; plaster reeds and plaster (wattle and daub) and various other materials including flints and stones. Again, due to settlement, additions to the building over a long time, alterations internally, rodents etc. any fire can spread through numerous cavities and break out almost anywhere.

(d) Other walls

There are numerous types of solid walls ranging from the old stone walls a meter thick to stone-fronted brick walls. Other walls can consist of hollow blocks faced with stone slabs or concrete blocks built up in brick formations and rendered with plaster.

Behaviour of load bearing walls in fire.

The stability of a brick or stone wall depends, amongst other things on:

(i) Its thickness in relation to its height;

(ii) On proper bonding (in particular on the use of sufficient headers to tie the wall together);

(iii) To some extent on its age; and

(iv) On any horizontal pressure or levering effect which may be exerted on it.

In a stone wall it also depends on the proportion of smaller stones which have been used and the skill of the builder. The fewer the number of joints and the thinner they are then the greater the strength of a stone wall.

A brick or stone wall, though capable of supporting a considerable vertical load, can only withstand a comparatively small sideways 'or lateral pressure and, for stability, the loading of a wall must be centred within the middle third. Provision is usually made in the design of the structure to withstand any normal lateral pressure, either by making the walls themselves thick enough for the purpose, or by the erection of transverse walls or buttresses. No provision is usually made for abnormal conditions such as may be brought about by fire.

The expansion of steel joists may exert lateral pressure upon load bearing walls into which they are fixed and expansion or other movement of the contents of a building may have a similar effect. Both these causes have been known to bring about the collapse of substantial brick walls.

A further frequent cause of collapse is uneven expansion. The heat-conductivity of brick or stone is low and it takes some time for heat to penetrate from one side of a wall to the other. The temperature of the surface of a brick wall in contact with a fire may, in consequence, be considerably higher then that of the farther surface and differences of as much as 500°C have been recorded in walls only one brick ie 228 mm thick.

Since a rise in temperature causes expansion it is obvious that, if one surface of the wall is exposed to heat and expands whilst the other remains cool, the effect will be to bend the wall and throw it out of vertical and, in extreme cases, to cause its collapse.

In general, the collapse of walls has occurred at fires due to:

(i) The burning away of the floors and cross walls leaving a high wall with no side support.

(ii) Expansion of beams built into the wall pushing it outwards, throwing it out of equilibrium.

(iii) Disintegration of the joints. Lime and cement joints may be so weakened by the fire that a jet of water from a branch may be sufficient to throw the wall off balance and bring it down or to wash loose mortar out of the joints and destroy stability.

(iv) The collapse of the support at the base of the wall, such as an arch or a heavy steel beam. Provided there is no other damage to the wall, however, the bricks or stones may fall in such a way as to leave a natural arch over quite a large span and thus prevent total collapse. If this happens it is necessary to see that there is ample wall remaining on each side of the gap to support the load above and to resist spreading the "natural" arch.

(v) Heating and consequent expansion of the inside face of the wall throwing the wall outwards.

(vi) The levering action of collapsing joists which are built into the wall.

Experience in the collapse of stone walls in a fire tends to be contradictory. There have been cases of collapse in mill buildings in the north of England and many experienced fire brigade officers consider that, once a fire has obtained a substantial hold, collapse of some part of the structure is almost inevitable. In Scotland, on the other hand, where stone walls are almost universal, hardly any collapses have occurred and stone walls are, generally, considered as safe in almost any circumstances. The reason for this difference in behaviour may be the greater thickness and solidity of construction in Scotland or, possibly, in the type of stone used. Provided, however, that a stone wall is well built its fire resistance may be considered as substantially the same as that of a similar thickness of solid brick.

In a fire, a solid brick wall faced by stone behaves much the same as a solid brick or stone wall and there is little danger of the stone facing peeling off. On the other hand, when a thin stone slab facing is used, often inadequately bonded to the wall, there is a danger of the slabs coming away from the wall as a result of a fire or explosion.

The wattle and daub wall is not fire resisting, but it is found, in practice, to delay the spread of fire and tends to smoulder rather than burn rapidly.

At the beginning of the nineteenth century many buildings were built with their walls covered externally with plaster or "stucco" as a cheap imitation of stonework.

In this type of building the ornamental features, such as cornices, balconies, columns etc, may consist of stucco on wooden laths fixed to a wood framework. The wood is often extremely dry and the number of concealed spaces make firefighting difficult.

5. Floors

In all except single-storey buildings, floors are a principal structural element and vary greatly according to the design of the structure. In a steel-framed building the frame is designed to support the floor and, therefore, a designer can use pre-cast concrete slabs which will span between the joists. In a reinforced concrete-frame building the whole frame and floors are usually pored in sequence to make a monolithic structure following which the shuttering is removed. A further development has come into use whereby the steel joists are spanned by light metal shuttering onto which a concrete floor is poured. The shuttering is left in place and becomes part of the floor. These are three examples of possible types of floor for, perhaps one office block design.

Floors can be regarded as being composed of 3 parts:

(i) The actual load bearing members;

(ii) The upper surface or finish of the floor; and

(iii) The lower surface of the ceiling of the compartment below.

In all but the most basic structures, where one construction combines all three, all three parts will be separate and identifiable.

For example, in a timber floor in a small house the load bearing members are the joists, the surface is the boarding and the ceiling is of plaster. Here the joists provide the preponderance of the strength of the combination and, while the boarding adds to the rigidity, it is not an essential contributor; the joists itself support the plaster.

Compare this with a reinforced concrete floor in which all three parts, ceiling, floor surface and structure may be completely merged. The whole thickness of the concrete slab contributes to the strength of the floor and the upper and lower surfaces provide the floor and the ceiling. This factor becomes more important when we come to consider membrane or suspended ceilings in compartmentation.

Construction of the more common types of floor is explained in the following paragraphs.

(a) Timber

(i) Timber floors will be found in many types of building and, in most cases, are required to provide certain levels of fire resistance according to the type and size of the building. Most timber floors are under drawn with ceilings of various materials and these usually add considerably to the fire resistance. Other factors in the performance of timber floors in fire include:

1. Whether the flooring is plain edged (butted, tongued and grooved) or is chipboard or plywood;

2. The thickness of the flooring; and

3. The load bearing capacity of the joists (and the load imposed).

(ii) Timber-joisted

The timber-joisted floor has been generally used for the upper floors of houses of all periods. Butt-jointed or tongued and grooved boarding between about 16 and 32 mm thick is used, laid on wooden joists usually not less than 50mm thick and varying in depth from 128 to 180mm according to the distance spanned. These joists may be prevented from twisting by strutting, of which each unit may be either a solid board or two cross herringbone struts, although nailed boards will have the same effect. On the underside of the joists is the ceiling usually, in modern work, of building board with a thin coat of plaster. This leaves a space between each joist enclosed by the floorboards and ceiling which constitutes hazard because fire can travel, undetected, in it. In the case of a hearth fire, in particular, it is often necessary to lift the floorboards at intervals to verify that the fire is not travelling to some other part of the structure.

In Scotland the laths or plasterboard are nailed to small battens called "branders" which run across the underside of the floor joists. These branders prevent the joists from twisting but, since the laths or plasterboard are held away from the joists fire can spread through the small air-space more rapidly than in other types.

Many houses are floored with plywood or chipboard and this is laid in either one continuous sheet which could cover the whole of an upper floor or in large squares each about 900mm x 900mm. These are screwed to the joists and it is obvious that they present a problem to firefighters seeking to inspect joists or floor voids for fire damage or fire travel.

For many years ground floors of houses and similar constructions have been of concrete but this is changing back to the old style of suspended timber flooring. The ground floor is now frequently constructed in a similar manner to the upper floors and services will be run under them as elsewhere. Occasionally the void will be underdrawn with polystyrene sheets or filled with mineral wool for insulation purposes.

The way that the joists are supported on the walls is of importance to the firefighter and several methods are used:

(i) In old work the joists are simply built into the wall and there is a risk that the collapse of the joists in a fire could lever the wall off balance.

(ii) A commoner method is the provision of a wood wall plate on to which the ends of the joists are nailed. This, if built into a wall, tends to weaken it.

(iii) A third method is to build in a wrought steel wall plate. Whichever design is adopted, unless sufficiently large "joist pockets" are allowed, collapsing joists will lever the wall off balance.

(iv) Of the more satisfactory methods used, from the point of view of fire, one is to support the wall plate on wrought-iron brackets built into the wall, a second is to corbel the brickwork out to form a ledge for the wood wall plate and a third is to reduce the thickness of the wall by 114mm at each floor level and to rest the wall plate on the ledge.

(b) Brick arches

This is a type of construction mainly found in old warehouses, mills and manufactories and they may be supported on brick piers, cast-iron columns and beams and even, occasionally, on huge timbers. The upper surface is often filled in with concrete to make a level and boarded or screeded over.

(c) Steel "filler" joists and mass concrete

There are many varieties of this type of floor but the principle employed is to divide up the area to be filled in by steel joists set at intervals sufficiently small to be spanned by mass ie un-reinforced, concrete.

(d) Reinforced concrete

This type of flooring has developed from a fairly simple steel rod reinforcing to a highly sophisticated, interwoven steel mesh and rod combination onto which is poured a particular type of concrete and the strength and stresses on the whole can be very accurately calculated.

The actual under-configuration of the floor can be shaped by plastic or metal moulds. These are sometimes called "waffle" or "honeycomb" floors.

(e) Pre-stressed concrete

Here pre-cast pre-stressed, either hollow or solid, concrete planks or sections are usually used to span between structural steel beams. After they are laid they are covered with concrete which bonds the planks together to make the finished solid floor. Some are designed with in-built tie bars, which help in the bonding when the concrete is overlaid.

(f) Hollow block and plank

There are numerous variations of the types of concrete planks, which can be quickly laid with spanning steel or concrete beams. A lighter variation consists of hollow clay floor blocks held together in a light concrete topping with, or without, reinforcing steel, depending on the proposed loading on the whole. This type of floor has a good fire record although a fierce fire will tend to spall off the lower edge of the tiles. The remainder of the construction however is usually sufficient to maintain the stability of the floor.

6. Roofs

It has been stated that "a roof is a structure, which surmounts a building to keep out the weather and may be flat, pitched or curved". Whether this could be applied to some modern buildings with roofs made of fabric, glass, plastics, tubing, cables etc. and which are suspended, cantilevered, sometimes geodetic, frequently braced and, occasionally, inflated is problematical.

Many single-storey industrial buildings appear to carry the walls straight over into the roof and consist of polymerised insulation sandwiched between metal cladding.

Others include large areas of glass or polycarbonate, which, again, covers both walls and roof. This section will, however, describe some of the commonest and simplest types of roof but emphasises the need for firefighters to note the construction of new types of roof in their areas.

(a) Flat

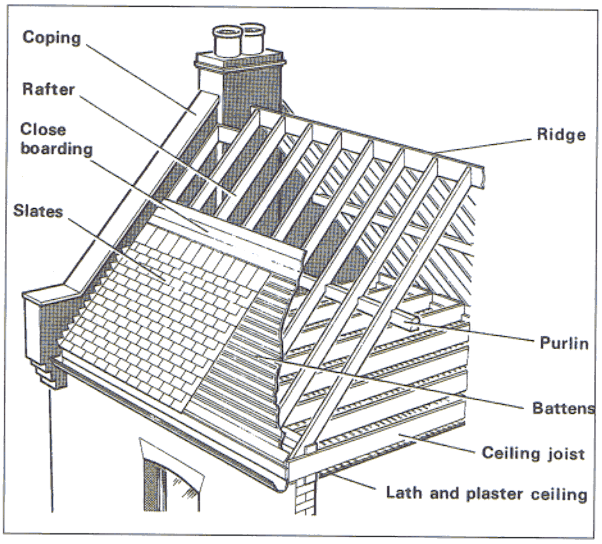
The construction of flat roofs varies from what is little more than a weatherproofed floor to a concrete plank assembly which is, itself, weatherproofed by screeding, grouting and bitumenising. The variety of flat roofs is endless.

(b) Pitched

Probably the most common type of roof used in 90% of houses and residential accommodation is the pitched roof.

(i) Close-coupled

The simplest and most common form of pitched roof is called a close-coupled roof. Timber rafters about 300mm apart run from a ridge-board to a wall plate on the top of an external wall at eaves level. These rafters carry the sloping roof, which can be of various materials. Where rafters are longer than about 2m they require support in the middle. This is done by a timber called a purlin, which supports the centres of all the rafters, and, on long spans, is itself supported by timber struts placed at intervals on the tops of internal walls.



Sketch showing the more important features of the form of roof construction often used in domestic dwellings

On every large close-coupled roofs there may be two purlins under each slope.

The ceiling joists are nailed to the wall plate and to the rafters (metal connectors may be used) so that the whole construction forms a series of triangles, which resist the tendency for the roof to spread outwards.

Occasionally the two sets of rafters are also connected together at about half the height of the roof by transverse timbers called collars. These help to stiffen the roof by reducing the free span of the rafters. The rafters may continue beyond the line of the wall and overhang to form the eaves.

Horizontal boarding may often be used below the eaves to keep out draughts and birds etc. from the roof space. In addition the spaces between the rafters should be filled with bricks to roof level but this is not often done.

This type of construction is mostly used in houses as well as for great numbers of other small buildings and there are several variations. For instance, the ceiling joists may be set up above the level of the top of the walls so that the rafters form part of the ceiling in the room below. This is known as a "camp roof". Again, it may be found that rooms have been formed in the roof space if it is high enough by means of vertical framing, the whole being lined with some sort of wallboard. The framing thus forms vertical walls to the rooms and there is some sloping ceiling on the underside of the rafters and a horizontal portion on the underside of the collars.

(ii) Mansard

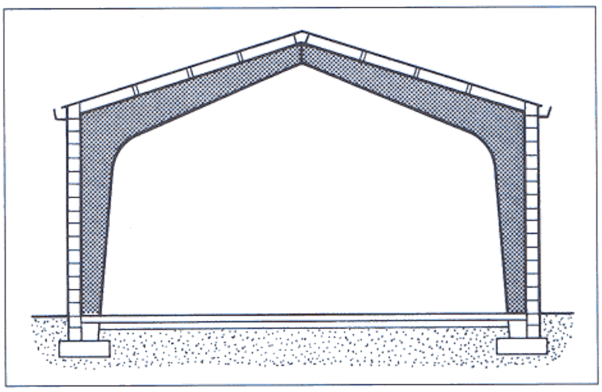
A mansard roof is a special type of pitched roof and instead of the roof running up at a constant angle from eaves to ridge there are two angles. One is a very steep pitch from the eaves to room height. The object of this is to enable a room to be built inside the roof space, which, in effect, becomes another storey.

(c) Trussed

This type of roof is used to spread the load and direct it to the walls and the ground. Construction varies widely both in its use and design.
The older styles of timber rafters, either tensioned by iron rods or timber, and the cast-iron trussing found in large old mills and warehouses etc. have been superseded by laminated timber, steel tubing, steel lattice girders and aluminium.
The large spans over concert halls theatres and cinemas are types of trussed roof as are the ultra modern tubular steel and geodetic fabrications in shopping centres and other large enclosed areas etc.

(d) The Portal or rigid frame

The Portal frame consists of, essentially, a continuous member conforming to the outline of the roof and connected to vertical columns. This continuous frame has the effect of passing the roof loading to the rest of the structure. They are especially suitable for single storey industrial or storage buildings giving long, wide open areas. Steel, aluminium and laminated timber are used but most are of pre-cast and pre-stressed concrete units.



Typical Portal or rigid frame roof construction

(e) Monitor

A type of roof found in factories or stores. It is of a relatively lightweight and is designed to give the maximum amount of light by the use of "up stands" of glass or polycarbonate. The non-glazed portions are usually light decking and the walls are generally of a lightweight "sandwich" cladding, the whole supported by pre-cast concrete frames.

Roofing materials:

(a) Slates and tiles

The simplest form of pitched roof covering consists of slates or tiles nailed or laid on wooden battens which are, themselves, nailed to the rafters. Felt is sometimes laid under the battens for the purpose of heat insulation or weatherproofing. In better quality work, boarding and felting may be employed the tiling battens being nailed through them to the rafters below. Slates may be thin and comparatively light in weight or they may be thick and heavy. All slates must be nailed on.

Plain tiles are flat or slightly curved on both sides and have "nibs" at the top which are used to hook them onto the battens. Tiles rest in position by their own weight and in only the best work are they secured by rails to the battens. Pantiles are heavier and curly in shape and are hooked on in most cases. Concrete tiles will also be found to resemble both the interlocking and the plain clay tiles.

To prevent entry of rain, especially where there is a heavy weather exposure, slates and tiles may be bedded in mortar. This is a process known as "torching".

Tiles can also be found made of asbestos-cement and were extensively used in bungalows, sports pavilions and other inexpensive structures. They can be distinguished by the considerably larger area covered by each tile and, owing to their light weight, should require less heavy roof timbers.

(b) Sheeting

Corrugated iron, aluminium and corrugated asbestos sheet require a different form of roof construction because the large sheets of material are fixed to purlins not battens. With these materials no common rafters are used. The principal rafters (or trusses in large buildings) are widely spaced and themselves support the purlins. There is a line of purlins to each row of corrugated sheet placed under the line where the sheets lap over one another.

Roofs of corrugated iron and corrugated asbestos-sheet have poor insulation and are often under drawn by match boarding or plasterboard. They will take little weight and firefighters must exercise the utmost caution when working on or near them.

(c) Cladding

Nowadays many single-storey industrial buildings are clad in metal sheeting, which is corrugated but usually in square or oblong section. As stated before, often the roof is all one part with the wall and consists of a polyisocyanurate or polyurethane foam insulation sandwiched between two sheets of steel sheeting or aluminium-alloy sheeting. These are fixed to metal rails along the walls and metal purlins in the roof.

This type of metal cladding is increasingly being used for finishing the roofs of commercial office buildings, leisure centres, schools etc. and is fixed to an appropriate metal or timber frame. The fixings vary widely and, in some cases, are extremely complicated to compensate for expansion, water penetration, building movement, wind etc.
The metals used eg steel, aluminium, copper, lead, zinc are alloys depending on what type of "finish" is required. The metal can be shaped over practically any former.

(d) Decking

Decking is usually found in flat or nearly flat roofs. The supports can be steel or aluminium girders or tubing, timber or reinforced concrete. The decking can be made up of almost any type of board eg fibreboard, straw board and weatherproofed with layers of asphalt or bitumenised roofing felt, possibly heat sealed and topped off with a further protective layer of tiles or heat reflecting material. Generally these roofs are safe for firefighters to work on but that will depend on the size of the fire beneath them and the strength of the roof supports.

Behaviour of roofs and roofing material in fire:

(a) General

Roof coverings are, in general, non-combustible or, at least, not readily combustible (an exception being thatch) so a roof is not normally vulnerable to fire from an external source. Generally it is the way roofs are built rather than the material used that causes difficulties for firefighters.

The pitched roof presents problems because of the large unused spaces that exist, ie lofts, attics voids etc., between the ceiling of the rooms below and the weather covering. As stated elsewhere, these voids can extend, unbroken, over several dwellings or, in some cases, over the whole of the building.

The amount of timber present, often of light cross-sectional area, the rising heat and smoke from a fire in the building coupled with the fact that there is seldom easy access to these areas from below or through the roof covering, means spread of fire into the void presents a difficult and punishing period of firefighting.

(b) Fireblocking

Most modern residential buildings with this type of roof are "fireblocked" ie where required in construction, fire resisting foam blocks are inserted to prevent fire spreading through cavities up into the roof. The roofs are also compartmented and precautions are taken to stop fire spread from one void to another including over the top of the compartment division.

(c) Connectors

A modern trend is for the light timber in roofs to be put together with metal connectors. These have been known to expand and fall out in a fire and leave the roof unsupported with the certainty of roof collapse.

(d) Slates and tiles

A fire attacking the underside of a pitched roof can release slates or tiles and these can slide off causing injuries to firefighters below. The rate at which this can happen will be dictated by whether the roof is underdrawn with close boarding or only with felt.

(e) Steelwork

Steelwork or wrought iron, especially of light section, is vulnerable to a fierce fire and a fairly rapid collapse can follow when the steelwork is unprotected. A lot will depend on the type of roof it is supporting and whether there is any roof venting eg automatic vents, thermoplastic roof lights etc.

(f) Cast-iron

Cast-iron is of greater cross-section and density than steel and such trusses can still be found in place after a fire providing there has not been a sharp change in temperature ie a heated truss struck by a jet of water.

(g) Trussing and cladding

The complicated trussing in, for instance, a cinema or theatre roof is usually of light section. Although protected by the auditorium ceiling firefighters must be aware of the possibility of a complete collapse in a large fire. The reaction of the newer insulated metal-clad roofs will depend largely on the types of support and the fixings. Both will be of light construction and, again, venting of the roof will keep the temperature down and the roof up.

(h) Concrete

Concrete is usually reinforced in some way and providing the steelwork is not exposed quickly to the fire, eg by spalling of the concrete cover, it will maintain its support.

PART 3 SERVICES IN BUILDINGS

1. Introduction

Most modern buildings are designed to include what are known as "services", eg air-conditioning, heating, lifts, dust extraction plants, electrical circuits. These will require roof or floor air-conditioning plants, boiler rooms, lift motor rooms, fans, electrical transformer rooms and, perhaps, "access floors", ie raised floors giving access to cables, ducting etc. Often very large buildings or complexes are "intelligent". All services are centred on a control room, which is usually staffed although much of the equipment in the building will be self-monitoring.

2. Natural and Mechanical Ventilation

(a) Natural

In natural ventilation the circulation and renewal of the air inside a building is effected by a combination of wind entering from outside the building and air currents generated inside. Wind enters on the windward side through doors, windows and ventilators and is drawn out by suction on the leeward side and up chimneys even though there is no fire. Natural ventilation is greatly increased by the internal air currents set up by fires, radiators etc. and the natural warmth of the occupants. The warmed air rises and escapes through the tops of windows and high level ventilators, and cold air is drawn in to replace it through the doors and windows.

Many different types of air inlets and outlets have been used at different periods and in different kinds of buildings. They are all, in essence, simply holes in the outer wall or roof fitted with flaps, grilles or louvres to allow air to enter or escape and, at the same time, excluding rain and draughts. The type most commonly used today is known as an "air-brick" and is placed at high level as an outlet in rooms, which have no chimney flue. It consists of a 230mm square opening in the wall protected on the inside and outside by grilles. Similarly air bricks are provided to ventilate the underside of a wooden ground floor where fitted, the air entering on the windward side, circulating round the house and out on the other side.

Low level air inlets are uncommon today but many old building have them, often screened by a metal tube which deflects the air upwards. In many modern buildings, particularly offices and hotels, fresh air inlets are often provided behind radiators placed under windows.

Older single storey factories and large halls are often ventilated by means of lantern lights in a flat roof or louvred ventilators placed at the apex of a pitched roof. More modern factories may have automatic ventilators or louvres fitted some of which are rain sensitive. These can all provide useful control of smoke in a building but could tend to draw fire into a roof space.

(b) Mechanical

In mechanical ventilation the circulation of air is assisted, or even carried out entirely, by a system of fans and ducting. It is used in many buildings such as warehouses, cinemas, theatres, offices etc. where large numbers of people congregate in a relatively small space. It is also used in factories where the occupants must be protected from harmful gases or dust produced in the manufacturing processes.

Mechanical ventilation can be divided into three principal groups:

(i) Where the stale air is extracted from the building by fans, fresh air finding its way in through doors and windows (known as 'exhaust' ventilation);

(ii) Where fresh air is forced into the building by fans, stale air finding its way out through doors and windows (known as 'plenum' ventilation);

(iii) Where fans are used both to force fresh air into the building and to drive out stale air (known as 'balanced' ventilation).

In the last two methods the air pressure inside the building is kept slightly above that outside so as to avoid incoming draughts ie they are balanced systems. All mechanical systems include ducting, usually made from steel sheeting, which distributes or extracts the air.

Firefighters must be aware of the possibility of spread of fire or smoke throughout the building via these systems

3. Air Conditioning Systems

These systems are, in effect, extensions of ventilating systems in that they provide ventilation air which has been warmed or cooled and has the desired level of humidity.

Basically an air conditioning system consists of:

(i) Fans for moving the air.

(ii) Filters for air cleansing.

(iii) Refrigerating plant connected to heat exchange surfaces such as finned coils or chilled water sprays.

(iv) Means for warming the air.

(v) Means of humidifying the air.

(vi) A control system to regulate the amount of heating or cooling automatically.

Depending on the type of use of the building some modern buildings have zoned systems (each zone having its own mini system) but more usually the top floor is given over to the air-conditioning plant and the cleaned, heated/cooled, humidified air is circulated round the building from there. On their own these systems present little hazard and most systems will have automatic controls which operate whenever a fire situation is monitored or can be manually controlled from the central control room. Smoke is then either prevented from spreading around the building or, if required by the brigade, extracted.

4. Dust Extraction

This is usually required by legislation in commercial or industrial premises to either protect the occupants from excessive inhalation of dust or the remove, or dilute a possible explosive hazard.

Finely divided dust, of almost any kind, has the potential of extremely rapid flame propagation or explosion once an ignition source is introduced.

Dust is usually collected by extractor fans through ducting to a collecting area. Any spark at the machine end can quickly be drawn along a duct and, as soon as it reaches the right mixture of oxygen and dust, can cause an explosion.

Quite often a minor explosion happens first which disturbs more dust and this larger cloud can cause a massive detonation.

Any fire in a duct is dangerous and firefighters should attempt to cut off the forced draught first and then operate fixed sprinklers or introduce sprays into the duct.

5. Fume Extraction Plants

In practically all processes involving chemicals, especially liquids eg paint spraying, there will be a need to extract fumes in order to keep processes safe. In some cases the fumes may be recovered, processed themselves and stored or re-circulated into the system. Here again automatic fire protection is usually required and safety regulations are strict.

Fires do occur in the ducting and these are sometimes fitted with light panels either to vent an explosion or to enable access to be made to the duct. Firefighters should take care and follow a similar procedure as in 4 above not forgetting to cover any storage area.

6. Mechanical Conveyors and Chutes

(a) Conveyor belts

Most conveyor belts, and similar automatic methods of transporting goods, are highly sophisticated and are found not only in factories and warehouses but in shopping complexes and hypermarkets.

Because they are constructed mainly with non-combustible materials they do not, generally, present a fire hazard. Regulations also expect a high degree of automatic protection where they penetrate fire resisting walls and floors.

Modern conveyors run on specially designed rollers which do not require grease or oil which eliminates one of the most prevalent causes of fires on belts.

There is still the possibility of static electricity building up and, unless the electrical earth is sound, providing a source of ignition with sparks.

Some older heavy-duty conveyors are still run on metal rollers and guides and the old hazard of grease build-up is still there.

Firefighters should try to stop a conveyor if called to a fire on or near one because this prevents burning material being carried around a building.

Occasionally fixed automatic sprinklers are fitted over the conveyor and these should be left operating until other firefighting media can be brought into use.

Mass-transfer of goods in high-bay warehouses and in other industrial areas such as vehicle manufacturers are common. Though not all strictly "belts" they are all practically continuous mass movement systems with similar problems of maintenance and possible overheating of motors etc.

(b) Gravity Feeds

Gravity feeds will be found either in the form of pipes or channel slides. Both forms are used in factories and warehouses. Piping is, of course, used for conveying industrial liquids from one part of a factory to another usually from tanks on upper floors or the roof. Such liquids as acids, alkalis and flammables used in industrial processes may be moved in this way. Obviously any leakage can lead to a very dangerous situation and firefighters should, wearing appropriate protective clothing, attempt to isolate the fracture by operating valves.

(c) Suction Pipes

Another method of mass transfer is by suction piping. Such materials as cement, grain, sugar, pulverised fuel, plastic pellets etc. are sucked out of the bulk transport eg a ship's hold and fed, via piping, to their storage areas. Grain elevators and fuel silos are often filled in this way.

As with any small grained material (see section 4) the danger is of a dust explosion and there are various systems preventing either the dust from attaining the right explosive mixture or of venting the pressure if it does explode.

Firefighters must take great care when working in, near or over any of these types of storage area and specific guidance in dealing with Silo incidents has been published.

7. Machinery Drives

Machinery in commercial and industrial use is driven by electrical power. The feeding of the power varies from light 3-core cable, to heavy multi-core MICS cable.

The design of the system is always peculiar to the task required, even to the point of requiring intrinsic safety eg for explosive atmospheres.

Any fires involving this type of power-drive will usually be due to the overheating of the electrical motor. Most systems will have either an automatic cut-off for the power ie an overload switch or a type of manual "punch" button to isolate the machine rapidly.

In large workshops containing a lot of machinery firefighters must move about with caution as machinery may still be running.

8. Heating Systems

Heating systems in buildings, other than private houses, are by warm air or hot water systems. These are usually run from a boiler fired by gas, oil, solid fuel or, very occasionally, electricity. The systems are such that, in addition to usually being enclosed in a fire resisting compartment, automatic safety devices are fitted which, in the event of dangerous conditions arising, will cut off the fuel supply and convey an alarm.

References

Fire Service Manual Volume 3 Fire Safety, Basic Principles of Building Construction.