

Technical performance and principles of system design

Fire

Legislation, guidance and insurance

Building Regulations - Fire Safety

Technical Guidance Document B (RoI) and Technical Booklet E (NI) are among the series of approved documents that provide practical guidance on meeting the fire safety requirements of Building Regulations.

The documents classify the use of a building into purpose groups and specify minimum periods of fire resistance to be achieved by the building elements. The periods of fire resistance vary according to the classification and the size of building. The greater the fire hazard a building presents, then the greater the period of fire resistance required to protect the elements within the building. The materials used to form the internal surfaces of the building are also controlled to reduce the risk of fire growth and internal fire spread.

Healthcare buildings

Hospitals and healthcare environments by their very nature contain people who are at risk from fire. Health Technical Memorandum (HTM) 05 series UK documents may also be useful in the fire safety design of healthcare facilities. These documents provide guidance on the standards of fire safety expected in healthcare facilities and include recommendations on internal fire spread, elements of structure, compartmentation, fire hazard areas, hospital streets, penetrations, protected shafts, ceiling membranes, cavity barriers and fire-stopping.

Educational buildings

The design of fire safety in schools is covered by TGD 021 from the Department of Education & Skills (RoI) and Building Bulletin 100 UK may also be useful.

Fire protection for structural steel in buildings, ASFP Yellow Book

Publication prepared by the members of the Association for Specialist Fire Protection (ASFP). Presenting the theory behind, and methods for, fire protection of structural steelwork to comply with Building Regulations. It provides a comprehensive guide to proprietary materials and systems, all of which are manufactured, marketed or applied on site by members of ASFP.

Principles of fire performance

Fire growth

The choice of materials for walls and ceilings can significantly affect the spread of fire and its rate of growth through a building, even though they are not likely to be the materials first ignited. The specification of linings is particularly important in circulation spaces where surfaces may offer the main means by which fire spreads, and where rapid spread is most likely to prevent occupants from escaping.

Two properties of lining materials that influence fire spread are:

- The rate of flame spread over the surface when it is subject to intense radiant heating
- The rate at which the lining material gives off heat when burning

Compartmentation

The spread of fire within a building can be restricted by sub-dividing it into compartments separated from one another by walls and/or floors of designated fire resisting construction.

The two key objectives are:

- To prevent rapid fire spread, which could trap occupants within the building
- To reduce the chance of fires becoming large, which is more dangerous – not only to occupants and fire service personnel, but also to people in the vicinity of the building

The appropriate degree of sub-division depends on:

- The use and fire loading of the building, which affects the potential for fires and their severity, as well as the ease of evacuation
- The height to the floor of the top storey in the building, and the maximum distance from a route of safe passage, which is an indication of the ease of evacuation and the ability of the fire service to intervene effectively

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Structural fire precautions

Premature failure of the structure can be prevented by fire protecting loadbearing elements.

The purpose in providing the structure with fire resistance is:

- To minimise the risk to the occupants, some of whom may have to remain in the building for some time (particularly if the building is a large one), while evacuation proceeds
- To reduce the risk to fire fighters engaged on search and rescue operations
- To reduce the danger to people in the vicinity of the building who may be hurt by falling debris, or because of the impact of the collapsing structure on other buildings

Fire limit state

In structural design terms, fire is considered to be an accidental limit state, i.e. an accidental occurrence, and one for which the structure must not collapse. Loads and their factors of safety used in design at the fire limit state reflect the low probability of occurrence.

Typically, structural members that are designed to be fully stressed under normal conditions would be subject to a load ratio of 0.5 to 0.6 under fire conditions. Within this book, loadbearing floors and partitions are quoted with respect to a stated load ratio. Many constructions have been tested at a conservative load ratio of 1.0 (100%) despite the fire state being an accidental load.

Structural behaviour of timber in fire

Although it is combustible, the charring that occurs around timber when it is exposed to fire helps to slow down its rate of degradation and maintain its structural capacity. Timber has a low thermal expansion coefficient, which minimises the possibility of protective layers and charred materials becoming displaced. It also has a low thermal conductivity, which means that undamaged timber immediately below the charred layer retains its strength. Generally, it may be assumed that timber will char at a constant rate when subjected to the standard heating conditions of the test furnace. The rate of reduction in the size of structural timber can be taken as 15mm to 25mm (depending on species) in 30 minutes for each face exposed; different rates apply where all faces are exposed. The undamaged timber can be assessed for structural stability using standard design guides in conjunction with stress modification factors.

For partitions tested with high load ratios it should be noted that when the timber is exposed to fire, the exposed face will shrink causing differential thermal movement. This can be important for axially loaded sections, as it introduces a degree of eccentricity, which may cause a loss of loadbearing capacity.

Structural behaviour of steel in fire

Steel generally begins to lose strength at temperatures above 300°C and eventually melts at about 1500°C. Importantly for design, the greatest rate of strength loss is in the range of 400°C to 600°C.

Using fire design codes such as the Structural Eurocodes EC3-1.2 and EC4-1.2 (designated *BS EN 1993-1-2: 2005* and *BS EN 1994-1-2: 2005*), the load on the structure at the time of the fire can be calculated by treating it as an accidental limit state. If used, this will allow designers to specify to the fire protection contractor a limiting or failure temperature for a given structural section. The fire protection contractor will then be able to use the required thickness of material to ensure that the steel section does not exceed this temperature within the fire resistance period. This process could be simplified by the designer specifying a maximum steel temperature, based on the worst case, for all beams or columns on one floor level.

Buildings that are not primarily used for storage, e.g. offices, residential units, schools and hospitals, have a high percentage of non-permanent loads. For this type of building, the structural Eurocode *BS EN 1991-1-1: 2002* assumes that a proportion of the design load will not be present at the time of the fire. Other types of buildings, such as warehouses and libraries, are primarily used for storage, so a high percentage of the load is permanent. The codes allow for no reduction in design load for the fire condition.

The fire testing standards effectively base the failure criteria for loadbearing elements on strength. However, beams should be designed at the fire state limit as well as in the cold state limit.

Columns are frequently designed so that a single length will be two or three storeys high. The lowest storey will be loaded; the highest and the upper storey will be lightly loaded. In buildings with a degree of non-permanent load (in terms of duration and magnitude), the load ratio of the structural members is unlikely to be greater than 0.6. In storage buildings, where the majority of load is permanent, the load ratio would normally be higher, but is unlikely to be greater than 0.65.

In C03. S01. P67 – Steelwork encasement systems, the thicknesses of protection required are specified for design temperatures of 550°C, unless otherwise stated. It is the responsibility of the design engineer, using design codes such as *BS EN 1993-1-2: 2005*, to specify the appropriate limiting steel temperatures.

The loss of strength of cold-formed steel at elevated temperatures exceeds that of hot-rolled steel by between 10% and 20%. Expert advice should be sought in determining the strength reduction factor at the limiting temperature.

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Why gypsum is so effective in fire

Our plasters, plasterboards and specialist boards provide good fire protection due to the unique behaviour of gypsum in fire. When gypsum-protected building elements are exposed to fire, dehydration by heat (calcination) occurs at the exposed surface and proceeds gradually through the gypsum layer.

Calcined gypsum on the exposed faces adheres tenaciously to uncalcined material, retarding further calcination which slows as the thickness of calcined material increases. While this continues, materials adjacent to the unexposed side will not exceed 100°C, below the temperature at which most materials will ignite, and far below the critical temperatures for structural components. Once the gypsum layer is fully calcined, the residue acts as an insulating layer while it remains intact.

Gypsum products are excellent performers in terms of reaction to fire, as the endothermic hydration reaction requires energy to be taken from the fire, so gypsum is a negative calorific contributor.

Fire resistance test standards

Building Regulations and supporting documentation require elements of structure and other building elements to provide minimum periods of fire resistance, expressed in minutes, which are generally based on the occupancy and size of the building.

Fire resistance is defined in 'the ability of an element of building construction to withstand exposure to a standard temperature / time and pressure regime without loss of its fire separating function or loadbearing function or both for a given time' (*BS 476: Part 20: 1987*).

The fire separating function of a construction is defined as the integrity and insulation performance.

- **Integrity** is the ability of a separating element to resist collapse, the occurrence of holes, gaps or cracks through which flames and hot gases could pass and sustained flaming on the unexposed face.
- **Insulation** is the ability of a separating element to restrict the temperature rise of the unexposed face to below specified levels.
- **Loadbearing function** is the ability of the loadbearing element to support its test load without deflecting beyond specified limits.

Conformance with Building Regulations can be demonstrated with test reports showing the system has been tested for the imperforate system in accordance with European (EN) or British (BS) fire resistance test standards, however, for service penetrations or other junctions, please check with the Gyproc technical department where such details are required to meet the European Norm.

EN fire resistance test standards

The Construction Products Regulation (CPR) within European legislation is designed to enable free trade across Europe in construction products. To enable free trade, harmonised test standards for technical performance are required. The area of technical performance most affected by this requirement is fire performance.

Fire resistance methods used across Europe were similar but the severity of furnaces varied due to factors such as different fuel sources and furnace geometry. To improve consistency between different furnaces, plate thermometers were introduced to measure the heat flux to which samples are exposed. The use of plate thermometers means the EN fire resistance test can be more severe, especially during the first 30 minutes of exposure when compared with BS fire resistance tests.

EN fire resistance test standard also imposes strict rules governing the use of tests to cover specific end use scenarios (field of application). This restricted field of application has most effect on partitions that are built with heights above 4m, as they may need to have enhanced levels of fire protection.

To claim up to 3m, the partition has to be tested at a height of 3m in the fire resistance test. To claim up to 4m, the partition has to pass the test with a partition test height of 3m and not deflect laterally by more than 100mm during the test.

To claim above 4m, the partition has to undergo an engineering appraisal where the thermal bow and strength loss of the steel studs are taken into account. This means that the same partition may have different quoted heights at different fire resistance durations. The only alternative to using an engineering appraisal is to conduct a test at the height under consideration.

We have conducted an extensive series of EN fire resistance tests on partitions with heights up to 6m. Data from these tests are used within the performance tables. Insulation materials, such as glass and stone mineral wool, can affect the fire resistance of a partition. These materials can provide additional insulation / integrity performance but can also increase the thermal bow of the partition and therefore reduce the partition height that can be claimed. Consequently, within the performance tables, there are instances where the partition height is reduced when a quilt is included within the cavity of the partition. It cannot be assumed that adding a quilt to a partition specification will not impact on its fire resistance.

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EN fire resistance and its application to Gyproc systems

The EN fire resistance periods claimed for systems in this document are evaluated in accordance with the relevant EN fire resistance test standards.

BS EN 1364-1: 2015

Specifies a method for determining the fire resistance of non-loadbearing walls.

BS EN 1365-1: 2012

Specifies a method for determining the fire resistance of loadbearing walls.

BS EN 1365-2: 2014

Specifies a method for determining the fire resistance of loadbearing floors and roofs.

BS EN 1364-2: 1999

Specifies a method for determining the fire resistance of non-loadbearing ceilings.

BS EN 13381-4: 2013

Test methods for determining the contribution to the fire resistance of structural members: Applied protection to steel members.

ENV 13381-2: 2014

Test methods for determining the contribution to the fire resistance of structural members. Vertical protective membranes.

BS fire resistance test standards

As both EN and BS fire resistance standards are acceptable for showing compliance with Building Regulations, this book shows tables for systems tested in accordance with both EN and BS standards.

Unlike the EN test standards the BS test standards do not impose restrictions with respect to maximum partition height. Within the *BS 476: Part 22* testing regime, the partition height in the fire state is not considered, and if a partition passes the fire test at 3m it is deemed to be suitable in fire resistance terms for any possible heights. Under the BS system, the cold state height would be the maximum height claimed regardless of the fire duration required.

BS fire resistance and its application to Gyproc systems

The BS fire resistance periods claimed for systems in this document are evaluated in accordance with the relevant BS fire resistance test standards.

BS 476: Part 20: 1987

Describes the general procedures and equipment required to determine the fire resistance of elements of construction.

BS 476: Part 21: 1987

Describes the specific equipment and procedures for determining the fire resistance of loadbearing elements.

BS 476: Part 22: 1987

Describes the procedures for determining the fire resistance of non-loadbearing elements.

BS 476: Part 23: 1987

Describes the specific equipment and procedures for determining the contribution made by components to the fire resistance of structures.

Reaction to fire test standards

Reaction to fire is the measurement of how a product will contribute to the development and spread of a fire.

The choice of materials for walls and ceilings can be of critical importance when designing a building especially in spaces which occupants will use when escaping from a potential fire.

EN reaction to fire

The European Classification System (Euroclass), devised for the classification of 'reaction to fire', has been introduced as part of the ongoing harmonisation of European standards. Reaction to fire has traditionally been assessed using at least 30 different national standards across Europe. The Euroclass system includes tests designed to better evaluate the reaction of building products to fire.

The Euroclass system predicts the performance of building materials in a real fire more accurately than the British Standard classification system.

The Euroclass test methodology is built around the Single Burning Item (SBI) test method (*BS EN 13823: 2010+A1:2014*), which is an intermediate scale test to evaluate the rate of fire growth from a waste paper basket fire positioned in the corner of a room.

Other tests used in the classification system are the non-combustibility test (*BS EN ISO 1182: 2010*), heat of combustion test (*BS EN ISO 1716: 2010*) and direct flame impingement test (*BS EN ISO 11925-2: 2010*).

The overall reaction to fire performance of a construction product or building element is presented in a classification report in accordance with *BS EN 13501-1: 2007*. This report uses the results from the relevant test methods and determines the Euroclass category rating for the product.

Gypsum products are intrinsically fire safe products and generally fall into the higher Euroclass classifications. Plasterboard is subject to a 'classification without further test' decision. This means that any type of plasterboard can be classified as A2, so long as the paper grammage of the

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liner does not exceed 220g/m² and the core of the board is classified as A1 (non-combustible). Any plasterboard product with a paper liner in excess of this grammage is required to be tested.

All our plasterboard products manufactured in accordance with *BS EN 520: 2004* are designated Euroclass A2. All our Glasroc products manufactured in accordance with *BS EN 15283-1: 2008* are designated Euroclass A1.

BS reaction to fire

The British Standard classification system determines the reaction to fire performance of a product based upon the performance in the fire tests *BS 476 Parts 4, 6, 7, and 11*. These fire test methods are material tests and measure the characteristics of the surface of the material, whereas the EN tests are measurements of the performance of the construction product in an arrangement representative of end use.

To help provide maximum fire safety in buildings, certain building elements need to be constructed of non-combustible materials. A building material is designated as non-combustible if it satisfies performance criteria when tested in accordance with:

BS 476: Part 4: 1970 (1984) Non-combustibility test for materials.

BS 476: Part 11: 1982 (1988) Method for assessing the heat emission from building materials.

Glasroc boards are designated as non-combustible materials. Some construction products can be described as materials of limited combustibility provided they satisfy the following requirements:

- (a) Any non-combustible material (listed in Technical Guidance Document B, section A18 (RoI) or Technical Booklet E, section 1.9 (NI)).
- (b) Any material of density 300kg/m³ or more, which does not flame or cause a 20°C temperature rise when tested to *BS 476: Part 11 under national classes*.
- (c) Any material with a non-combustible core at least 8mm thick having combustible facings (on one or both sides) not more than 0.5mm thick. Where a flame spread rating is specified, these materials must also meet the appropriate test requirements under National classes.
- d) a material classed as A2-s3,d2 per BS 13501-1 under European classification.

Gyproc plasterboards are all designated materials of limited combustibility or greater.

Surface spread of flame

Flame spread over wall and ceiling surfaces is controlled by providing materials that are either non-combustible or materials of limited combustibility. Combustible materials

(or certain materials of limited combustibility that are composite products) when tested to the standard below, are classified Class 1, 2, 3 or 4. Class 1 provides the greatest resistance to surface spread of flame:

BS 476: Part 7: 1997 Surface spread of flame tests for materials.

The exposed surfaces of our plasterboards and specialist boards are all designated Class 1.

Fire propagation

Investigations concerned with the growth of fires in buildings show that the surface spread of flame test does not measure all the properties that are relevant for placing combustible materials in the proper order of hazard. Such considerations led to the test which is described in *BS 476: Part 6: 1989 Method of test for fire propagation for products*. This test takes into account the amount and rate of heat evolved by a specimen whilst subjected to a specified heating regime in a small furnace. The standard describes the method of calculating the results to obtain indices of performance, which help to determine the suitability of combustible wall and ceiling lining materials when used in areas requiring maximum safety.

Class 0

In addition to the degree to which combustible materials used as wall and ceiling linings can contribute to the spread of flame over their surfaces, consideration must also be given to the amount and rate of heat evolved by these materials when used in areas requiring maximum safety. Building Regulations, by means of associated documentation, make provisions that wall and ceiling surfaces must be Class 0 in circulation spaces (which are often escape routes) and in other specific situations.

In Technical Guidance Document B (RoI) or Technical Booklet E (NI), a Class 0 material is defined as either:

- (a) composed throughout of materials of limited combustibility (this term includes non-combustible materials)
or
- (b) a Class 1 material that has a fire propagation index (I) of not more than 12 and a sub-index (i1) of not more than 6.

Materials of limited combustibility are those achieving an EN reaction to fire classification of A2-s3, d2 or greater.

For further information, please refer to Technical Guidance Document B (RoI) or Technical Booklet E (NI). The exposed plasterboard surfaces of Gyproc specialist boards are designated Class 0 in accordance with current building regulations.

Although Class 0 is the highest performance classification for lining materials, it is not a classification identified in any harmonised test or standard.