DELIVERING THE FUTURE OF COMPOSITE SOLUTIONS

CIVIL & ARCHITECTURAL FIRE REQUIREMENTS APPLIED TO COMPOSITE STRUCTURES
INTRODUCTION

Building regulations ensure that, in case of fire, building occupants are warned and can safely escape the building to a place free from danger. This is achieved through firefighting systems that are either active or passive. Active systems are designed to be triggered when a fire breaks out and comprise systems such as sprinklers, fire alarms and ventilation. Passive systems are generally built-in to the structure and include indicated escape routes, fire compartmentation and materials with superior fire performance. The firefighting system requirements depend on the building height, its usage and the size of its rooms.

It is possible to draw a simplistic time-temperature curve to represent the life of a fire in a building, as shown in Figure 1. The ignition is the primary stage of a fire, when the temperature is still low. At low temperature, most materials are difficult to ignite. As temperature rises, more materials ignite and the fire develops. Once most materials are alight, the fire is in a steady state, until the materials acting as fuel start to become depleted and the fire undergoes decay. Building regulations divide fire performances in two categories: reaction to fire and fire resistance.

Figure 1: Time-temperature curve representing the life of a fire
**Reaction to fire** determines the material fire performance at low temperature, such as the ignitability, the spread of flame, the heat release, the generation of smoke and the production of flaming droplets. Reaction to fire is critical in the early stages of a fire, to keep escape routes safe for the building occupants. This is typically relevant to cladding and lining materials.

**Fire resistance** determines the material fire performance at high temperature, such as its stability (load bearing capacity), integrity (fire containment) and insulation (thermal transmittance). Resistance to fire is more critical in the mature stages of a fire, to ensure the stability of the building. This is typically relevant to structural elements such as beams and columns.

**Building regulations per country**

The European Standard EN 13501-1:2007+A1:2009 and the International Building Code ICC IBC (2009) are two major building regulations. In the UK, the British Building Regulations have been harmonised with the European Standard. The British Building Regulations governing fire safety are presented in the Approved Document B, which is made of two volumes. The first volume defines the legislation for dwellinghouses, while the second volume is applicable to other buildings. To define test standards, both volumes refer to the British Standards, such as BS 476 6-7 for reaction to fire and BS 476 20-24 for fire resistance. The International Building Code refers to test standards from the American Society for Testing and Materials, such as ASTM E 84 for reaction to fire and ASTM E 119 for fire resistance.

To take an example, a three-storey school building typically requires Class 0 linings in its circulation spaces, in terms of reaction to fire, according to Document B and to European Standards. A material has Class 0 fire performances if, in addition to being Class 1 according to BS 476 7, it has a limited heat release according to BS 476 6. The structural elements of such a building require a fire resistance of 60 minutes, as tested by BS 476 20-24.

**TEST STANDARDS**

**BS 476 7 Spread of flames (Reaction to fire)**

The BS 476 7 test, which is used for walls and ceiling linings, involves exposing a flat specimen to a radiation gradient along its length, as shown in Figure 2. The specimen is held at 90° to the face of the radiation panel. During the first minute, a pilot flame is applied to the specimen lower corner closest to the radiation panel.

![Figure 2: Experimental set-up of BS 476 7](image)
The flame spread is measured visually along the sample length over time. A minimum of six and a maximum of nine samples are tested and their results are organised in classes as shown in Table 1. Similar test methods in the European classifications can be used to obtain equivalent ratings to the classification based upon BS 476 7.

### Table 1: Classification of BS 476 7 test results

<table>
<thead>
<tr>
<th>Classification</th>
<th>Spread of flame (mm) at 1.5 min</th>
<th>Final spread of flame (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>165</td>
<td>165</td>
</tr>
<tr>
<td>Class 2</td>
<td>215</td>
<td>455</td>
</tr>
<tr>
<td>Class 3</td>
<td>265</td>
<td>710</td>
</tr>
<tr>
<td>Class 4</td>
<td>Exceeding limits of Class 3</td>
<td></td>
</tr>
</tbody>
</table>

**BS 476 20-24 Fire resistance of load bearing elements**

The fire resistance of load bearing elements is measured in the time span for which the load bearing elements maintain their stability, integrity and insulation when exposed to fire. The test specimen, the loads and the conditions of fixity are identical to, or representative of, the element of building construction to be evaluated. If the building element is too large to be tested, it can be scaled down, along with the load applied to it.

Vertical separating elements are exposed to heating and pressure conditions along one face. Free standing columns shall be exposed to heating and pressure conditions equally on all four faces. The load is applied either by dead weights or by jacking systems. The standard temperature-time curve is given in Figure 3.

![Figure 3: Temperature-time curve for BS 476 20-24](image-url)
The fire resistance of the test specimen is assessed against stability, integrity and insulation criteria. The stability criterion specifies that the specimen has failed if it is no longer able to support the test load or if the ratio of span over deflection becomes smaller than 20. The integrity criterion specifies that the specimen has failed when a 6mm diameter gap gauge can penetrate through the specimen or when a cotton pad on the specimen cold surface starts to burn. The insulation criterion specifies that the specimen has failed if the temperature on the specimen cold face increases by more than 140°C.

FIRE PERFORMANCE OF GURIT MATERIALS

Reaction to fire

Gurit fire retardant (FR) products are designed to deliver high performance laminates whilst presenting excellent reaction to fire. Gurit FR composite materials are either Class 1 or 2 according to BS 476 7 and they are also compliant with standards from other industries. Gurit materials can be used in combination with intumescent fire retardant thin film coatings to further improve their reaction to fire. For example, intumescent thin films are typically water based non-toxic coatings that swell as a result of heat exposure. Due to the swelling, the density of the film drops, which produces good insulation properties and reduces the spread of fire. The coating thickness depends on the fire rating being required.

Resistance to fire

Many insulation solutions can be used to protect Gurit materials and produce load bearing fire resistant composite structures, as shown in Figure 4. Gurit works closely with a range of fire insulation material providers to offer a tailor-made solution for each project, such that our fire resistant structures maintain the light weight and high stiffness advantages of composites. As each application is different, Gurit liaises with test houses to ensure that insulation solutions meet Building Regulations. Typical insulation solutions might include rockwool, calcium silicate products, concrete or vermiculite. Figure 5 shows a carbon composite pillar insulated with concrete to be tested for resistance to fire.

![Figure 4: Example of a fire resistant composite panel](image4.png)

![Figure 5: Fire test set-up with carbon composite pillar insulated in concrete](image5.png)

Photo credit: PCT