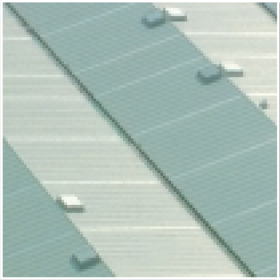
# Performance of external cladding systems in fire



This guide presents the results of the first major fire research programme to verify the Reaction to Fire behaviour of insulated panels and other external cladding systems.

Fire aspects are an important requirement in the specification of a cladding system. However, apart from specific fire resistance capabilities defined by BS476 Part 22 and required for some building applications, the actual fire performance and particularly the reaction to fire of cladding systems is little known and poorly documented.

The EPIC Fire Guide has been prepared to fill this void by presenting extensive and factually supported data about how such systems react to fire. By analysing the results, specifiers and designers can make more informed decisions about the choice of insulated systems and how they should be used.

The information should also help fire brigades understand how insulated panels and cladding systems will behave should they become involved in a fire.

# External cladding systems

The guide is concerned exclusively with insulated panels and systems used for the external cladding of industrial, commercial and other buildings. The comments and tests described do not relate to panels used as internal walls, ceilings or linings though certain features which benefit the fire performance of external claddings may assist designers of internal systems.

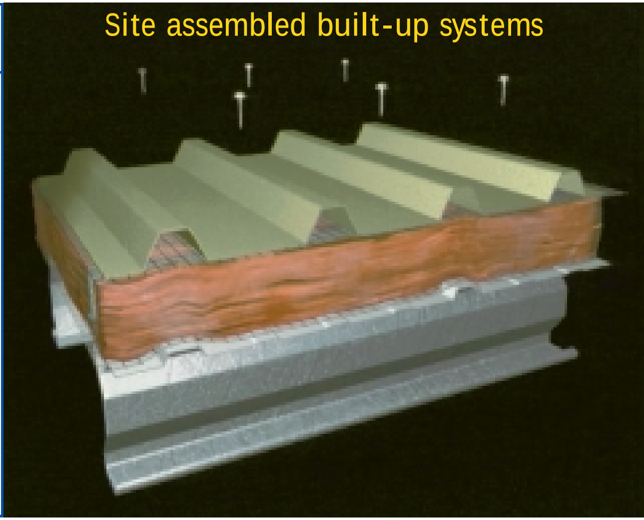
A review of the fire performance of both factory engineered insulated panels and site assembled insulated systems shows that both cladding methods have a good record in actual fires and that very rarely have fires initially involved the external cladding.

# External cladding systems

Historically the majority of insulated industrial and other metal clad buildings have been clad with an external profiled metal sheeting, an internal lining and a glass fibre quilt insulation, nominal density 11 kg/m$^3$. More recently a number of specifications have changed to 23kg/m$^3$ rock fibre quilt.

These site assembled built-up systems accounted for about 90% of metal cladding up to the late 1980's.

| Insulation types | Construction |
|---|---|
| Glass fibre quilt (11 kg/m$^3$ approx.)<br>Rock fibre quilt (23 kg/m$^3$ approx)<br>High density rock fibre batt: (100kg/m$^3$ approx) - fire resistance/high fire risk projects | Multipart site assembled systems<br>secure through fixings/ secret fix standing seam design<br>facing joints - simple overlap or rolled seam (external)<br>Open structure- voids/chimneys in crown |

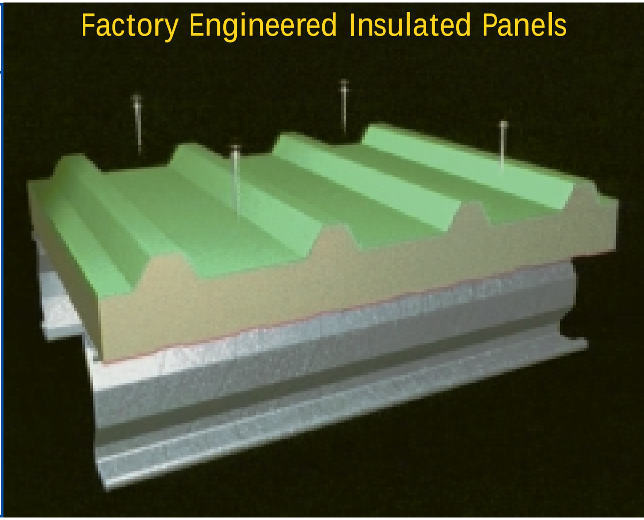


# External cladding systems

## Growth of insulated panels

Specifications are now rapidly changing to factory engineered insulated panels. EPIC estimate that in 1998 over 35% of insulated metal clad buildings will be constructed using rigid urethane insulated panel systems.

| Insulation types | Construction |
|---|---|
| Rigid urethane [PUR]<br><br>Fire rated rigid urethane [PIR]<br><br>High density rock fibre lamellas: (100kg/m³ approx) - fire resistance/high fire risk projects<br><br>(Polystyrene:bonded/ cassette panels <1% usage for external cladding) | Single piece factory engineered panel<br><br>Secure through fixings - visible or secret fix.<br><br>Engineered panel joints- good fire protection<br><br>Fully filled closed cell insulation between facings - no voids or chimneys |



# Resistance to fire

*'Reaction to fire' concerns the performance of materials when exposed to the conditions of a developing fire.*

The behaviour of materials, singly or in combination, when subjected to the conditions that exist in a developing fire has been a major concern when specifying cladding systems. There are a number of small scale tests called up in building regulations designed to control the use of materials/composites which have an adverse influence on fire growth.

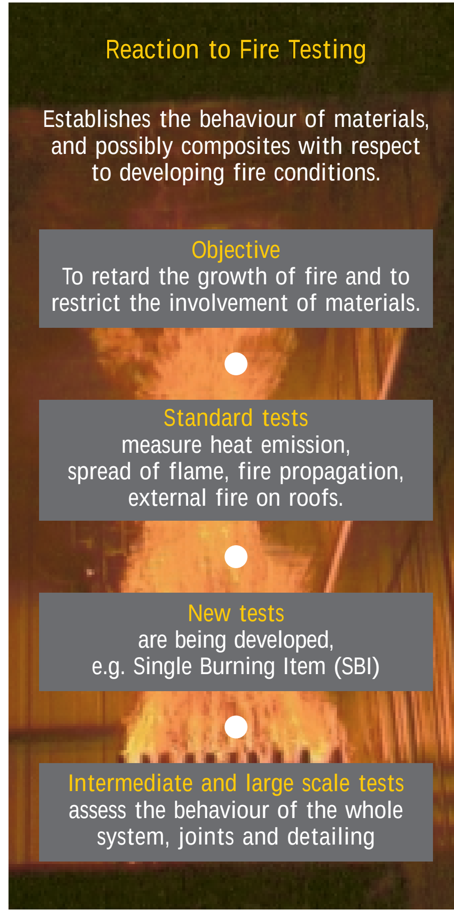
The standard tests called up in regulations include:

**BS476: Part 3: External fire exposure roof tests**
**BS476: Part 4: Non-combustibility**
**BS476: Part 6: Fire propagation**
**BS476: Part 7: Spread of flame**
**BS476: Part 11: Methods for assessing heat emission**

The EPIC Fire Research Tests went beyond the traditional assessment of components in that an actual building was tested and the heat source chosen to create a 'late developing' fire condition.

**In common with the requirements of European, ISO and Insurance companies the tests:-**

– investigated the cladding systems and not the component parts
– tested systems as they are installed in practice.
– were of sufficient size to enable a realistic assessment of behaviour to be determined including; development and spread of fire; effect on the insulant; the effectiveness of the whole system; its joints and associated detailing.
– assessed the structural integrity of the cladding systems



# Resistance to fire

*Fire Resistance is defined in the Building Regulations and concerns the properties and performance of a system in the case of a fully developed fire.*

The fire resistance test procedure is designed to evaluate the ability of an element of construction, e.g. a cladding system and its supporting framework, to resist the spread of a fully developed fire, against pre-determined criteria including;

– **Loadbearing capacity (for the framework):** if appropriate

– **Integrity:** the ability to prevent the spread of hot gases and flames

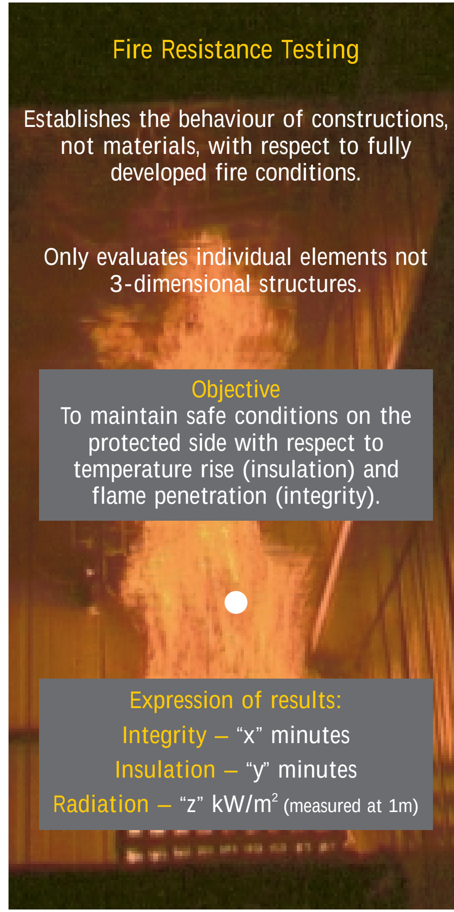
– **Insulation:** the ability to prevent the transmission of fire by means of construction.

Radiation measurements are recommended, but there are no pass/fail criteria within the standard.

The fire resistance of an element is evaluated either by BS476: Part 21 (loadbearing elements) or BS476: Part 22 (non-loadbearing elements).

The Building Regulations for England and Wales recommend in Approved Document B(AD-B), the levels of fire resistance for the various elements of structure which are related to the use, height and size of the building, sometimes modified by its relationship to the site boundary or whether it is protected by an automatic suppression system.

Fire Resistance Testing does not measure ignitability, combustibility or smoke production.




(Note: The EPIC Fire Research Programme did not assess the Fire Resistance of the various cladding systems.)

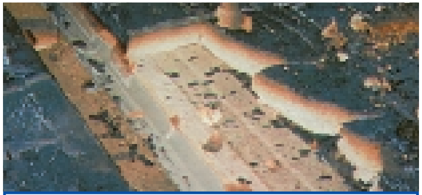
# Performance in fire
## Behaviour of systems

*The behaviour of insulated panels and cladding systems in a fire depends primarily on:*

**- the insulant or core material**
**- the degree of restraint (fixings) provided to the external and internal facings.**
**- the joint design between panels or facings**

### Insulating core materials

Not all insulating core materials exhibit the same characteristics with regard to their structural stability, thermal insulation properties, or response to elevated temperatures.

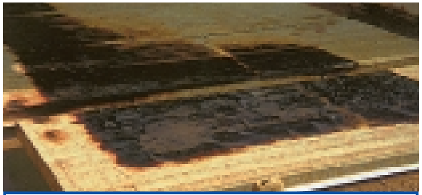


### Rigid urethane

Rigid urethane (PUR) and fire rated rigid urethane (PIR) are thermosets which in a fire harden and form a char. The char acts as a barrier which has some effect in protecting the lower layers of the material from the effects of the fire.

### Polystyrene

Polystyrene is a thermoplastic which melts and flows when heated. In a cladding system this means that the Polystyrene insulation can become a viscous liquid that will flow from between the facings and may ignite and create flaming droplets with the possibility of spreading the fire beyond the original area.



### High density rock fibre

High density rock fibre used successfully for fire resistant applications is often considered to be non-combustible. However the high density of the fibre core means that synthetic resins are used as binders, which together with the adhesives bonding the core to the facings are often combustible and are affected by high temperatures.

# Performance in fire

### Restraint of facings

With the majority of external cladding panels and systems, the internal and external facings are firmly secured to the structural steel work with through fixings. Tests and experience indicate that structural integrity will be maintained even in a developed fire irrespective of any loss of adhesion or deterioration of the insulation core.

### Design details

Design detailing of the joints and interfaces is fundamental to the performance of the panels in fire. The more effectively the joints are sealed the less the flames will impinge on the core materials reducing any contribution to the fire. Stronger engineered joints restrict buckling and mechanical damage reducing exposure of the core material to the fire.

### Damage

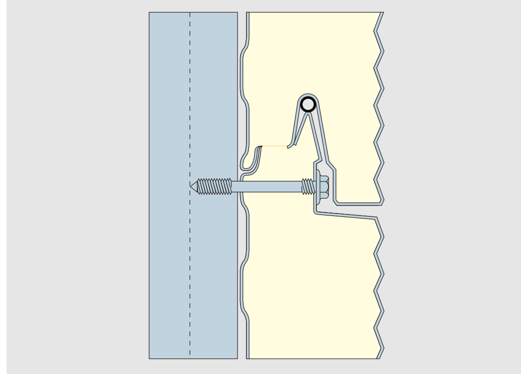
All panel systems are damaged by fire irrespective of insulating core.

In addition to scorching and blackening of the facings buckling, mechanical damage and loss of adhesion will occur in the vicinity of the fire source resulting in damage and ultimate replacement.

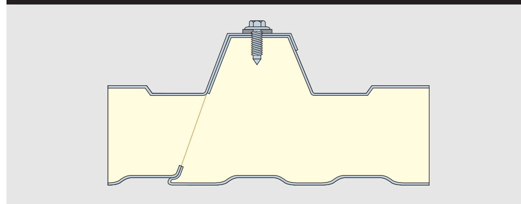
For some systems there may be shrinkage or loss of core insulant.

**Typical joint details - panel systems**

Horizontal panel joint



Standard panel joint



**Buckling of internal lining - all systems**

# Performance in fire

## EPIC Fire Tests -Method

*The EPIC Fire Research Tests went beyond the traditional assessment of components in that an actual building was assessed and the heat source chosen to create a 'late developing' fire condition.*

The test programme was developed by EPIC in conjunction with consultants Arup Fire and carried out by Warrington Fire Research.

The Programme assessed the Reaction to Fire of the cladding systems on a realistic scale using the Loss Prevention Council's standard LPS 1181 Building test for walls and ceilings. This is a large scale test in which the realistic performance of a complete cladding system can be appraised.

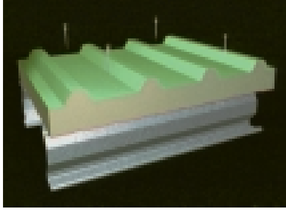
A 35kg timber crib to simulate a real fire is placed in the corner of a large test building (10m x 4.5m x 3m high). The room configuration gives rise to a severe test generating an average heat output of 510 KW over the period of the test and a maximum output of 1MW, sufficient to represent a fire in the late stages of development.

Comparative tests under identical conditions were carried out on the most commonly used lightweight external cladding systems, both insulated panels and site assembled systems.

Fully instrumented test building

Observation and recording

# Performance in fire
## Rigid urethane insulated panels



*Factory engineered panels with a rigid urethane insulating core (PUR or PIR) account for over 90% of all insulated external cladding panels installed. They have been used extensively and successfully in the UK and throughout Europe for over 30 years meeting the designers requirements for a quality, energy efficient and quickly erected cladding system with minimal condensation risk.*

Rigid urethane covered panels have been involved in relatively few fires. Rarely have the panels been associated with the initial stages of a fire and overall their performance has been exceptionally good.

Factory engineered panels  from the earliest designs have been steel faced, fully filled elements with engineered joint details and installed with through fixings - fundamental points for good behaviour in fire.

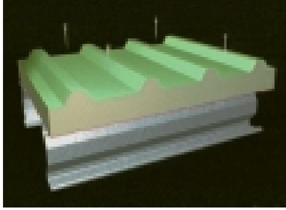
### Structural stability.

Secure through-fixing and tight joint details coupled with predominantly steel external facings are the fundamental reason why rigid urethane panels perform well in fire.

The tests showed that the panels remained securely fixed to the supporting steel work. The internal facings buckled but the interlocking joints remained intact. Loss of adhesion between the internal facing and the insulating core occurred in the area adjacent to the core but did not compromise the structural integrity of the panels.

Rigid urethane insulated panel system

The fire rated (PIR) insulated panel wall claddings remained intact in this major fire although the internal structure behind had totally collapsed



# Performance in fire
## Rigid urethane insulated panels

### Performance of the insulating core - Temperatures > 1000°C

Rigid urethanes are thermosetting materials which in a fire harden and form a char. They do not exhibit the same characteristics as polystyrene, a thermoplastic, which melts and will ignite when in contact with flames.

The tests clearly showed that with rigid urethane panels, either PUR or fire rated PIR insulation there is no hidden spread of flame through the core between the facings.

Even though the internal facings buckled slightly, the interlocking joints remained intact. Flames did enter the core of the panels at the joint immediately adjacent to the fire source, but inspection revealed only local charring.

With rigid urethane panels heat from the fire creates a slow gradual decomposition of the insulation, creating a stable protective char.

Initially only the insulation next to the internal face chars protecting the insulant furthest away from the hot face. The depth of char progressively deepens as long as the fire source continues. The process stops when the fire is extinguished or the fire source dies down.

Smoke is emitted. The level is low with fire rated (PIR) urethanes but greater with other PUR products.

**Rigid urethane insulated panel system**

No spread of flame through the core between facings

# Performance in fire
## Rigid urethane insulated panels

**Rigid urethane insulated panels**
**Performance behaviour – Large scale fire test**

– Integrity of the structure maintained
– No spread of fire within the core
– Insulation criteria satisfied
– No flaming droplets
– Gradual decomposition above 300°C – low smoke emissions
– Loss of adhesion and damage (buckling of liner) adjacent to heat source – integrity not compromised
– No additional risk for fire fighters

Site assembled built-up systems

# Performance in fire
## Rigid urethane insulated panels with sprinklers

### Effects of sprinklers
One of the rigid urethane panel tests was repeated with the addition of sprinklers to assess their effect.

The sprinkler heads were activated manually to ensure that the fire had developed sufficiently before activation. Within 30 seconds the flaming at the joints on the side wall had been extinguished and the smoke colour changed to grey and then to white as the operation continued. The temperature readings on the walls dropped from 550°C to less than 100°C within 1 minute of sprinkler activation and the mean temperature of the smoke layer reduced to 270°C.

### Beneficial effect of sprinklers
Sprinklers can be used not only to control the fire in the traditional sense but in the case of rigid urethane cored panels to maintain temperatures sufficiently low to prevent the core material from contributing to the fire.

**Rigid urethane insulated panels (with sprinklers)**

EPIC Tests indicated that cooling from the wetting action of sprinklers effectively:-

- limited flaming and contribution
- restricted the area of damaged panels
- reduced smoke emissions

**Panel damage significantly reduced**

**Internal inspection shows minimal contribution**

# Performance in fire
## Polystyrene insulated panels

*Polystyrene cored panels have only rarely been used as external cladding systems. Of these a substantial proportion are installed within a frame support system or as a cassette style design as distinct from systems with through fixing.*

This low usage contrasts with the mix of panels used to create internal insulated rooms or compartments within buildings eg. food processing factories, where the bulk usage incorporates polystyrene as the insulant.

### Behaviour in fire
Polystyrene behaves totally differently in fire to rigid urethanes (PIR/PUR). Being a thermoplastic material, it melts, shrinks and burns. The softening temperature is approximately 100$^{0}$C and melting temperature 180$^{0}$C

As the temperature increases the polystyrene melts and recedes from the heated surface creating a void. Flames entering the void cause molten flaming droplets to flow out on both the external and internal sides of the cladding.

Polystyene insulated panels
External view during test

Polystyrene melts to produce flaming droplets
with potential to spread the fire

# Performance in fire
## Polystyrene insulated panels

The tests indicate that once the flames have entered the core, the fire can spread unchecked between the facings consuming the core material as it progresses. If the facings are unsecured with no through fixings early collapse can occur significantly affecting the speed of spread of flame. Whilst the facings remained secured and the joints remained tight, there was no sudden spread of flame down the wall.

Fire continues to travel within the core between the facings. Fire source is no longer contributing
Some panels have collapsed

**Polystyrene insulated panels**
**Performance behaviour – Large scale fire test**

– Melted and shrank
– Produced flaming droplets
– Contributed to further fire spread
– Flame spread unseen within facings
– Collapse of unsecured, frame retained facings

End of test showing extent of structural collapse of frame panels

# Performance in fire
## Rock fibre insulated panels

### High Density Rock Fibre Panels.

*These panels with a nominal density of 100kg/m$^3$ are primarily used as external claddings where a fire resistance classification of more than 30 minutes (insulation) is required by the Building Regulations, or for high fire risk applications.*

The high density rock fibre panels performed well in the tests as expected with a fire rated product. These panels, in common with all insulated systems, were damaged by fire through the buckling of the internal facing and temperature effect on the core such that replacement would be required.

The organic binders were affected by heat and flame to a depth of 25mm. The tests showed the adhesives bonding the rock fibre lamellas to the facings burnt at temperatures over 300°C.

**Rock fibre insulated panels**

**Performance behaviour – Large scale fire test**

- Structural stability maintained
- No spread of flame within the core
- Minimal contribution from core materials
- Insulation integrity maintained
- Adhesives and resins affected above 300°C
- Loss of adhesion and damage (buckling of liner) adjacent to the heat source

In common with other panel systems, internal facings buckled and were damaged adjacent to the fire source.

# Performance in fire

## Glass and rock fibre quilt insulated site assembled systems

*Comparative tests were carried out on standard multi-part site assembled systems comprising internal liner sheet; 86mm quilt insulant; and external weather sheet. The reaction to fire of both glass fibre (11kg/m³)and rock fibre quilt (23kg/m³) were assessed.*

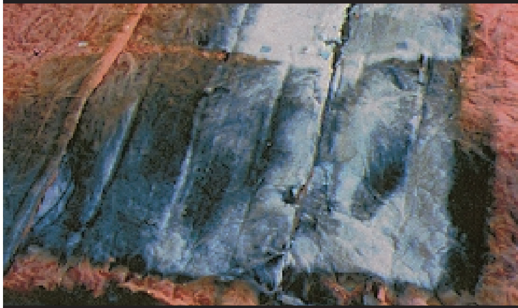
The mineral fibres themselves, being ‘non-combustible’ do not contribute to a fire. However the bonding agents used to bind the fibres, together with the breather membrane do burn and make a limited contribution to the fire load and smoke emission

Inspection showed that low density quilts experience severe shrinkage at temperatures over 600°C. The higher density rock fibre quilt still showed significant damage adjacent to the fire source but performed better with less shrinkage and reduced loss of insulation.

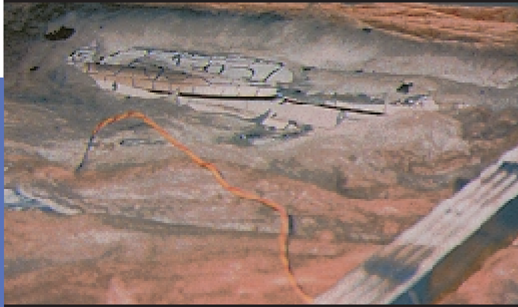
**Glass and rock fibre quilt insulated site assembled systems
Performance behaviour – Large scale fire test**

– Structural stability maintained
– Shrinkage of insulation at temperatures over 500°C
– Loss of insulation (g.f.) above 850°C
– Minimal contribution from core materials
– Buckling of liner adjacent to heat source

**Glass/rock fibre quilt systems**



Shrinkage of glass fibre quilt from 86 to 20mm. (600°C)
Insulation performance reduced



In common with other panel systems, internal facings buckled and were damaged adjacent to the fire source.

# Building regulations

For safety and more recently energy efficiency, the design and specifications of buildings is controlled by means of building regulations, in one form or another.
The United Kingdom is divided into three regions for building legislation purposes;

**(i) England and Wales   (ii) Northern Ireland   (iii) Scotland**

The regulations in England and Wales and Northern Ireland are functional, supported by guidance documents, whereas the Building Standards (Scotland) are prescriptive in nature.

The use and nature of cladding has an impact on fire safety and is one of the factors controlled by the regulations. This guide sets out to provide guidance as to how insulated composite panels for use as roof or wall cladding systems are controlled, and briefly considers their use for internal walls.

## England and Wales – Building Regulations –1992

For matters related to fire safety, Approved Document B(AD-B) has been issued in support of the Building Regulations B1 to B5, which are expressed in functional terms. AD-B provides a prescriptive solution deemed to meet the regulation. The specific regulations of relevance to non-loadbearing external cladding systems are:

**B2 – Internal Fire Spread (linings)   B4 – External Fire Spread**

The guidance given in AD-B to these regulations draws heavily on other documents such as British Standards, in particular the BS5588 series which deals with Fire Precautions in the design, construction and use of buildings. Architects and designers are under no obligation to accept any of the recommended solutions given in AD-B if they prefer to meet the requirements in another way. They are obliged, however, to demonstrate that they have met the function in a different way, e.g. by using a fire engineered approach.

# Building regulations

**Northern Ireland** – The Building Regulations (N.I.) 1994

The regulations covering Northern Ireland are also of a functional nature supported by a guidance Technical Booklet, Section E. In respect of the controls imposed on cladding systems for roofs and walls the recommendations are technically identical to those in the England and Wales AD-B.

**Scotland** – The Building Standards (Scotland) Regulations 1990, amended December 1997

Parts D and E of these regulations deal with fire safety. Unlike the two other regions, the Building Standards in Scotland are supported by mandatory prescriptive solutions which require formal procedures to be observed if they are to be varied. The regulations that influence the specification of roof and wall cladding systems in Scotland are;

**Part D:** Structural Fire Precautions
**Part E:** Means of Escape and Facilities for Fire Fighting

**Note:**

1) **Interpretation of Building Regulations**
Whilst every attempt has been made to verify the guidance given, it should not be regarded as definitive. As individual manufacturers' products vary, the requirements should be confirmed by them.

2) **Prescriptive nature of regulations in Scotland**
Because of the need to reproduce the actual requirements when considering the control over cladding systems, the requirements themselves have been omitted from this guide.

# Building regulations
## Roof cladding systems

*"The roof of a building shall resist the spread of fire over the roof and from one building to another having regard for the use and position of the building."*

The requirement will be met if the roof is constructed so that the risk of spread of flame and or fire penetration from an external fire source is restricted so as to limit a fire spreading from the building to a building beyond the boundary or vice versa.

The extent to which this is necessary is dependent on the use of the building, its distance from the boundary and in some cases its height.

Roofs are not recommended to exhibit any fire resistance unless they are used for escape routes, parking etc., as they are not considered to be elements of structure.

It is important however, that roofs in boundary situations, including either side of a compartment wall, are not penetrated by brands or radiation, nor allow uncontrolled spread when ignited.

As compartment walls are required to be firestopped at their junction with the roof, it is important that the roof behaves in a predictable manner.

Roof coverings are rated from AA (best) to DD (worst) when evaluated by BS476: Part 3: 1958 and their permitted proximity to the boundary is controlled accordingly.

Rigid urethane insulated panels with a standard coated steel facing have a designation AA and are suitable for all distances from any point or relevant boundary.

The AA designation also allows rigid urethane panels to be used over and either side of a compartment wall where this does not extend up through the roof.

# Building regulations
## External wall cladding systems

*"The external walls of the building shall resist the spread of fire over the walls and from one building to another having regard to the height, use and position of the building."*

The requirement will be met if the external walls are constructed so that the risk of ignition from an external source and the spread of fire over their surfaces is restricted by making provision for them to have low rates of heat release.

The amount of unprotected area in the side of the building is restricted to limit the amount of thermal radiation that can pass through the wall, taking the distance between the wall and the boundary into account.

The first of these requirements is met by using materials with a low fire propagation index, as measured by BS476: Part 6: 1989, and a low spread of flame (Class '1') in accordance with BS476: Part 7: 1987. The second requirement is met by having walls that resist fire according to BS476: Part 22, except for those 'unprotected' areas (without fire resistance) recommended in AD-B.

### Surface spread of flame

**External face** – Where the wall of a building is less than 1m from the boundary that wall shall have a Class '0' Surface Spread of Flame. There are no restrictions on surface burning characteristics for buildings less than 20m high which are more than 1m from the boundary but some restrictions apply to buildings over 20m high.

**Internal face** – Unless an internal lining is applied directly to the sheeting rails, the internal lining shall exhibit a Class 'I' surface spread of flame with respect to BS 476: Part 7, except where it forms part of a protected route in which case it shall have a Class '0' rating.

# Building regulations
## External wall cladding systems

### Compartment Walls
Compartment walls are intended to provide fire separation between fire compartments designed to restrict the uncontrolled spread of fire or to separate individual occupancies or ancillary areas (>20% of the total area). By definition these walls have to be fire restricting in respect of loadbearing capacity (when appropriate), integrity and insulation and be impermeable to smoke and hot gases. They shall be fire stopped where they abut adjacent walls.

**Rigid urethane panels are not recommended for compartment walls.**

### Internal Walls
Internal walls need possess no fire resistance provided that they are non-loadbearing and are not required for compartmentation or to provide a protected escape route.

Regardless of whether fire resistance is recommended, internal walls shall have a surface spread of flame rating of not less than Class '1' (except for rooms less than $30m^2$ which can be Class '3') or Class '0' where a protected route for escape purposes.

Rigid urethane insulated panels with standard external and internal coatings achieve Class '0' spread of flame classification

# Building regulations
## External wall cladding systems

*For insulated cladding panels where external walls carry only their own weight and wind loads, but do not carry floor loads, there may be no requirement to possess any fire resistance.*

### Fire Resistance

Clause 0.47 of B3 in AD-B exempts non-loadbearing cladding from requiring any fire resistance except in respect of the recommendations given in B4 to restrict the spread of fire between buildings.

Within the 1m boundary distance, external cladding on single storey industrial or storage buildings is required to satisfy integrity and insulation for 60 minutes. This is reduced to 30 minutes if the building is sprinklered.

For industrial and storage buildings less than 10m high, sprinklered buildings have to be 12.5m, and unsprinklered 25m from the relevant boundary before the exemption from fire resistance applies to 100% of the area. Between 1m and the above distances, greater proportions of the area are allowed to be unprotected (see AD-B, table 16).

For those areas that are recommended to be fire resisting in this zone, the insulation is permitted to be reduced to 15 minutes. For tall and multi-storey buildings the allowable unprotected area is calculated using the method given in a BRE Report of 1991.

A special case is made for non-loadbearing external walls in single storey buildings in that there may be no need for them to possess any fire resistance providing:-

1. the wall does not form part of a compartment wall or wall common to two or more buildings *or...*

2. it is more than 25m from the boundary for industrial, commercial and storage buildings and more than 12.5m for assembly and recreation buildings.

3. Where sprinklers are provided throughout the building and the system complies with the recommendations of BS 5306: Part 2. the values quoted in (2) may be halved.

Note

1) For the relaxation permitted by the use of sprinklers to be taken into account, the sprinkler installation should comply with BS 5306: Part 2.
2) Class ‘0’ is a product performance classification for wall and ceiling linings and is the highest classification for lining materials. It is not a classification identified in any British Standard test but is a composite of two tests:- surface spread of flame and fire propagation.