Fire Spread in External Cladding – A Literature Review

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EXECUTIVE SUMMARY

As part of a programme of work to review the guidance given in BR135 "Fire Performance of Thermal Insulation for walls of Multi-Storey Buildings" [1], this paper identifies and summarises;

- the types of external cladding systems currently in use,
- the current requirements and guidance as given in Approved Document (B), 2000 revision, and
- the research previously undertaken on external fire spread in buildings.

The main findings from this review have been:

1. There are many definitions for each type of cladding system and it is important to clearly and consistently define each system type to avoid confusion.

2. The 2000 revision of AD (B) goes some way to addressing the issues of fire performance of external cladding systems, the review of BR 135 will seek to resolve any outstanding issues as identified.

3. The work to date suggests that a full-scale test method is required to assess the performance of the complete system.

4. Intermediate scale tests may be suitable to categorise component material fire performance in the event of a fire can only be assessed at large-scale.

5. The shape and dimensions of the BRE large-scale test facility are comparable with those in the draft ISO CD 13785, with exception of the primary wing which is longer than that set out in the BRE test method.

6. The BRE thermal exposure conditions are more severe, at 90 ± 20 kW/m^2 at a height of 1 m above the opening, than the conditions used in the other tests reviewed in this paper. However, most are relatively close to this level.

INTRODUCTION

As part of a review of the guidance given in BR135 "Fire Performance of Thermal Insulation for Walls of Multi-Storey Buildings" [1], this paper has been prepared to identify and summarise:

- the types of external cladding systems currently in use,
- the current requirements and guidance as given in Approved Document (B), 2000 revision, and
- the research previously undertaken on external fire spread in buildings.

TYPES OF CLADDING SYSTEMS

In Connolly's 1994 [2] paper it was reported that there were over 3,000 tower blocks in the United Kingdom, representing about 225,000 homes capable of housing almost 1 million people. The majority of these tower blocks were erected in the 1950's and 60's using a variety of system built concrete construction techniques and many of these buildings are now in need of refurbishment. Since rebuild is an uneconomic option for many of the property owners, usually Local Authorities one of the more popular methods of refurbishment is the use of external cladding systems.

One of the main issues involving cladding systems is the definition of the systems themselves. It is therefore useful to identify the types of systems that will be discussed in this paper. Both Finegan [3] and the House of Commons (HoC) report [4] provide definitions of different walling types:

Finegan [3] identifies:

- facings
- rainscreen and overcladding
- curtain walling, and
- in-fill panel systems.

The HoC report [4] describes three different systems for external cladding:

- external wall insulation or 'render' systems,
- rainscreen or 'sheet boarding' systems, and
- pre-formed in-fill systems.

Curtain walling was not discussed as it fell outside the remit of the enquiry.

Facings/Render Systems

As described by Finegan [3], facings are a method of finishing such as rendering and wall tiling which require a continuous background structure to give the necessary support and fixing for the materials forming the external face of the building. The HoC report [4] describes this as a two component system:

- insulating material fixed to an external wall, and
- external surface membrane (typically rendered) to provide weather protection.

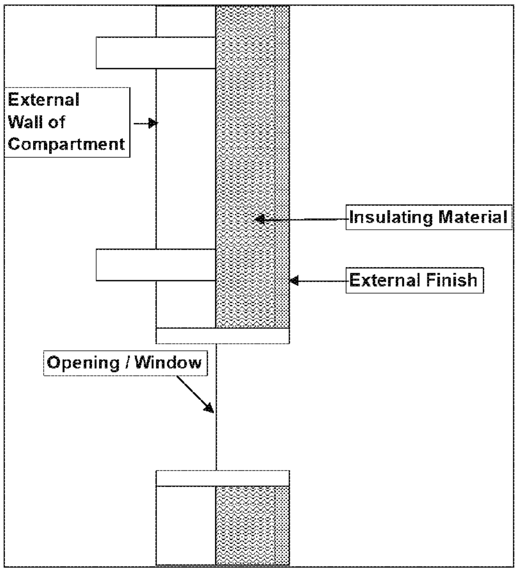

Figure 1. Facings/Render Systems

BRE 135 [1] gives guidance on the selection of the appropriate combinations of insulants, fire barrier and fixing details to prevent fire spread in these systems.

Rainscreen

Finegan [3] makes the distinction between overcladding and rainscreen. Overcladding is described as the process of applying a facing or cladding to an existing building. Whereas rainscreen consists of an external wall with an inner structural leaf, insulated on its outer face.

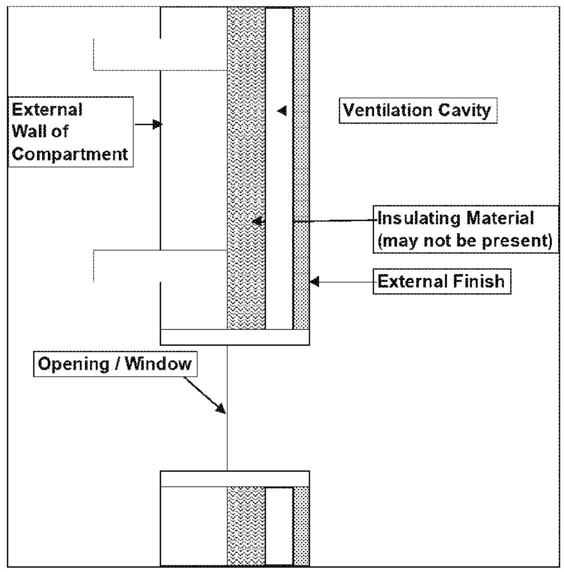

Figure 2 . Rainscreen Overcladding

External rainscreen is designed with an airspace that can be drained, back ventilated and, if required, pressure-equalised. Both reports describe the rainscreen system as having both an external surface membrane, or cladding assembly and an insulation layer fixed to the external wall. In practice, the insulation layer may not always be present.

The HoC report [4] cites Knowsley Heights, Liverpool, as an example of rainscreen overcladding, Plate 1 and states that these systems constitute some 40% of the market.

Plate 1. Knowsley Heights, and an example of a rainscreen system.

In-fill Systems

The HoC report [4] suggests that 'in-fill' systems are sometimes considered to be outside the 'overcladding' family, but undoubtedly constitute external cladding and fall within the terms of the Committee's reference.

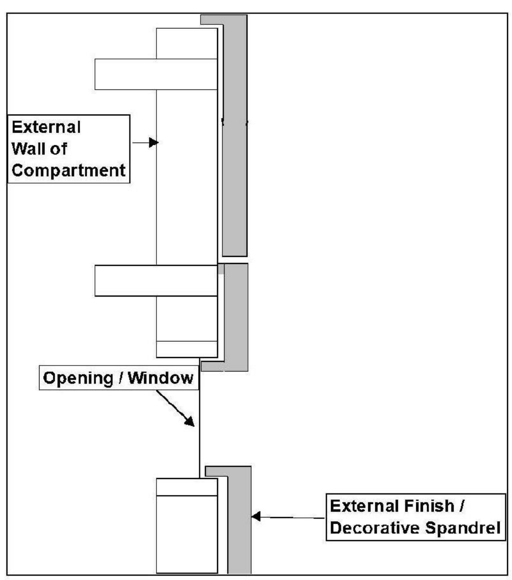

Figure 3. In-fill panels

In-fill systems are typically pre-formed off-site and brought to the site for installation. They are installed in a wide variety of configurations and differ from render and rainscreen systems in that they are generally fixed between members of the structural frame over existing external finishes such as spandrels or window pods, to form a decorative finish to the building. This type of system was used in Garnock Court, Irvine, Ayrshire, plate 2.

Plate 2. Garnock Court

Curtain walling

Curtain Walling systems consist of a metal framework that supports pre-assembled panels. The panels are generally constructed from glazing and decorative insulated panels. The units are held in place with synthetic seals to provide weather-tightness. Fire stopping is generally installed at floor level to stop the progress of smoke and flames between floors. The frame is attached to the building structure at floor slab or beam level by steel or aluminium brackets. These systems typically form the external face of the building.

Cladding Materials

Based on Finegan's paper [3] the following cladding materials have been identified:

- Clay – used in panel systems as small standard-sized components, such as tiles.
- Concrete - pre-cast concrete panels as slabs applied to a solid background or as cladding to a structural frame, independent of any in fill walling.
- Thin stone – can be used with or without insulation as a natural veneer, epoxy bonded to honeycomb backing panels.
- Metal - steel, stainless steel, copper, bronze and aluminium are generally used in sheet form for cladding to walls as:
    - Profiled metal sheeting
    - Metal panelling
    - Aluminium and steel profiled cladding

- Brickwork - due to its weathering properties and excellent appearance and range of colour make it a very suitable cladding for other materials such as concrete.
- Glazing - found in the majority of facades in a variety of forms ranging from in-fill panels, windows, and suspended glazing. Single, double or fire resistant glazing may be used.

Façade Costs

Finegan [3] highlights the typical costs associated with different cladding systems based on figures given in the Architects Journal (AJ) in February 1998, in Tables 1, 2 and 3.

Table 1 - Types and costs of claddings as quoted in AJ, Feb 1998 for overcladding.

Cladding	Costs - £/m^2
Limestone with stainless steel fixings	210-370
Granite with stainless steel fixings	210-420
Exposed aggregate precast concrete cladding	230-330
Reconstituted stone on concrete backing	290-330
Brick-faced precast concrete cladding	320-390
Limestone- faced precast concrete cladding	470-600
Granite-faced precast concrete cladding	450-640
Mineral enamel-faced rigid fibre cement board e.g. Eternit Glasal	70-80
Melamine finish solid laminate panels, invisible fixing	80-115
Terracotta- faced rainscreen panels, insulation, invisible fixing	200-250
Drained and back ventilated overcladding, aluminium rainscreen panels, insulation, vapour barrier, invisible	250-300

Table 2 - Types and costs of curtain wall as quoted in AJ, Feb 1998.

Curtain walling	
Standard non fire resistant stick system - single glazing	130 - 160
As above but with double glazing and steel faced insulated spandrel panels	170 - 370
Extra for fire resistant glazing	80 – 140
Aluminium-framed unitised double-glazed window walling, opening lights, opaque spandrel panels.	300-450
One hour fire resistant curtain walling	750 +
Lift surround double-glazed or laminated glass with aluminium or stainless steel framing	580-700
Extra for bomb-proof glazing	50-100

Table 3 - Types and costs of In-fill panels as quoted in AJ, Feb 1998.

Infill Panel Systems	
Composite metal panels, 35-60mm thick, profiled galvanised steel outer sheet, PVF2-coated rigid polyurethane insulation and galvanised steel inner sheet polyester coated	35-55
Composite panel 175mm thick, aluminium toughed sheets, natural stucco embossed, liner sheet, vapour barrier, insulation	50-80
50-70mm sandwich panel of 0.7mm colour coated miniprofiled galvanised steel inner skin, secret fixed	80-110
Composite panel of 0.5mm stove lacquered aluminium ,3mm polyethylene core, 0.5 mm mill-finish aluminium, with insulation and vapour barrier bonded to rear face	160-210
Demountable pressed aluminium cladding panels; rockwool insulation, vapour barrier, perforated galvanised steel lining tray, unistrut framing with anodised aluminium fixing clamps.	250-300

BUILDING REGULATIONS

The 2000 edition of Approved Document B (AD B) (Fire Safety) to the Building Regulations 1991 was published in January 2000 [5] and will 'enter into force' on 1 July 2000. To comply with the guidance in the Approved Document, external walls may need to have sufficient fire resistance to restrict fire spread across a site boundary. The combustibility of the outer surface should be of a value that minimises the danger of ignition from an external source and the subsequent fire spread up the external face of the building.

Limitations on Materials

Paragraph B4(1) of Schedule 1 to the 1991 Building Regulations [6] states:

External fire spread

B4.-(1) The external walls of the building shall adequately 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.

External Surface

Provisions are made in AD B to restrict the combustibility of external walls of buildings that are less than 1000mm from the relevant boundary. This is in order to reduce the surface's susceptibility to ignition from an external source, (e.g. an adjacent building).

Irrespective of boundary distance, Diagram 40 (Provisions for external surfaces of walls), in AD B, restricts the combustibility of external walls of high buildings (where the top floor is at least 18m above ground level) and those of the Assembly and Recreation Purpose Group, to reduce the danger from fire spread up the external face of the building.

Internal Surfaces

In the case of the outer cladding of a wall of 'rainscreen' cladding i.e. where a drained and ventilated cavity is provided, the surface of the outer cladding that faces the cavity should also meet the provisions of Diagram 40, AD B.

Insulation

In a building with a storey 18m or more above ground level, insulation material used in ventilated cavities in the external wall construction should be of limited combustibility (see Appendix A of AD B). This restriction does not apply to masonry cavity wall construction, which complies with Diagram 32 in Section 10 of AD B.

Unlike most of the guidance given for the external and internal surfaces of the cladding systems above, this provision restricts the specified material down to ground level. (Timber cladding could be used at low level on a high rise building but the insulation would be controlled at all levels).

Subdivision of Cavities

Paragraph B3 (4) of Schedule 1 to the 1991 Building Regulations [6] states:

B3. - (4) The building shall be designed and constructed so that the unseen spread of fire and smoke within concealed spaces in its structure and fabric is inhibited.

Provisions are made in the Approved Document to restrict this by interrupting cavities that could form a pathway around a barrier to fire, sub-dividing extensive cavities, and by closing the edges of openings. Provisions for cavity barriers are set out in Table 13 of AD B against specified locations and purpose groups. For external wall constructions that include cavities (such as rainscreen cladding), cavity barriers are recommended at the junctions between the wall and every compartment floor or wall or other wall or door assembly that forms a fire-resisting barrier (Table 13 items 1,3,4 & 9 of AD B).

Masonry or concrete cavity walls are exempted from this provision where both leaves of the wall are concrete or masonry and where the cavity is closed around any openings and at the top of the cavity itself. This is regardless of the combustibility of the insulation or the dimensions of the cavity. The cavity closures need not be fire resisting or non-combustible (Diagram 32 of AD B).

Other cavities may be exempted provided that the cavity does not contain combustible insulation, para 10.11.f in AD B. This exemption does not however apply to residential buildings over 18m in height where cavity barriers must be provided at every floor level (compartment floors or otherwise) and on the line of compartment walls, Item 9, Table 13 in AD B. This reflects the importance placed on compartmentation with regard to the design of multi-unit residential buildings. It is expected that the revised editing of BR 135 will give better guidance on fire stopping and the location of cavity barriers.

Fire resistance

External walls may need fire resistance in order to satisfy paragraph B4 of the regulations where the wall is near to a boundary or by virtue of paragraph B3 (1) of schedule 1 to the regulations [6] which states:

B3. - (1) The building shall be designed and constructed so that, in the event of fire, its stability will be maintained for a reasonable period.

Provisions for fire resistance are only made for "elements of structure". This is the term applied to the main structural load-bearing elements, such as structural frames, floors and load-bearing walls. External walls such as curtain walls or other forms of cladding which transmit only self weight and wind loads and do not transmit floor load are not regarded as load-bearing. External walls may also need fire resistance if there is a boundary requirement, however, it is often the case that the external walls of a building are not required to have any fire resistance.

BRE Fire Note 9

Where the provisions of Diagram 40 cannot be met in the 2000 revision of Approved Document B [5], reference is made to BRE Fire Note 9 [3] as an alternative method for demonstrating compliance with regard to the spread of fire over the external walls. Where the guidance in AD B on materials and / or cavity barriers has not been followed, this test can also be used to establish whether the guidance for restricting the spread of fire over external walls has been satisfied. The test does not replace the provisions for fire spread between buildings or fire resistance.

Guidance on the use of external insulation material is also referenced in the 2000 revision of AD B through BR135 [4].

EXTERNAL CLADDING FIRES – LITERATURE REVIEW

Moss [7] identified the typical mechanisms of vertical fire spread in multi-storey buildings as found from reviewing reported incidents in the Fire Journal and Fire Prevention Journal:

1. flaming from broken windows causing the windows of the storey above to break and allowing fire to enter;
2. inadequate fire/smoke stopping of the gap between the edge of the floor slab and the exterior wall allowing flames and hot gases through,
3. heat induced distortion of low melting point metals or alloys, such as aluminium, causing fire stopping to become ineffective and possibly fall out,
4. areas around lift shafts and in stairwells acting as chimneys to hot gases and flames; and
5. inadequate stopping of service penetrations and gaps formed when services are retrofitted.

Of these mechanism types, 1, 2 and 3 are most relevant to the issues being discussed, with items 2 and 3 the most relevant for curtain walling systems.

External Cladding Research at BRE

Work at BRE on external fire spread in buildings dates back to the early 1960's when the London County Council (LCC) commissioned a study to investigate the potential for fire spread between floors in multi-storey units [8]. Various facing materials were investigated on a three storey (36'), single faced test facility with timber crib fire load. As a result of this work minimum window separation distances were proposed together with the use of non-combustible spandrels and balconies to deflect flame.

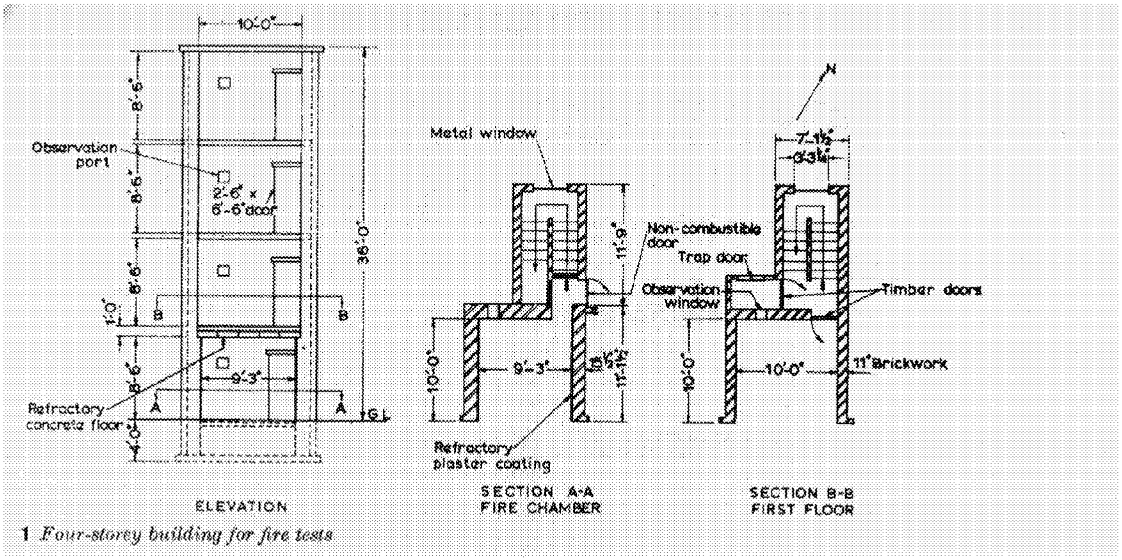

Figure 4. Schematic of Ashton [8] test facility

Work continued throughout the 1960's at full-scale for commercial clients investigating the fire performance of 'new' products such as aluminium and polymeric insulating materials.

In 1985 Stirling and Southern [9] undertook a series of fire tests involving external insulation at full-scale, on six rendered and two timber insulated systems.

A four-storey rig 9.2 m high and 3.7 m square in plan, with windows at the second and third floors was designed and constructed. The fire source was a wooden crib designed to provide at least 20 minutes of fully developed flaming impinging up to 2 m on the facade and with a heat flux of at least 100 kW/m² on the facade.

The tests found that there was possible danger to other buildings and persons through the dripping, drifting and falling of burning products. The tests also highlighted the fire damage and smoke spread between the cladding and the wall could be increased considerably by inadequate fixing and sealing at edges and openings.

In 1987 Stirling and Southern [10] undertook a second series of tests to investigate the influence of cavities in systems and the performance of different insulating materials. Three types of insulant were considered:

- Non-combustible – glass and stone wool products.
- Thermosetting –Polyurethane foam (PUR) and Polyisocyanurate (PIR) foam.
- Thermoplastic – Expanded Polystyrene (EPS) was used for these tests.

The two types of cavities considered were:

- Continuous cavities that extend several metres or the entire height of the rig. In this case it was found that flames or hot gases could penetrate the cavity and increase the level of damage considerably.
- 'Fortuitous' cavities occurred when board insulants were badly fitted leaving wide joints, tilted boards or uneven substrates. This type of cavity could extend over the entire area of the wall and it was found that the insulants could be damaged, especially thermoplastic insulants, due to the hot gases moving within the narrow cavities and causing them to widen by melting.

Based on the results of this work, additional tests were carried out by Rogowski, Ramaprasad and Southern in 1988 which lead to the production of BR135 "Fire Performance of Thermal Insulation for Walls of Multi-storey Buildings" [1].

Fire Barriers

The design and effectiveness of the fire barriers in insulated render systems was investigated by Stirling and Southern, in 1988 [11] using the full-scale fire test rig from the earlier work. The effect of fire barriers was determined by testing systems with and without barriers. This comparison was carried out for lath and glass fabric claddings. The results of these experiments showed metal fixings were the most effective and, especially for glass fabric claddings over external insulation, horizontal fire barriers at every storey between the cladding and the wall provide support for the insulation, restrain the cladding and restrict the damage. For rendered metal lath systems, fire barriers at every second storey significantly reduce fire damage. The work showed that systems could be adequately fixed using a combination of metal and plastic fixings, but not plastic fixings alone. Small-scale tests for these fixings showed that loaded fixings fail at much lower temperatures than unloaded fixings. Tests carried out on a multi-storey rig showed the effectiveness of supplementary metal fixings and fire barriers for mechanically fixed and adhesive fixed systems.

As a result BRE published Defect Action Sheet 132 [12] 1989 which details the use of fire barriers in overcladding systems and how far apart they should be.

Rainscreen Cladding

Connolly [2] reported that external cladding systems that contained cavities, such as rainscreen cladding, required the installation of fire barriers to reduce the potential fire hazard. Although the provision of fire barriers changed the nature of the air movement within the cavities of the façade, it was reported that they did not inhibit the operation of the ventilation systems in controlling the dampness.

The only fire barriers found to be adequate in reducing fire hazard were those which were fixed to the masonry substrate and fitted independently of the aluminium sheeting rails. However, the nature of the fire barriers required to prevent fire spread was found to depend on the nature of the cladding itself. Certain barrier systems were found to be adequate for some sheeting materials but not for others. The only fire barriers, which substantially reduced the fire hazard, required the vertical sheeting rails to be cut and therefore interrupted at regular intervals. Consequently such barrier systems may be unwieldy and expensive to fit in practice.

The investigation [2] also found that small-scale tests did not reflect the fire hazard associated with full-scale cladding system. The report states that there is a clear need for full-scale testing of system performance in fire. Such tests would help determine the adequacy of fire barrier systems when used in conjunction with a particular sheeting system. The use of fire protection solely around the windows and the use of intumescent grill fire barriers were found to be inadequate in ensuring containment of the fire spread.

Stirling [13] also looked at the fire performance of ventilated overcladding systems. The results of these tests were consistent with the observations of Connolly [2] in that the fire spread associated with certain sheet systems raised doubts as to the suitability of small-scale tests to determine the performance of these systems at full-scale. Stirling also reported that the use of mineral insulation around windows did not, by itself, prevent the vertical spread of fire. The introduction of windows was observed to reduce the vertical spread of fire but some lateral deflection at sill level into unobstructed cavities was observed. When stainless steel barriers were used, vertical fire spread was reduced and the use of steel weathering flashing, extended beyond the external face of the sheeting, may provide some deflection and reduce the rate of entry into upper cavities.

Connolly [2] reported the work on the development of a full-scale test scenario based around a vandal fire, plate 3, corner fire, plate 4 and window fire, plate 5.

Vandal Fire – Plate 3

Corner Fire – Plate 4

Window Fire – Plate 5

An assessment of the flame stability and exposure conditions suggested that a scenario based on a post flash-over fire exiting from a window was the most reproducible and realistic scenario.

The specification of the fire source was determined through experimental investigation and involved the use of both wood cribs and Avtur fuel. The results from the liquid fuel suggested that these were variable and that the wood crib fires produced a more reproducible fire load. The fire load was characterised as a thermal exposure of 90 ± 20 kW/m^2, at a height of 1m above the window opening, with a test duration of 30 minutes.

The initial design of the test facility was a single face facility. However, work within ISO suggested that a winged system would provide a more onerous test and the BRE test facility was modified accordingly, Figure 5.

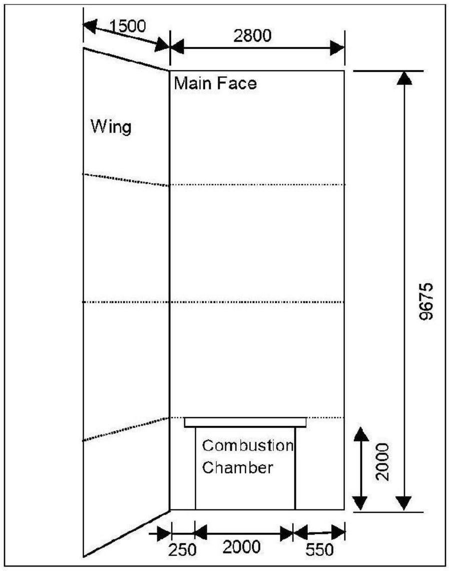

Figure 5. BRE test facility (dimensions in mm)

In 1997, Colwell and Smit [6] published a full-scale test method for assessing the fire performance of external cladding systems. The test method enables an assessment of the behaviour of non-loadbearing exterior wall assemblies including external wall insulation systems and curtain walling when exposed to an external fire. The test determines the comparative burning characteristics of exterior wall assemblies by evaluating the following:

i. Fire spread over the external surface.
ii. Fire spread internally within the system being tested.
iii. Mechanical response such as distortion and collapse.

Plate 6. BRE Full-scale fire test

BRE00041

The test method does not assess:

i. The fire resistance of the exterior wall assembly.

ii. The fire performance of the test specimen when subjected to the effects of a fire migrating through the external compartment wall, attaching the rear face of the system, Figures 1,2 and 3.

Other Research Groups

Kotthoff at MFPA in Germany has produced the most recent work in this area. This work is in response to the need to develop an intermediate scale test in ISO. He has tried to correlate the results from his full-scale tests with data from samples tested using the Single burning Item (SBI) Test. In addition, work to develop full-scale test methods has also been undertaken by both the Canadians at the Institute for Research in Construction and in Sweden at the Lund Institute of Technology.

The initial studies undertaken by Oleszkiewicz [14] in Canada, during the 1980s assessed the effect of window geometry on the fire plume. This work was based on a modified standard ASTM burn room. The results of the test showed:

- The ratio of the window height to its width controls the flame plume;
- Tall windows tend to project flames away from the building; and
- Squat windows produce plumes that hug the building exterior.

Hence the thermal exposure of the exterior wall is affected by the geometry of the system and fire plume characterises.

Based on these findings Oleszkiewicz [14] carried out a series of full-scale experimental studies using a three-storey test facility during the late 1980s. Both wooden cribs and a simulated crib heat source, using propane burners (exposure 45±5 kW/m² at a height of 0.5 m above the top of the fire-place) were used to carry out these tests. The range of materials investigated covered both combustible and non-combustible materials with and without cavities. Correlation between the results of the full-scale tests and several standard flame spread tests (Steiner tunnel test, radiant panel test and roof deck test) were explored and it was concluded that the full-scale test was the most appropriate method to evaluate the fire hazard of combustible wall assemblies.

Work on a small-scale facility called the "Vertical Channel Test" was also undertaken but the results appear to be inconclusive.

The need for full-scale testing was also confirmed by tests carried out by Ondrus and Pettersson [15] at Lund in 1986. The factors considered were:

- the surface spread of fire with the surface of the façade contributing to the fire;
- spread within the construction e.g. burning of insulation, wall studs and via air cavities;
- spread via the windows; and
- spread resulting from large sections of the insulation collapsing.

Fourteen tests were carried out with different types of external insulation systems applied to the facades of a three-storey test facility. The fire source was based on typical domestic loading of 110 MJ/m^2 providing a post flash fire through a window opening for a 10 minute duration on the face of the façade. The fire load was generated using 60 litres of heptane in a trough (0.5 m wide x 2.0 m long x 1 in deep) providing a thermal exposure of approximately 140 kW/m^2 immediately above the window opening and approximately 75 kW/m^2 at the second floor level.

The report noted that the combination and order of materials within the systems, as well as the constructional detailing were more important than the reaction to fire properties of the individual component materials involved, and consequently the fire hazard should be determined by testing the complete system at full-scale.

A performance classification system was suggested based on the following criteria by Moss [7]:

1. No collapse of major sections of the external additional thermal insulation system.

2. The surface spread of flame and the fire spread within the insulation should be limited to the bottom part of the window on the third floor. External flames that could ignite eaves should not be permissible.

3. There should be no spread of fire to the second floor through the windows - deemed verified if the total heat flux towards the centre of windows was 80 kW/m^2.

This test method is now specified as SP FIRE 105 [16] and in the new Swedish building regulations facades, have to be of non-combustible materials or have passed the full-scale test according to the above criteria.

Moss commented that the results of this test are likely to be conservative, based on the findings of the Canadian work which indicated that the window configuration can produce a flame plume which hugs the wall above the window, causing a more severe exposure than in a normal square window.

The New Zealand approach suggested by Wade [17] uses the ASTM E1354 and ISO 5660 cone calorimeter test methods to determine a range of burning rates for different external cladding component materials. In this report the cone calorimeter data is compared with the Australian surface spread of flame test standards AS 1530.1 and AS 1530.3. Wade concludes that the cone calorimeter enables a fire engineered solution because:

- instead of stringent pass fail criteria, the heat release information allows for a continuum of performance to be considered, from a low level to a high level as circumstances demand.
- it offers a measure of performance with a physical interpretation, where material properties using engineering units can be recorded
- it reduces the demand on samples required. The cone calorimeter test method uses 100 mm x 100 mm samples
- the test also provides greater reproducibility of results and better quality control.

This research by Wade [17] proposes a three-stage classification system based on the rate of heat release data from the cone calorimeter tests, focusing on the peak rates of heat release and the total heat release over the duration of the test. The cone calorimeter also provides for a range of heat flux levels more representative of conditions experienced in actual fires. No comparison with full-scale fire testing is made and it is unlikely that the cone calorimeter data alone could be used to provide an assessment of the fire performance of a complete cladding system.

In the most recent work by Kotthoff at MFPA [18] a series of comparative fire tests have been undertaken to assess the suitability of the SBI test as an intermediate scale test for assessment of complete cladding systems. Comparisons were made of the performance of cladding systems in both the SBI test and at full-scale. The full-scale work was undertaken using the draft ISO Standard test method CD 13785 [19], Figure 6. The heat source specified in the draft standard can be any that provides a duration of 15 minutes with a thermal exposure of 55 kW/m², at a height of 0.5m above the top of the window opening and 30 to 40 kW/m² at a height 1.5m above the top of the window opening. In the case of MFPA work, the fire source is a fully furnished room fire. Four cladding systems were investigated in this study and the summary report suggests that the SBI test would not be a suitable alternative to the full-scale test method. The full research report is due to be published later this year.

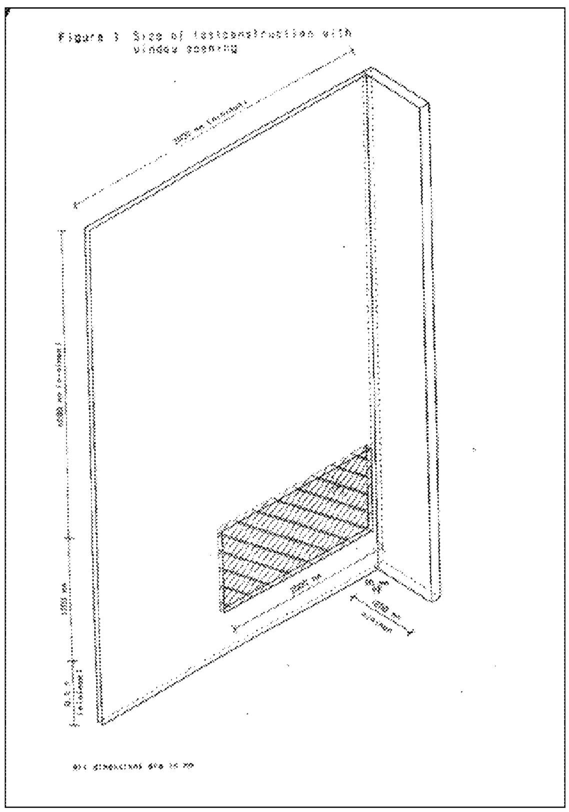

Figure 6. Draft ISO test facility

Curtain Wall Research

In 1978, Raes [20] published a review of research on external cladding fires. This paper covered full-scale experimental studies, work involving scale models and analysis of actual fires, which showed that fire spread to upper storeys typically occurs after the structural failure of windows and indirectly via the ignition of curtains, and wall and ceiling linings. The transfer of fire via the façade was strongly influenced by the behaviour of the exterior covering in a fire. The height and width of the windows primarily influenced the rate of flame spread on to the façade from the room of origin. An insufficient air supply - i.e. small windows – increased the duration of flaming within the room of origin and hence increased the fire exposure on the façade surface.

Raes suggested that the :

- windows should be wide and not 'too' high in order to reduce the flame height on the façade from a fire breaking out through a window in the room of origin.
- curtain walls should be fixed at each floor level to reduce deformation during fire, and
- the use of non-flammable curtains and wall linings should be considered.

A comprehensive series of tests were recently carried out by LPC [21] to evaluate the potential for fire spread and damage in multi-storey buildings with curtain wall facades. The results showed that in an unsprinklered building, with unfavourable environmental conditions, the typical assumption that the fire would be contained to one or two floors requires revision since uncontrolled fire spread from floor to floor was highly probable. The components of curtain wall systems such as 'transoms' and 'mullions' suffered significant deformation under fire exposures at elevated temperatures. This deformation was more important than collapse as it occurred much earlier and created gaps in fire stopping to allow fire spread to the floors above.

Windows

Fardell, Murrell and Rogowski [22] investigated the performance of UPVC and wooden double-glazed windows, when installed in a real-scale compartment with different wooden crib fires producing varying fire growth rates and intensities. The behaviour of UPVC window frames was compared to that of the traditional wooden frames. The double-glazed units were exposed to experimental fires designed to provide slow and rapid growth patterns. The tests showed that little damage was evident to both UPVC and wood frames until the glass panes were displaced. After the failure of one the glass panes, the increased ventilation accelerated the fire growth and in most cases the other panes fell out shortly afterwards. The wooden frames burned after the displacement of the panes while the UPVC frames were found to soften and sometimes fall out.

Oleszkiewicz [23] looked at vertical separation of windows in an attempt to reduce fire spread. He looked at the results of incidents and full-scale tests to demonstrate the hazard of the 'leap frog' effect of the spread of fire from one window to the window above. It was found that the introduction of a spandrel wall or a horizontal projection, such as a canopy or a balcony, above an exposing window, protects storeys above from flames issuing from the opening. The tests showed that a horizontal projection was very effective, however for a spandrel wall to be equally effective, an impractical height of spandrel is required. These results confirmed the findings of the work by Ashton [8] work in the early 1960s.

CONCLUSIONS

The main findings from this review have been:

1. There are many definitions for each type of cladding system and it is important to clearly and consistently define each system type to avoid confusion.

2. The 2000 revision of AD (B) goes some way to addressing the issues of fire performance of external cladding systems, the review of BR 135 will help to clarify any remaining issues as identified.

3. The work to date suggests that a large-scale test method is necessary to assess the performance of the complete system.

4. Intermediate scale tests may be suitable to categorise component material fire performance but system performance in the event of a fire can only be assessed at large-scale.

5. The shape and dimensions of the BRE large-scale test facility are comparable with those in the draft ISO CD 13785, with the exception of the primary wing which is longer than that set out in the BRE test method.

6. The BRE thermal exposure conditions are more severe, at 90 ± 20 kW/m^2 at a height of 1 m above the opening, than the conditions used in other tests reviewed in this paper.

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