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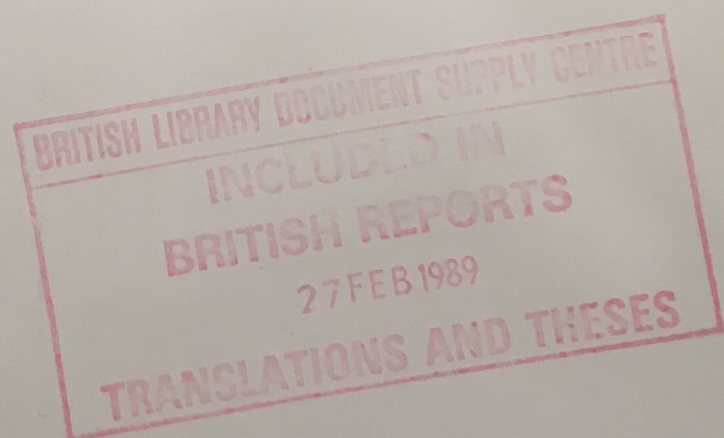
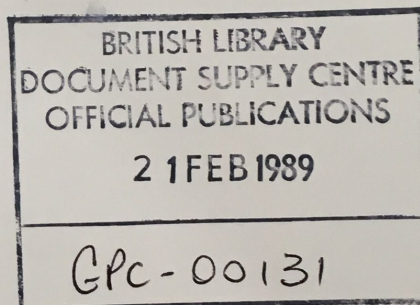


Fire performance of external thermal insulation for walls of multi-storey buildings

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SUMMARY

The application of external thermal insulation is a technique relatively new to the UK. The use of appropriately designed systems particularly on walls of high rise buildings provides an attractive method of energy conservation. To identify the design principles affecting the safety of occupants and the probable extent of fire spread, BRE has conducted large-scale tests in a four-storey experimental building. The rig was insulated externally either by direct application of a range of insulation/weathering systems or by a ventilated cladding system. An insulated timber cladding system typical of current accepted practice was used as the basis for comparison. A series of fundamental design recommendations has consequently been drawn up to minimise the hazard to life and to restrict the extent of necessary reinstatement following a serious fire.

ACKNOWLEDGEMENTS

The experimental work, carried out under contract by the Loss Prevention Centre, was supervised and assisted by staff of the Fire Research Station and Scottish Laboratory of the Building Research Establishment. The authors gratefully acknowledge their assistance and also the generosity of members of the External Wall Insulation Association who provided components for many of the insulation systems tested.

INTRODUCTION

The need for improved thermal insulation of buildings has led to the introduction of a range of systems designed originally for external application to solid masonry walls. Their applications have been extended to multi-storey developments where they have the advantage of improving insulation without disturbing the occupants during installation.

Insulation sandwiched directly between rendering and wall (Figure 1).

An insulant applied to the walls is protected either by a weathering finish of traditional sand/cement render, reinforced with metal lathing supported by fixings to the masonry, or by a thin rendering reinforced with glass fabric supported mainly by the insulant and finished with a masonry paint or chippings. Non-combustible inorganic insulating materials such as rock or glass fibre are marketed for such use, often as composite products incorporating a facing of breather paper and a metal lathing for use as a key for the rendering. Alternatively, the fibre insulant can be replaced by combustible thermoplastic or thermosetting cellular plastics insulants, applied as rigid boards or sprayed as appropriate. The insulant thicknesses can vary from 25 to 100 mm depending on the standard of insulation required. Other methods include products such as cementitious-based homogeneous lightweight renders incorporating, as an aggregate, expanded polystyrene beads or similar.

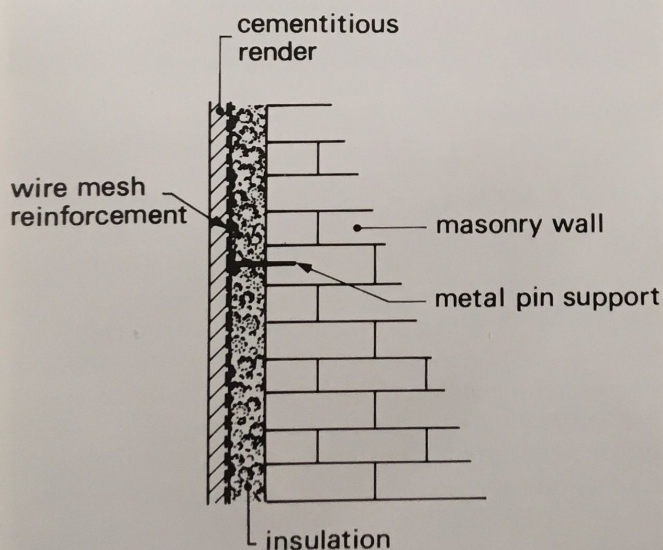


Figure 1 Typical non-sheeted external insulation system

Insulation protected by a ventilated cladding (Figure 2)

Again, insulants used may be mineral or plastics based but in these systems, non-combustible or metal facing sheets provide the weathering protection. In either case the resistance to the passage of water vapour introduces a risk of condensation within the wall/cladding system which could lead to corrosion problems and increased heat loss and consequently a ventilated cavity must be provided. This is sited

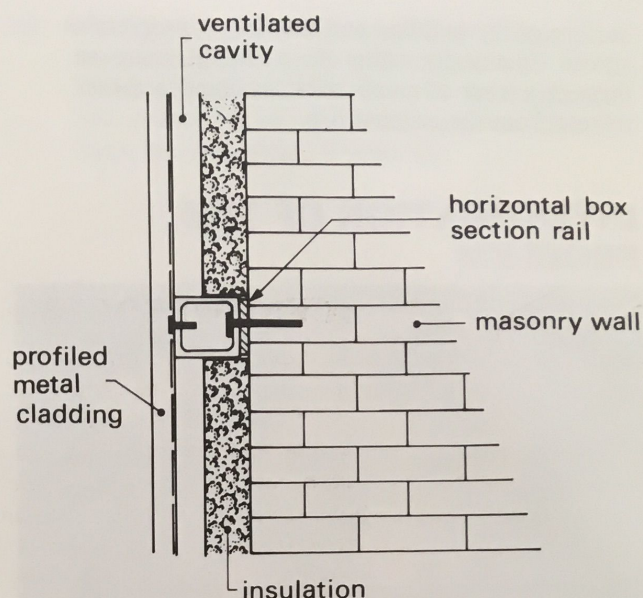


Figure 2 Typical sheeted system incorporating ventilated cavity

between the insulant, which is attached to the external wall and the cladding sheets which may be supported on a metal or timber framework.

Systems of both types have been widely used in Europe and recently in the UK at least four 12-storey blocks of flats have had rendered expanded polystyrene insulation systems applied to the walls and blocks of flats up to 22 storeys high have been treated with polystyrene incorporated behind a ventilated cladding, the cladding sheets being supported on a timber or metal framework. Other systems based on rock or glass fibre as insulant are used extensively. Possible advantages in terms of economy and ease of installation might favour increased use of polymeric insulants were there not fears about the effects of these on fire spread and doubts as to their acceptability under the provisions of the Building Regulations.

REGULATORY ASPECTS

Control over the external surface of walls of buildings, particularly those of multi-storey flats, to avoid ignition and flame spread which might endanger the lives of residents above by breaking down effective 'compartmentation*' is currently controlled^{1,2} by reference to tests specified in BS 476: Parts 6³ and 7⁴. However, these tests only provide information on surface fire behaviour. The overall fire performance of a ventilated cladding system or insulated assembly, incorporating independently-supported weathering finishes and complicated reveal details, can only be investigated under actual fire conditions on a full-scale building facade. To identify the design principles on which constructional recommendations might confidently be based demanded research. This would be to determine both the risk of flame spread over the

*compartmentation implies the confining of a fire to a given space by the provision of fire resisting walls and floors.

surface of the building and the risk of progressive spread via a cavity within the cladding system or through a layer of combustible insulant to areas remote from the original fire.

INVESTIGATION OF THE PROBLEM

Current concern has involved the likely performance in fire of large areas of external wall insulated in these ways when a flame plume emitted from a window on one storey impinges on the facade above.

In high rise buildings it was felt that a life risk might be caused by the penetration of fire or smoke through walls or upper windows resulting from:

- unconfined flame spread over the surface of the facades
- fire spread through continuous cavities or combustible insulants contained between the solid wall and the external finish of the system.

Other factors that might influence design included:

- the influence on surrounding buildings and access ways of radiated heat and/or flaming materials falling from the burning insulation systems
- the extent of repair required following a fire.

TEST PROGRAMME

The BRE Fire Research Station and Scottish Laboratory designed a research programme to investigate these problems excluding, because of experimental constraints, the effect of wind on the deflection of flames.

A 4-storey rig, 9.2 m high and 3.7 m square in plan rising above a recessed opening was constructed inside the FRS Cardington Laboratory (see Figure 3). This enabled in-situ fixing, and where appropriate, the drying and curing of three experimental assemblies simultaneously. Instrumentation was provided to measure the temperatures and heat flux at various locations on the rig and the radiated heat likely to fall on an adjacent building.

The experimental fire, a 400 kg timber crib with a 3 MW heat output which could be maintained over a period of 25 min, was designed to provide

- a) flames typical of a fully-developed building fire impinging on the facade up to 2 m above the recess for at least 20 minutes.
- b) heat flux on to the facade of at least 100 kW/m²

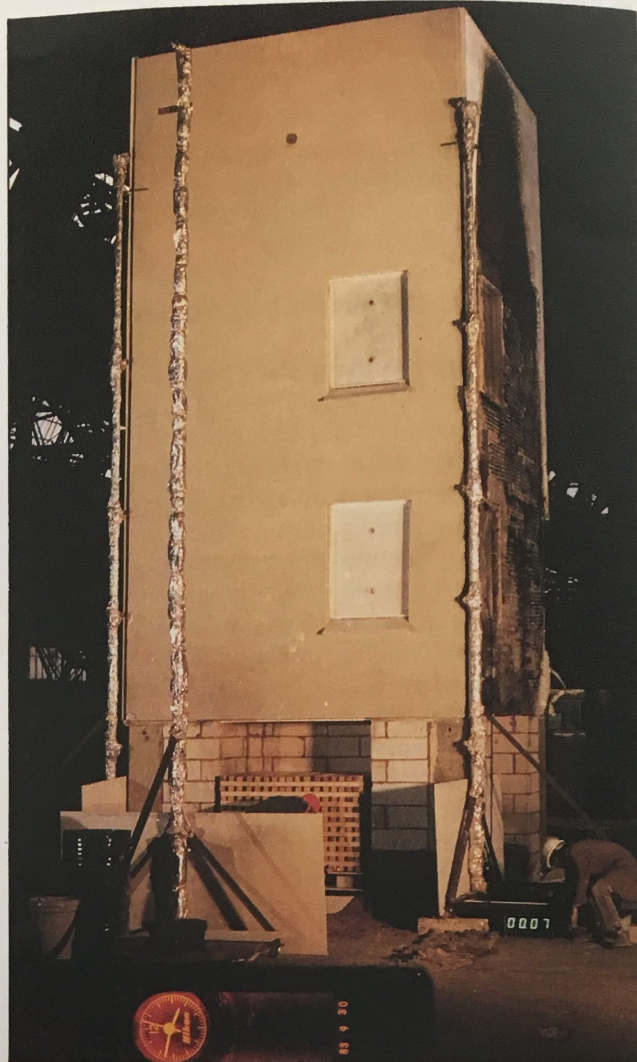


Figure 3 The rig before a test

INSULATION SYSTEMS INVESTIGATED

The assemblies were designed to incorporate a selection of individual components of a range of external wall insulation systems; some of which were supplied and installed by members of the External Wall Insulation Association. These provided a wide spread of information on performance rather than data on any specific proprietary system. Additionally, a selection of cladding systems typical of those already in use were installed and tested on the multi-storey rig.

EXPERIMENTAL FIRES

Typical experimental fires are illustrated involving

- a) a system with insulation sandwiched between rendering and wall (Figure 4);
- b) an aluminium-faced cladding system incorporating expanded polystyrene, the extent of the ventilated cavity being limited by fire barriers (Figure 5);



Figure 4 Flames from crib impinging on reinforced cementitious render over EPS insulant

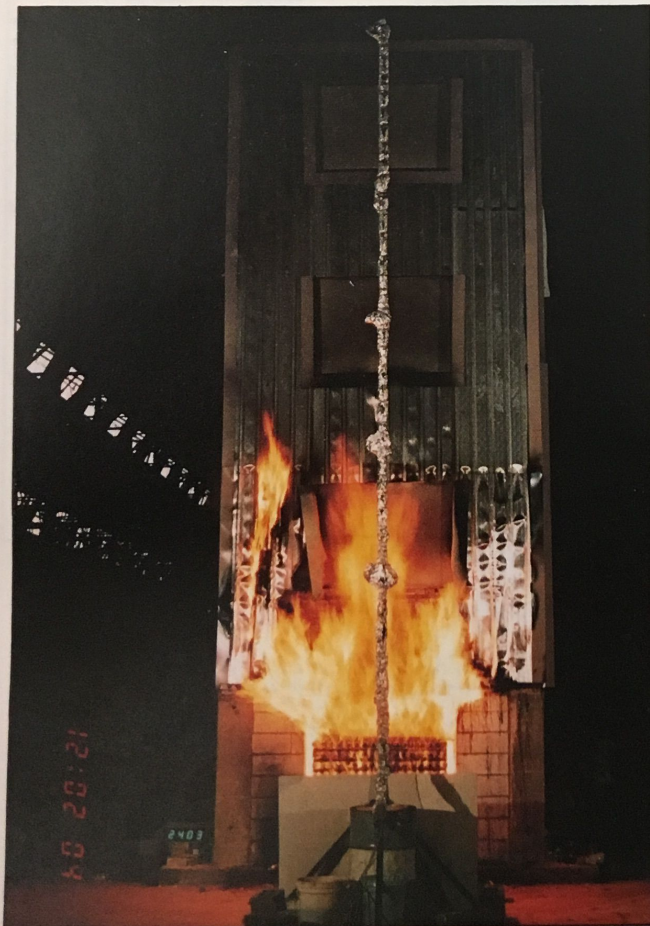


Figure 5 Flames extending above fire barrier in aluminium clad system

- (c) a traditional timber clad facade, at present accepted as meeting the provisions of the Building Regulations for low rise developments and included in the fire test programme as a basis for comparison (Figure 6).

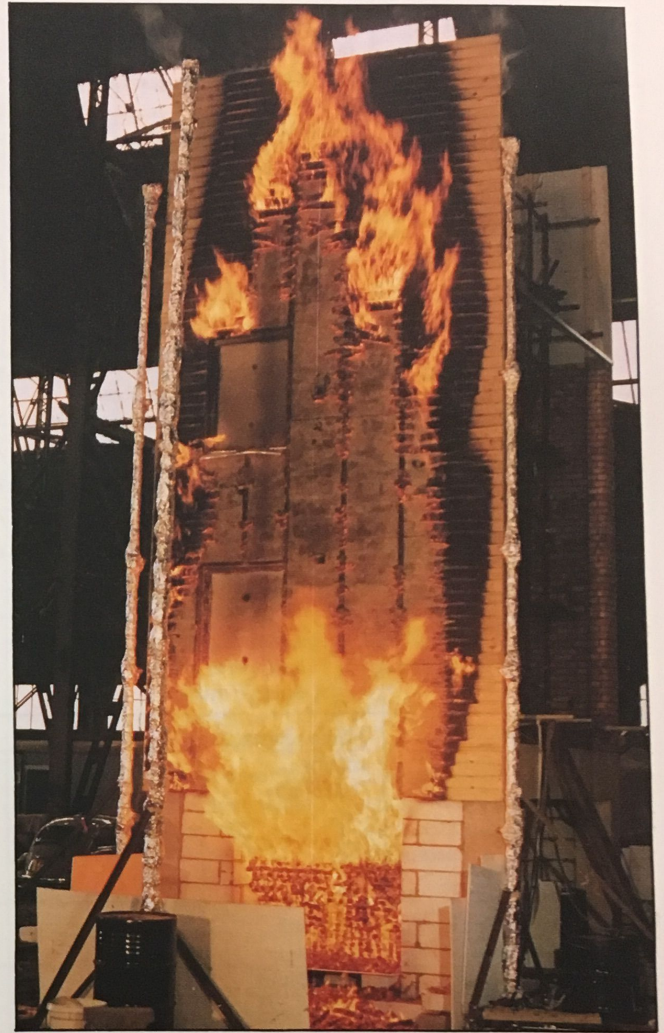


Figure 6 Flame spread over surface and within cavity in timber clad system

The salient features of the systems investigated, their fire performance and recommendations based on the latter are given in Tables 1 and 2.

Analysis of these results indicates (the last column of each table) the performance required to ensure that no significant additional hazard to life or excessive damage to the system is likely to result from a fire in the building damaging the external insulation.

Heat radiated from the burning facades was not, by itself, intense enough to create an exposure risk to neighbouring buildings.

Table 1 Design recommendations based on fire behaviour of non-sheeted external insulation systems

Insulant	Finish	Fixing	Fire barrier	Performance	Recommendations and comments
EPS (FRA)* – 50 mm	Glass fabric reinforced polymeric render – 4 mm	Adhesive	—	Render detached. Extensive degradation	Fire barrier and inorganic based surface render necessary with thermoplastic insulants
EPS (FRA) – 50 mm	Glass fabric reinforced polymer modified cementitious render – 50 mm	As above	Mineral wool barrier at each storey. Glass fabric returned onto masonry to provide support	Limited extent of degradation of insulation or finish	Above recommendations restricted surface failure and barrier design prevented extensive damage of the insulant
EPS (FRA) – 40 mm	Metal lath reinforced cementitious render – 25 mm	Polypropylene fixings	—	Distortion of metal lath allowed extensive damage to EPS. Flaming round upper windows	Heavy render needs rigid fixing of reinforcement to avoid distortion
EPS (FRA) – 40 mm	As above but 20 mm render	As above supplemented by one metal pin per square metre	Mineral wool barrier at every two storeys	Very limited degradation	Provision of rigid pin fixing prevented distortion of reinforcement and barrier restricted damage of the insulant
Render of EPS bead in cementitious matrix – 65 mm	Polymer finish	—	—	Minimal degradation	Each new product must be assessed
Polyisocyanurate – 45 mm	Flame retardant coating – 0.5 mm	Sprayed	—	Rapid vertical flame spread self sustained. Severe damage with pieces of flaming foam detached	Not suitable for dwellings
Polyurethane board – 35 mm	Metal lath reinforced cementitious render – 25 mm	Metal pins	—	Insulant decomposed only where render directly affected by fire	Recommendations on support of reinforced render effective. Barrier not necessary
Glass fibre – 40 mm and breather membrane	Metal lath reinforced cementitious render – 25 mm	Polypropylene fixings	—	No fire spread but deformation of reinforced render	Adequate support of heavy render needed even with non-combustible insulant

* FRA = Containing flame retardant additives

Table 2 Design recommendations based on fire behaviour of external insulation systems incorporating ventilated sheeted claddings

Insulant	Cladding	Cladding support	Cavity barrier	Performance	Recommendations and comments
EPS* (FRA) – 50 mm	Aluminium sheet – 0.9 mm	Horizontal aluminium box rails at 1.2 m intervals	—	Cladding melted allowing active EPS fire in cavity and dropping from base of cladding. Process slowly self-sustaining	Aluminium sheet requires fire barriers in cavity to limit extent of fire spread
EPS (FRA) – 50 mm	Aluminium sheet – 0.9 mm	As above but on steel rails	Mineral fibreboard 50 mm thick at first floor level	Fire barrier resulted in delay in failure of cladding. Damage less extensive than above	Localised fire spread above barrier delayed long enough to prevent progressive spread
EPS (FRA) – 50 mm	Aluminium sheet – 0.9 mm	Timber battens at 1.2 m vertical centres and horizontally between windows	Mineral fibreboard 50 mm thick at second floor level	Localised flaming in cavity. Extent of spread limited by fire barrier	Positioning of barriers at two-storey intervals limits extent of vertical spread of flame
EPS (FRA) – 50 mm	Steel sheet – 0.6 mm	Horizontal angle iron rails at 1.2 m intervals	—	Extensive damage to insulation in cavity. Isolated external flaming	Fire barriers recommended to limit extent of damage
EPS (FRA) – 50 mm	Reinforced calcium silicate panels – 50 mm	Vertical aluminium rails at 0.5 m centres	—	Spalling of sheeting. Active cavity fire. Extensive damage to insulant	Fire barriers recommend to limit extent of damage
Mineral wool – 25 mm air cavity and breather membrane	Timber siding – 20 mm	Vertical timber battens at 0.6 m centres	—	Self-sustained flame spread over siding accelerating following penetration of cavity	Limitation on height of timber siding permissible on facade should be maintained
Mineral wool – 50 mm	Aluminium sheet – 0.9 mm	Horizontal aluminium rails at 1.2 m intervals	—	Melting of directly exposed cladding and distortion of rails	None but localised damage is possible with severe fire exposure

* FRA = Containing flame retardant additives

RECOMMENDATIONS

To reduce the risk of vertical fire spread in existing and proposed external insulation systems the following recommendations based on this test programme are proposed by the Department of the Environment.

1. Mineral insulants may be safely used either

- attached to the wall and protected by adequately supported metal-reinforced cementitious renders; or
- in cladding systems incorporating metal or non-combustible sheeting supported by steel or timber framework and ventilated by a continuous cavity; fire barriers are not essential.

2. **Combustible insulants** may be used without a specifically designed system of surface protection only if shown by a full-scale fire test to be satisfactory (eg expanded polystyrene aggregate in cementitious matrix).

3. Existing systems incorporating combustible insulants with sheeted overcladding of

- aluminium: fire barriers should be fitted in the ventilated cavity every two storeys
- steel or non-combustible sheet: fire barriers should be fitted every two storeys *if a suitable opportunity arises*.

4. **Proposed systems incorporating combustible insulants with sheeted overcladding** should be designed to incorporate fire barriers in the ventilated cavity every two storeys.

5. **Combustible insulants incorporated in non-sheeted systems** are likely to suffer only limited fire spread if the following recommendations are applied:

- *Cementitious rendered metal lathing over thermoplastic insulants* should be provided with sufficient metal pins (about one every square metre) to secure the reinforcement to the masonry in order to stabilise the cladding and fire barriers should be installed every two storeys from the second floor upwards. With satisfactory full-scale test evidence barriers may be omitted up to the 15 m level.
- *Cementitious rendered metal lathing over thermosetting insulants* should be provided with sufficient metal pins (about one per square metre) to stabilise the cladding.
- *Thin renders with glass fabric reinforcement over thermoplastic insulants* should be fitted with fire barriers (which also support the protective finish) at every storey from the second floor upwards. With satisfactory full-scale test evidence barriers may be omitted up to the 15 m level.

6. **Surface protection** applied directly to all combustible insulants must be carefully designed and installed, round windows and other openings.

7. **In situ sprayed polyurethane or polyisocyanurate foamed insulants protected only by a flame retardant coating are not suitable for multi-storey housing developments.**

8. **Timber cladding** should continue to be used only in low rise developments (up to 15 m) to avoid extensive self-propagating flame spread over the surface.

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