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Fire safety considerations in the design of structural sandwich panels

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Lightweight sandwich panels are being increasingly used in buildings. They often employ combustible foamed plastic cores which can, without careful design, introduce a life hazard if fire occurs.

This Paper will be of use to building designers and architects, as well as approval authorities and includes a checklist of design guidance.

INTRODUCTION

Sandwich panels are being increasingly used as external wall and roof claddings for buildings because they are lightweight, energy efficient, and can be easily handled and rapidly erected. They are used in many types of building ranging from large factories and warehouses to domestic dwellings, their high thermal insulation making them especially suited to extreme climates. The panels often employ cores made of rigid foamed plastics because of low thermal conductivity, high moisture resistance and low cost. Foamed plastics are, however, often regarded as a fire hazard, often unfairly, and it is a purpose of this paper to show where they may or may not be safely used.

Sandwich panels can serve a variety of structural roles. They are usually defined as secondary structural elements since, unlike beams and columns, which are primary structural elements, they are rarely designed to transmit dead and imposed loads to the foundations. It is common for a sandwich panel to be designed to resist forces which place the panel in flexure eg wind loads on walls and snow loads on roofs. It is less usual but feasible for a panel to transmit shear forces, as in stressed skin construction, but it is rare for panels to transmit axial forces, as in lightly loaded walls.

Many different core materials may be used in sandwich panels. Board materials include flaxboard, foamed glass, compressed mineral wool, foamed phenolic resin, extruded polystyrene (XPS) and expanded polystyrene (EPS). These are adhered to the facings where the shear and tensile properties of the core are to be used. Some core materials may be injected between the facings such that they expand to fill the void and automatically adhere to the facings; polyurethane (PUR) and the closely related polyisocyanurate (PIR) rigid foams are examples. Facings may include steel or aluminium sheet, glass reinforced plastic, glass reinforced cement, gypsum plasterboard or timber based products. The number of different combinations of materials used in facings, core and, where appropriate, adhesive is large, and it is therefore difficult and misleading to give general guidance on the fire behaviour of such panels in a paper of this length. Such data are given elsewhere[1,2].

STANDARD TESTS

Most countries use a number of standard fire tests for life safety regulatory purposes. Tests which assess the rate of fire growth of building materials and composites from ignition to flashover form a family called the 'reaction to fire' tests which include tests for ignitability, combustibility, flammability, heat release and surface spread of flame. From flashover, when all the surfaces and contents of a room are involved in fire and combustion gas temperatures reach 500°C, the object is to limit the spread of fire beyond the room of origin and prevent collapse of the structure: here the ability of walls and floors to remain stable, prevent the passage of flame and hot gases through holes and prevent unexposed surfaces from reaching high temperatures, are measured in the fire resistance test (ISO 834). In the United Kingdom the above mentioned tests are specified in various parts of British Standard 476 and brief descriptions are given elsewhere[3].

Standard tests cannot reveal all the important fire characteristics of a material or composite, and non-standard tests have been developed for this purpose. The room corner-wall test is one such which is relevant to sandwich panels incorporating combustibl cores[4,5]. The large-scale test structure may be a cube, with two adjoining walls absent, Figure 1. The fire is usually simulated by a timber crib or an item of furniture placed in the corner close to the specimen walls. Many measurements are made including time taken for ignition of the specimen panels and failure of the facing, rate of fire spread over panels, radiation intensity, rate of burning, temperature of combustion gases and their chemical composition, and smoke emission rates. Among other things the test can identify composites which permit rapid fire spread but which appear acceptable when tested in the standard surface flammability test apparatus. This difference in behaviour can, for example, be clearly shown with rigid polyurethane foam faced with aluminium foil, and is caused by the high rate of decomposition of the polyurethane foam following failure of the facing at levels of incident heat flux far higher than those obtained in the standard tests. The level of incident heat

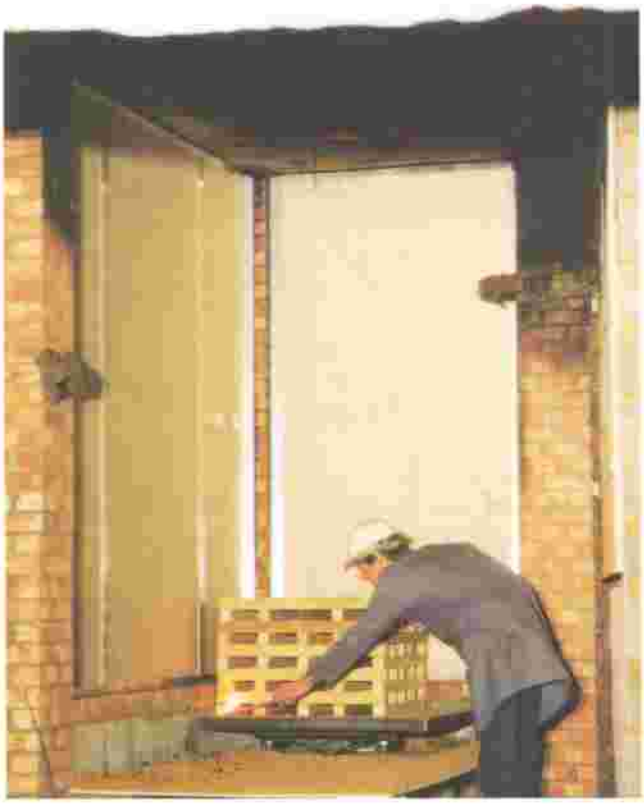

Figure 1 Corner-wall test rig showing panels and crib before test

flux is also an important factor in assessing the benefit of flame retardants, as it has been shown that a retardant which effectively quenches a flame after removal of a small ignition source may have no effect when a larger source is involved; indeed some flame retardants may increase the fire hazard by producing more smoke of a dense and irritant nature than the non flame-retardant product.

APPLICATION

The importance attached to the fire behaviour of a sandwich panel, as with any element of construction, depends upon the likely scenario, and this is shown in a simplified form in the following two extreme examples. The sandwich panels are the same in both examples. They have a core of PUR or PIR, with an external facing of profiled steel sheet, and an internal facing of aluminium foil used as a vapour barrier and to obtain a low surface flammability rating in the standard test.

Example 1

The panels are to be used for roof cladding in a modern, undivided, tall single storey storage building. Very few people occupy the building. There are several escape doors spaced around the perimeter with unimpeded escape routes to them from any point of the building. The roof requires no fire resistance. What is the life risk?

First decide likely sources of ignition bearing in mind accidents, arson, normal usage of the building, standard of housekeeping, building maintenance activities and so on. We shall assume that fire is unlikely to start at roof level since electrical faults in wiring in a modern building are unlikely. A fire occurring in the stored goods at ground level will produce a plume of smoke which will be visible throughout the building as it is deflected by the panels and travels horizontally until it contacts the external walls and begins to build downwards. A tall building has a large smoke reservoir and it will take longer for smoke to build down to head height, giving more time for escape.

The rate of lateral fire spread within the stored goods will be governed by the ignitability and rate of burning of the items (including their packing materials), their spacing and the production of flying brands. If the goods are not stacked high there will be no direct flame impingement onto the panels and little feedback of radiation from hot gases at roof level, and fire spread within the contents will be far slower than would occur if the contents were, say, only 1 metre below the roof panels. Hence the roof panels are likely to contribute to fire only at a late stage and the products of combustion from the panels, though possibly more toxic and irritant, will add little to the hazard from smoke generated by the fully developed fire in the contents below. Hence there is negligible life risk to the occupants or professional fire-fighters.

Where, however, fire starts in a high stack of contents spaced away from other stacks, it is possible for fire rapidly to spread vertically through the stack and involve the roof panel core in fire over a large area before further fire spread at ground level has occurred. This could provide a hazard for fire-fighters inside the building even though the occupants had safely escaped. A similar hazard could arise from a localised fire next to the bottom of a wall such that fire spreads easily up the wall to get the roof panel core involved in fire over a large area. A wall lining able to act as a 'fire bridge' in this way should be avoided and this is a good reason for wall panels employing combustible cores (eg XPS, EPS, PUR and PIR) to be protected on the fire-exposed face with an inert fire protecting layer such as 12.5 mm plasterboard or a cementitious spray coat of equivalent protection. A fire-protecting layer could be avoided by using wall panels employing non-combustible cores of mineral wool or foamed glass for example, but the layer may be needed for other reasons such as appearance, resistance to impact damage, and contribution to flexural strength.

Example 2

The panels are to be used as 2-storey external wall panels in terraced housing. A half-hour fire resistance from the inside is required. What is the life risk?

Setting aside the unacceptable impact resistance and the difficulty of achieving half-hour fire resistance from a panel whose core is only protected from the occupants or a fire by aluminium foil, we can see that, unlike the building in Example 1, the core material is more vulnerable to impact damage. Ignition of the core by over-heating faulty electrical wiring in contact with it is possible; ignition of an item of furniture close to the wall is also possible and is a more likely occurrence leading to early involvement in fire of the core and its rapid contribution to the initiating fire. The absence of a large smoke reservoir and the likelihood of rapid fire spread beyond the room of origin, and up the stairs if the door is open or of poor fire resistance, in a building in which people may be asleep, makes the use of such panels in housing unacceptable in terms of life safety.

But what if the panels incorporated a fire-protecting lining such as 12.5 mm plasterboard? Large-scale fire tests[6], sponsored by an Industrial Consortium, have been recently undertaken by the Fire Research Station, using a corner-wall test rig, Figure 1, lined on two adjacent masonry walls with a variety of cellular plastics insulants (XPS, EPS, PUR, PIR and phenolic foams), mostly 25 mm thick and faced with 9.5 or 12.5 mm plasterboard. The fire source was a 57 kg wood crib designed to give the heat output of a burning armchair of modern plastics foam-filled type and capable of overcoming the protecting plasterboard facings, Figure 2. The test was conceived because the standard surface flammability tests (BS 476 Parts 6 and 7) were not severe enough locally to represent the above scenario, whereas the standard fire resistance test does not allow measurements to be made of the relevant properties and cannot simulate the localised thermal shock associated with the initial high rate of burning of a piece of modern furniture. The results showed that in no case was a significant additional contribution made to life hazard in excess of that introduced by the ignition source. Small-scale tests, to check the possibility of hidden ignition of the insulants behind plasterboard due to electrical faults, showed that there was only slight damage and little risk of decomposition products entering the room even with a simulated heavily loaded short circuit.

Figure 2 Corner-wall fire test in progress

RECOMMENDATIONS

The two examples above cannot highlight all the fire considerations. The following checklist and guidance may therefore help the designer to achieve a design which is acceptable to his client, regulatory authorities and insurers.

(i) Establish the fire performance required. If in doubt, consult the building regulation authority. Consult fire insurer to see if proposed panel design attracts extra insurance premium.

(ii) Consider safety of occupants, fire-fighters and people near the building. For example, avoid external wall panel designs which, in fire, allow outer facing to become detached and fall or be blown thus providing a missile hazard and allowing unexpected unrestricted thermal radiation to people and property nearby.

(iii) Try to use wall panels with an effectively fixed fire-protecting inner facing such as plasterboard or other fire-protecting board which does not decompose, disintegrate or shatter in fire (see Figure 3). This is more important where cores are combustible and capable of producing toxic and irritant combustion products. The use of poorly protected foam plastics cores is less objectionable if escape routes and exits are good, few people occupy the building, the building has a large smoke reservoir, there is good visibility and a fire detection and alarm system is installed.

(iv) Avoid using timber inner facings where it is important to minimise surface flammability. Small areas of timber, which do not form part of an escape route lining, may not require the use of flame retardants to achieve this.

(v) Before insisting that the combustible core or, if appropriate, inner facing is treated with flame retardants, check with the manufacturer to determine the range of fire size and levels of incident radiation for which the retardant works.

(vi) If combustible materials are present in the panel, they should preferably not melt and form flaming droplets to cause new outbreaks of fire. This is especially important in roofing applications.

(vii) Junctions between sandwich panels and fire separating walls or floors should always be fire-stopped so that fire cannot spread beyond the fire separating element via the combustible core of the panel. Intermediate fire stops around the perimeter of each panel, and within large panels, are also highly desirable (see Figure 4). This reduces the life hazard and property loss.

(viii) Where the panel serves an important structural role be sure to understand the basis of design at ambient temperature before designing for good behaviour in fire.

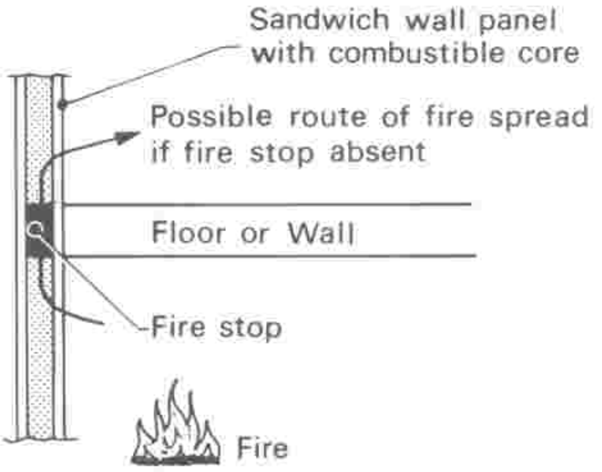

Figure 4 'Junctions between sandwich panels and fire separating walls or floors should always be fire-stopped . . . . '

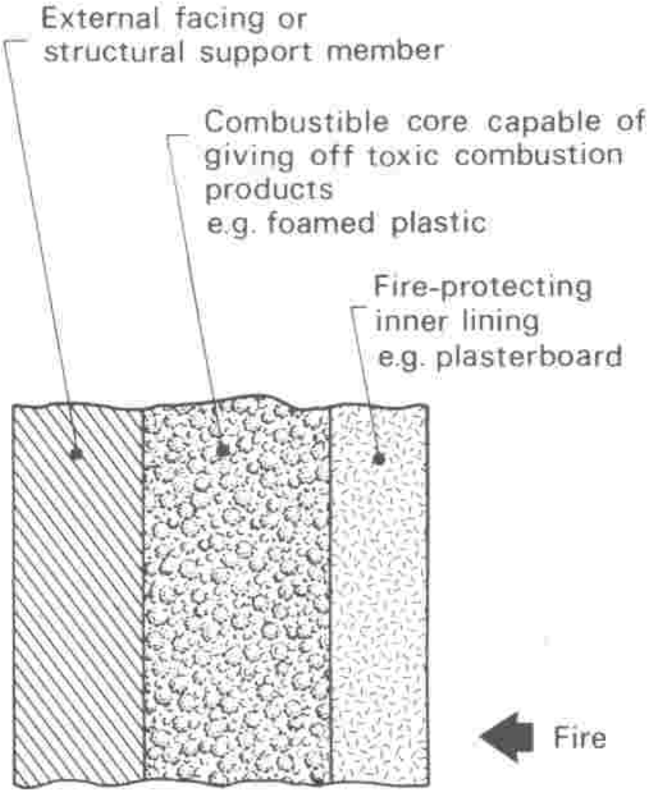

Figure 3 'Use wall panels with an effectively fixed fire-protecting inner facing such as plasterboard which does not decompose, disintegrate or shatter in fire . . . . '

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