

The fire safety design of sandwich panels used in buildings

G M E Cooke BSc, PhD, CEng, MIMechE, MICE,
FIFireE, MSFSE
Fire Research Station
Building Research Establishment
Borehamwood, Herts
United Kingdom

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 buildings 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 of rigid foamed plastic because of low thermal conductivity, high moisture resistance, and low cost. Foamed plastics however, are often regarded as a fire hazard, often unfairly. The number of different combinations of materials used in facings, core and, where appropriate, adhesive is large, making it difficult to give general guidance on the fire behaviour of panels in a paper of this length. Such guidance is given elsewhere^{1,2}.

Building regulations often control the life risk by reference to standard fire tests which aim to measure ease of ignition, rate of heat release, flame spread or a combination of these, and, in some cases, smoke production and toxicity.

The primary objective is to ensure that occupants inside or nearby a building are not exposed to a life threat if fire occurs. Life threats can arise by rapid spread of flame and hot gases, smoke obscuration and irritancy, and toxicity.

Standard fire tests

Tests which assess the rate of fire growth in building materials and composites from ignition to flashover form a family called the "reaction- to-fire" tests which include tests for ignitability, combustibility, flammability, rate of heat release, smoke production and toxicity.

From flashover, when all the surfaces and contents of a room are involved in fire and combustion gas temperatures reach around 500°C and above, 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 temperatures which would ignite combustible materials in contact with them, are measured in the ISO 834 standard fire resistance test.

In the United Kingdom the above mentioned tests are specified in various parts of British Standard 476 and a brief description is given elsewhere³.

Ad hoc fire tests

Standard tests are limited in the information which they can reveal about the important fire characteristics or hazards of a material or composite, and non-standard tests have been developed for this purpose. The room corner-wall test is relevant to sandwich panels incorporating combustible materials^{4,5}. The test apparatus can be visualised as a small room with two adjoining walls absent. The fire is usually simulated by a timber crib or an item of furniture placed in the corner close to the specimen walls. Measurements taken include time taken for ignition of the specimen panels, rate of heat release, extent of failure of the facing, rate of fire spread over panels, radiation intensity, temperature of combustion gases and their chemical composition, and rate of smoke production.

The corner-wall test can identify composites which permit rapid fire spread but which appear acceptable when tested in the small scale standard 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 early failure of the foil facing at levels of incident heat flux far higher than those achieved in the standard tests.

The level of incident heat flux is 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 a non-flame retarded product.

Large-scale fire tests, sponsored by an industrial consortium, have been 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 (ie the crib). 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.

The variety of corner-wall tests now available will be supplemented and perhaps replaced by the ISO Room fire test which comprises a room nominally 3.6 m long x 2.4 m wide x 2.4 m high with a door opening in one of the short walls from which the combustion products are collected. The standard for this test is in draft⁶ at the time of writing this paper (August 1991).



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



Figure 2 Corner-wall fire test in progress

Proliferation of fire tests

It has been mentioned that standard fire tests fall into two groups: reaction to fire, and fire resistance. In 1988 the author made a survey of fire tests for structural sandwich panels in some EEC and EFTA countries as part of work within CIB Working Group 56 (lightweight structures). The questionnaire asked for information on national Building Regulations and associated fire tests, and the responses showed that there was a wide range of standard test methods reflecting different fire scenarios. This wide variation in fire tests represents a technical barrier to trade between the different countries and underlines the need for harmonization which is especially important for smaller companies which cannot afford the high cost of testing in each country.

European common market developments

The Construction Products Directive (CPD) which came into force in the 12 member states in June 1991 is expected to have a major impact on the design, testing and installation of all products used in buildings and civil engineering works. Products in this context include materials, components (eg windows and roof lights), elements (eg walls and roofs), installations (eg automatic sprinkler installations) and prefabricated systems. The CPD requires that construction works (eg buildings) satisfy several Essential Requirements. One of these is Safety in case of fire. The CPD does not attempt to harmonize safety levels (Building Regulation requirements), but will harmonize fire tests and calculation methods for assessing performance in fire. It will accomplish this by mandating CEN (the European standards making body) to produce harmonized test standards and technical approvals.

A series of documents called Interpretative Documents have been prepared to provide links between the essential requirements (functional statements) in the CPD and mandates to CEN. The European Commission has, via the work of an expert group, identified that more than 37 reaction-to-fire tests exist in Europe and has made recommendations for work leading to a harmonized family of reaction-to-fire tests which could apply for many years - the so-called Robust Solution. It is not possible to say what these tests will be until a careful programme of research,

development and testing work has been undertaken to establish the most appropriate fire tests and classification methods.

Fire safety considerations

* Consult, at an early stage, the building and fire authorities, and the insurer, to establish the desired fire performance.

* Try to use wall panels with an effectively fixed fire-protecting inner facing such as plasterboard or other fire protecting board which does not fail early in fire. This is more important where cores are combustible and capable of producing toxic and irritant combustion products, Figure 3.

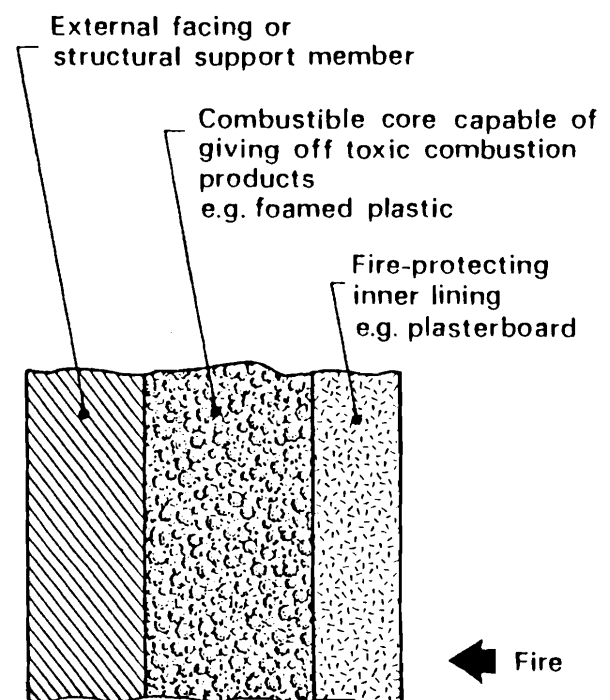


Figure 3 'Use wall panels with an effectively fixed fire-protecting inner facing such as plasterboard which does not decompose, disintegrate or shatter in fire....'

* The use of poorly protected flammable plastic cores is less objectionable if: escape routes and exits are good and easily seen, few people occupy the building, the building has a large smoke reservoir or a system of smoke vents, and a fire detection and alarm system is installed so that the occupants can vacate the building before the atmosphere becomes untenable⁷.

* Before insisting that the combustible core or, if appropriate, inner facing is treated with a flame retardant, check with the manufacturer to

determine the range of fire size and levels of incident radiation for which the retardant works. 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.

* Avoid using timber 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.

* Minimise the combustible content of all materials in the panel. In particular minimise the use of materials (eg pvc) which give off HCl when involved in fire which can damage building services, cause corrosion to concrete and damage finishes in the rest of the building.

* Minimise the use of materials which can melt and form flaming droplets to cause new outbreaks of fire. This is especially important in roofing applications.

* Avoid panel seals which are easily penetrated by fire or give off toxic fumes.

* Fire stop junctions between sandwich panels and fire separating walls or floors so that fire cannot spread beyond the fire separating element via the combustible core of the panel, Figure 4. Intermediate fire stops around the perimeter of each panel, and within large panels, are also highly desirable. This reduces the life hazard and property loss.

* Avoid extrapolation of stability data gained from standard fire resistance test results when designing the stability of tall wall panels supported at the lower edge since thermal bowing may produce eccentric loading which leads to instability of the panel. Suspend tall panels from the upper edge making due allowance for vertical expansion.

* Consider the forces caused by unsympathetic thermal movement acting on panels in the fire condition. Unsympathetic thermal bowing can occur at external and re-entrant corners leading to rupture of the panel or, more likely, panel joints, allowing fire to pass through.

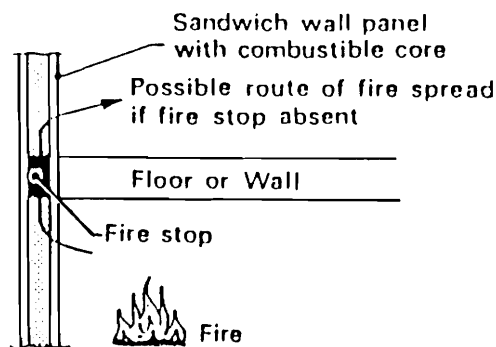


Figure 4 'Junctions between sandwich panels and fire separating walls or floors should always be fire-stopped....'

* Consider safety of firemen and people near the building. For example, avoid external wall or roof panel designs which, in fire, allow the outer facing to become detached and act as a missile hazard, and allow unexpected high levels of thermal radiation to people and property nearby.

References

1. Dowling V P and Martin K G. Assessment of fire performance of rigid cellular plastics in buildings, Part 2 furnace exposure of sandwich panels, CSIRO, Division of Building Research, Australia, 1981.
2. Rogowski B F W. Fire performance of building elements incorporating cellular polymers. Cellular Polymers, 1985, 4, 325-328.
3. Read R E H and Morris W A. Aspects of fire precautions in buildings, London, HMSO, 2nd edition, 1988.
4. National Bureau of Standards. Products Research Committee, Fire Research on Cellular Plastics: The Final Report of the Products Research Committee, Washington DC, April 1980.
5. Holmes C A. Room corner-wall fire tests of some structural sandwich panels and components. Journal of Fire and Flammability, 1978, 9 (October) 467-488.
6. International Standards Organisation, Room fire test in full scale for surface products, ISO DP 9705, (ISO/TC92/SC1/WG7/ N70)
7. Cooke G M E. Fire safety considerations in the design of structural sandwich panels. BRE Information Paper 4/87, Building Research Establishment, UK, May 1987.