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Publisher's version / Version de l'éditeur:

<https://doi.org/10.1177/073490418400200303>

Journal of Fire Sciences, 2, 3, pp. 179-188, 1984-05

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COMBUSTIBILITY OF INSULATION IN CAVITY WALLS

by K.K. Choi and W. Taylor

ANALYZED

Reprinted from
Journal of Fire Sciences,
Vol. 2, No. 3, May/June 1984
p. 179 - 188

DBR Paper No. 1248
Division of Building Research

Price \$1.00

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RÉSUMÉ

On augmente de plus en plus la quantité d'isolant thermique dans les bâtiments pour réduire la consommation d'énergie. Dans les bâtiments de construction incombustible, il est préférable pour le rendement thermique et la sécurité incendie de placer l'isolant dans la cavité des murs extérieurs. L'utilisation de mousses plastiques isolantes a été réglementée en raison des caractéristiques d'inflammabilité mises en évidence par des essais entrepris dans ce but. Il a été admis à la suite d'essais comparatifs des mousses isolantes et d'autres types d'isolant que les méthodes employées ne permettaient pas d'évaluer convenablement le comportement au feu des mousses plastiques placées dans les murs creux.

COMBUSTIBILITY OF INSULATION IN CAVITY WALLS

K. K. Choi

*Division of Building Research
National Research Council of Canada
Ottawa, Ontario
K1A 0R6*

W. Taylor

*Esso Chemical Canada
2300 Yonge St.
Toronto, Ontario
M5W 1K3*

(Received February 24, 1984)

(Revised June 21, 1984)

ABSTRACT

Increasing amounts of insulation are used in buildings to conserve energy. In buildings of noncombustible construction, insulation is usually placed in the wall cavity with or without an air space. The use of foamed plastic insulation has been restricted due to its combustibility characteristics when tested by methods adopted for regulatory purposes. A series of tests on foamed plastics and conventional insulation materials show that these methods do not realistically assess the fire performance of foamed plastic insulation when used in cavity walls.

INTRODUCTION

IN CANADA AND THE UNITED STATES, MORE THAN ONE THIRD OF THE total energy consumption is used for heating and cooling of buildings. The efficient use of energy in buildings is therefore of paramount importance if the objective of energy conservation is to be met. One of the most effective measures of reducing energy consumption in buildings is

Part of this paper was presented at "Cooperating to Fight Fire," the Third Symposium on Combustibility and Plastics, Toronto, October 24-28, 1983.

Reprinted from JOURNAL OF FIRE SCIENCES, VOL. 2—MAY/JUNE 1984

to add insulation to the building envelope. Unfortunately, the use of insulation to improve the energy efficiency of buildings may adversely affect fire safety. One of the potential hazards is the spread of fire in concealed spaces of buildings, particularly in cavity walls containing combustible insulation. Some of the pertinent aspects of this problem and their investigation are discussed in this paper.

CAVITY WALLS

Cavity wall construction was developed to overcome the poor resistance of solid walls to rain penetration [1]. This type of construction consists of an external cladding separated from the internal wall by an air space, or cavity, that is vented to the atmosphere. Since there is very little pressure difference between the outer and inner surfaces of the cladding, rainwater driven through the unavoidable leaks by wind, gravity and capillary forces tends to flow down its inner surface. The water is intercepted by the flashing at the bottom of the cavity and led back to the outside through weep holes. The cladding therefore acts as a screen for rainwater, keeping the wall dry. A typical cavity wall construction is illustrated in Figure 1.

INSULATING CAVITY WALLS

When insulating a cavity wall, insulation can be placed on the inner or the outer face of the internal wall (Figure 2). If it is placed on the in-

Figure 1. Typical cavity wall.

Figure 2. Two methods of insulating a cavity wall.

side face, the entire masonry wall will be kept at or near the outdoor temperature and the masonry will be subjected to compressive and tensile stresses due to changes in temperature and moisture content. Such an arrangement can cause cracking and results in frequent thermal bridges at floor and roof slabs and at cross-walls, since the structure generally remains uninsulated at these locations.

By placing the insulation at the outside face of the internal wall, the entire structure is maintained at a relatively constant temperature and humidity, minimizing the disruptive dimensional changes that can result in cracking.

CAVITY WALL INSULATION

Although in principle any insulation material can be used in cavity walls, in practice only a few are suitable for such an application. Those most widely used fall into two categories: glass fiber and foamed plastic.

Glass fiber insulation is a rigid board consisting of fibers of glass bonded together with a resin binder. The board is sometimes faced with a vapour barrier to control water permeability. This type of insulation is normally regarded as a low-fire-hazard material although it is not classified as noncombustible due to the presence of the binder.

Foamed plastic insulation can be made of polystyrene, polyurethane, polyisocyanurate or phenolic, and is usually produced in the form of rigid boards. However, polyurethane foam can also be applied on-site by spraying or pouring.

Many foamed plastics are flammable and spread flames quickly once

ignited. The National Building Code of Canada [2] requires that all foamed plastics, when used in buildings of noncombustible construction, be protected by suitable thermal barriers to reduce the chance of accidental ignition by excessive heat transfer to the foamed plastic insulation during a fire. Since masonry and concrete are acceptable thermal barriers, the use of foamed plastic insulation in cavity walls is permitted by the National Building Code of Canada, provided that, to limit the spread of fire, fire stops are installed at prescribed locations.

COMBUSTIBILITY OF FOAMED PLASTIC INSULATION

The increasing use of foamed plastics in the building industry has made their combustibility an important consideration. The traditional way of assessing the combustibility of building materials is to assign to them a flame spread index (FSI), a number derived from the ASTM E 84 tunnel test [3]. These indices rank materials in a sequence of surface flame spread merit; for regulatory purposes it is assumed that the sequence would not be altered under any condition encountered in fires.

In studies of foamed plastics, serious discrepancies have been reported between results obtained from tunnel tests and those from experimental or real-life fires [4]. Recognition of this fact in the United States has led to the development of alternate tests which more closely simulate a plausible fire situation in which foamed plastics may be involved.

In Canada, on the other hand, the tunnel test is still the principal method by which the surface burning characteristics of foamed plastics are determined for regulatory purposes. In an attempt to accommodate the anomalous behaviour of foamed plastics in the tunnel test, however, an amended calculation method for determining the flame spread classification (FSC) was introduced [5]. This method places emphasis on the high flame spread velocity in the earlier part of the test, which is a characteristic of some thermoset foamed plastics, and discounts the subsequent static behaviour of the flame front. The equation for determining the FSC for materials that exhibit nonuniform flame propagation is given in the Canadian standard [6] by $FSC = 28.2 d/t$, where d is the distance progressed by the flame front before slowing or stopping and t is the time at which this occurs.

This equation, when applied to polyurethane foam with an FSI of less than 75 as calculated by the E 84 method, resulted in increases in the flame spread classification between two and ten times, while for other urethanes with higher flame spread or for conventional materials, it resulted in little or no change.

The test procedure has also been changed for thermoplastic foams such as polystyrene, which melt before reaching the pyrolysis temperature. The material to be evaluated is placed on the floor of the

tunnel as in the testing of floor-covering materials [7]. Under these test conditions, expanded polystyrenes with an E 84 classification of 25 have been found to have FSCs in the range of 100-200.

With these modifications in place, it has been assumed that the tunnel index will place foamed plastics in their correct position in a universal surface flame spread merit sequence [8] and hence reflect the "real-world" performance of these materials in fire situations.

FIRE SPREAD IN CAVITY WALLS

In a fire, flames issuing through broken windows may penetrate the external cladding and ignite the insulation behind it. Once ignited, the insulation can propagate fire to the upper storeys along the cavities in which it is installed. To limit the spread of fire in the wall cavities, the allowable flame spread rating of the insulation is restricted to values that depend on the building type.

A limited amount of experimental work has been done on fire spread in cavity walls in which foamed plastic insulation is installed. Some tests with polyurethane foams indicated that such insulation, when used in a vertical position between two layers of concrete with no internal air space, was unlikely to contribute to fire propagation within the assembly, regardless of the flame spread rating of the polyurethane [9]. When there was an air space, somewhat more extensive fire spread was reported; therefore an upper limit of FSC 25, as measured by ASTM E 84 tunnel test, was suggested for the insulation to limit the spread of fire in the cavity. Subsequent tests with a vertical cavity enclosed by asbestos cement board gave similar results [10].

The inadequacy of tunnel test results, with or without the Canadian modifications, as a basis for judging the fire performance of foamed plastics in wall cavities was clearly reflected by these tests. Exclusion of the air space, which was suggested as one of the conditions under which foamed plastics could be safely used in wall cavities irrespective of their flame spread ratings, would be impracticable, since the air space is highly desirable to control the flow of moisture.

In a study conducted by Taylor [11], foamed plastics of different flame spread ratings were tested in an apparatus designed to simulate a two-storey wall cavity of noncombustible construction (Figure 3). The objective was to measure the fire spread within the wall cavity, and to determine its dependence on the characteristics of the insulation material and the width of air space in the cavity. Flames were introduced into the cavity, lined with the insulation materials under test, for 10 min through a 25 mm high horizontal slot located at the bottom of the apparatus. The propagation of fire was observed through a number of viewing ports in the front panel.

When tests were performed with polyurethanes at air space widths of 12.5 and 15 mm the spread of fire along the insulation was limited to

Figure 3. Cavity wall test rig.

1-2 m of the flame source, irrespective of the flame spread rating of the insulation. Increasing the air space to 25 mm resulted in more burning of the foam, although the fire spread was confined to the lower 2 m of the cavity. When the width of the air space was increased to 40 mm, continuous fire propagation throughout the full height of the test assembly was observed. Tests with polystyrenes and an air space of less than 25 mm also revealed very insignificant fire spread; however, melting of the insulation was noted. The molten material flowed down to the bottom of the apparatus, where it was ignited by the flame source and burned as a pool fire. With air gaps of 25 and 40 mm, ventilation in the cavity resulted in less melting of the insulation, but in both tests the fire spread to the top of the apparatus.

The results of these tests indicate that the danger of fire spread in

wall cavities depends on the nature of the foamed plastic, the width of the air space and the ventilation of the cavity. The flame spread rating of the materials used in the tests was not a significant factor. It is not surprising to find that polyurethane and polystyrene foams behaved quite differently, since the former is a char-forming material while the latter is a thermoplastic that melts on heating before it reaches the pyrolysis temperature.

With masonry-faced cavity walls, glass fiber insulation is still used predominantly. Its properties are given in Table 1. The use of this material in buildings of noncombustible construction is not restricted because it has a flame spread rating of less than 25. To determine the validity of using flame spread rating as a measure of the fire spread potential in cavity walls, the fire behaviour of this material was studied. A series of tests using different widths of air space was performed on glass fiber insulation in the same apparatus as that illustrated in Figure 3. The test conditions and procedure were identical with those in the earlier study. Because visual monitoring of fire propagation in the cavity can be quite subjective, thermocouples were used to indicate the flame front. The changes in oxygen concentration in the cavity were monitored by sampling gas through a probe situated 1 m above the bottom of the apparatus. Locations of the thermocouples and the gas sampling probe are shown in Figure 4.

The graph in Figure 5 shows air temperature vs. time as measured by the thermocouple located 2.3 m above the flame source. This level represents a floor-ceiling interface. Obviously, if the spread of fire is to continue from storey to storey, the insulation at the 2.3 m level must be involved in the burning process. In a test with no insulation and an air space of 25 mm, a mean air temperature of 220°C was measured by the thermocouple at the 2.3 m level. In tests with insulation a temperature rise in excess of 220°C is considered to be caused by additional heat generated by the burning insulation. If burning occurs at this level, the probability of fire spread to the next storey is greatly increased. The sudden rise in temperature, 5 min into the tests for air spaces of 25 mm and 38 mm, indicates that propagation of fire beyond the single-storey height can be expected.

The changes of oxygen content in the cavity during tests with dif-

Table 1. Properties of glass fiber cavity wall insulation.

Density (kg/m ³)	48
Binder Content (% by Weight)	5
Flame Spread Rating (Glass Face)	15
Smoke Developed Classification (Glass Face)	5
Thermal Resistance Per mm (m ² °C/W)	0.0288

Figure 4. Location of thermocouples and gas sampling probe.

ferent widths of air space are shown in Figure 6. In these tests, oxygen was consumed by the combustion of fuel from the burner as well as the pyrolysis products from the insulation material. The level to which the oxygen content dropped depended on how fast the lost oxygen could be replenished. In a very narrow air space, the oxygen cannot be replenished rapidly owing to flow restriction. As a result, the oxygen content in the cavity drops to a level where it becomes impossible for the insulation to burn. As the air space is increased, the rate of replenishment increases to the point that the oxygen content in the cavity reaches a high enough level to support the continuous burning of the insulation material. As shown in Figure 6, such a transition takes place when the air space is 25 mm wide. This is in agreement with the conclusion derived from temperature-rise measurements.

The results of this test series confirm the influence of ventilation on the spread of fire in wall cavities. When the air space is large enough to allow an adequate supply of oxygen for the burning process, the likelihood of fire propagation from storey to storey within the wall

Figure 5. Air temperatures measured at 2.3 m from bottom of test apparatus.

Figure 6. O₂ content measured at 1 m from bottom of test apparatus.

cavities increases greatly, even if insulation of low flame spread rating is used. The critical width of the air space is about 25 mm, which agrees with the measurements reported in the tests with polyurethanes and polystyrenes.

ACKNOWLEDGEMENT

This paper is a contribution from the Division of Building Research, National Research Council of Canada and is published with the approval of the Director of the Division.

REFERENCES

1. Davison, J.I., "Rain Penetration and Masonry Wall Systems," Building Practice Note No. 12, Division of Building Research, National Research Council of Canada, Ottawa (May 1979).
2. Associate Committee on the National Building Code, National Building Code of Canada 1980, NRCC 17303, National Research Council of Canada, Ottawa.
3. ASTM Designation E84-80, "Standard Test Method for Surface Burning Characteristics of Building Materials," Annual Book of ASTM Standards, Philadelphia, Part 18, p. 795 (1980).
4. Williamson, R.B., and Baron, F.M., "A Corner Fire Test to Simulate Residential Fire," *Journal of Fire and Flammability*, Vol. 4, p. 99 (April 1973).
5. D'Souza, M.V., and McGuire, J.H., "ASTM E-84 and the Flammability of Foamed Thermosetting Plastics," *Fire Technology*, Vol. 13, p. 85 (May 1977).
6. Underwriters' Laboratories of Canada, ULC-S102-1978, "Standard Method of Test for Surface Burning Characteristics of Building Materials," Toronto (1978).
7. Underwriters' Laboratories of Canada, ULC-S102.2-1978, "Standard Method of Test for Surface Burning Characteristics of Flooring, Floor Covering and Miscellaneous Materials," Toronto (1978).
8. McGuire, J.H., and D'Souza, M.V., "Significance of Flame-Spread Results," Building Research Note No. 137, Division of Building Research, National Research Council of Canada, Ottawa (December 1978).
9. Lie, T.T., "Contribution of Insulation in Cavity Walls to Propagation of Fire," Fire Study No. 29, Division of Building Research, National Research Council of Canada, Ottawa (November 1972).
10. D'Souza, M.V., private communication.
11. Taylor, W., "Fire Spread in Concealed Foamed Plastic Insulation," *Fire Technology*, Vol. 19, p. 192 (August 1983).

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