Water vapor transmission and moisture accumulation in cellular plastics

Schwartz, N. V.

Publisher's version / Version de l'éditeur:

Polyurethanes 88: Proceedings: SPI 31st Annual Technical/ Marketing Conference: 18 October 1988, Philadelphia, Pennsylvania, USA, pp. 316-318, 1989

National Research Council Canada
Conseil national de recherches Canada

Institute for Research in Construction
Institut de recherche en construction

Water Vapor Transmission and Moisture Accumulation in Cellular Plastics

by N.V. Schwartz

Reprinted from
"Polyurethanes 88"
Proceedings of the SPI 31st Annual Technical/
Marketing Conference
Philadelphia, PA, October 18-21, 1988
p. 316-318
(IRC Paper No. 1573)

NRCC 29771

Canada

RÉSUMÉ

On a mesuré l'accumulation d'humidité dans un certain nombre d'isolants de polyuréthane projeté, de polystyrène extrudé et de mousse phénolique sous un gradient de température. On a aussi déterminé la dépendance de la perméance à la vapeur d'eau du polystyrène extrudé et de la mousse phénolique à l'égard de la température. Les mesures d'accumulation d'humidité dans le polyuréthane projeté se trouvant dans un mur à ossature de bois d'un bâtiment d'essai exposé à un hiver, à Ottawa, n'ont pas révélé d'accumulation importante d'humidité dans la mousse lorsque le revêtement situé du côté froid de l'isolant était perméable à l'humidité transmise.

Water Vapor Transmission and Moisture Accumulation in Cellular Plastics

N. V. SCHWARTZ
National Research Council of Canada
Institute for Research in Construction
Montreal Road, Building M-24
Ottawa, Ontario, CANADA K1A 0R6

ABSTRACT

The moisture accumulation in a number of sprayed-in-place polyurethane (PUR), extruded polystyrene (XEPS), and phenolic foam insulations under a temperature gradient has been measured. The temperature dependence of the water vapor permeance of the XEPSs and the phenolics has also been determined. Field measurements on the accumulation of moisture in sprayed-in-place PUR in a wood frame wall of a test building exposed to an Ottawa winter has shown no significant moisture accumulated in the foam when the sheathing on the cold side of the insulation was permeable to the transmitted moisture.

INTRODUCTION

The temperature dependence of water vapor permeance and moisture accumulation of polyurethane and polyisocyanurate foams under the condition of a temperature gradient were recently reported by the author [1]. This work has now been extended to an examination of the moisture accumulation in a number of sprayed-in-place polyurethanes (PUR), extruded polystyrenes (XEPS), and two closed cell phenolic insulations, and to the temperature dependence of water vapor permeance of XEPS and phenolics. Field measurements on the accumulation of moisture in sprayed-in-place PUR in a wood frame wall exposed to an Ottawa winter have also been carried out. The paper summarizes the results of both studies.

EXPERIMENTAL

Materials

Five XEPS, six PUR and two closed cell phenolics were used in this study. The XEPS samples were 25 mm boards and measurements were carried out on these materials with their skins intact. XEPS 1, 2 and 3 came from one manufacturer and had densities of 30.3, 32.3 and 45.6 kg/m^3 respectively, while XEPS 4 and 5 came from a second manufacturer and had densities of 30.1 and 25.2 kg/m^3 respectively.

The PUR samples were sprayed-in-place foams supplied by a single supplier as buns approximately 600 mm square by 100 to 150 mm thick. The densities of the PUR were all nominally 32 kg/m^3. One of the components in the PUR formulation was varied in a systematic fashion. The specimens used were cut from the core of the buns.

The phenolics came from two different manufacturers, and each had a density of 40 kg/m^3. The facings on each were removed before testing.

Temperature Dependence of Water Vapor Permeance

Water vapor permeance measurements were made using the modified cup method described previously [1]. An open ended cylinder in which the specimen (144 mm diameter × 25 mm thick) was sealed in place with RTV silicone was clamped between containers of water and calcium chloride respectively (Figure 1). The desiccant was separated from the specimen by a highly permeable layer of spunbonded polyolefin. The assembly was maintained at constant temperature and separated periodically in order to weigh the desiccant. The procedure was repeated for a number of constant temperatures.

Temperature Gradient Measurements

The specimens, 300 mm × 25 mm thick were sealed at the edges into polymethyl methacrylate (PMMA) frames with RTV silicone. The specimen container was sandwiched between a cold plate at 5°C and a pool of water maintained at 50°C by a hot plate (Figure 2). An air gap of 40 mm separated the surface of the water from the bottom surface of the specimens, and a gap of 2–3 mm separated the top surface of the specimens from the cold plate. The specimen containers were periodically removed from the assembly and weighed to determine the amount of moisture picked up by the specimens.

REPRINTED FROM **POLYURETHANES 88**
PROCEEDINGS OF THE SPI 31st ANNUAL TECHNICAL/MARKETING CONFERENCE

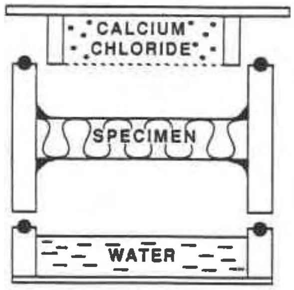

Figure 1. Schematic of the modified cup.

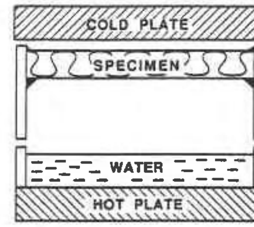

Figure 2. Schematic of the temperature gradient method.

Field Test on Moisture Performance of Sprayed-in-Place PUR

A field test on the moisture performance of a typical 32 kg/m^3 sprayed-in-place PUR was also carried out. Four stud spaces 2.1 m × .37 m with 13 mm waferboard sheathing were filled with 75 mm of the PUR in a test building. The exterior of the sheathing was covered with 6 mm plywood panels that acted as weather screens. These were hinged at the top to allow easy access to the sheathing for observation. The interior of the wall was covered with 13 mm gypsum board with two coats of latex paint. A 75 mm diameter hole to simulate air leaks in the gypsum board due to such things as electrical boxes was cut in the gypsum board on the center line between the studs at 150 mm from the floor on stud space 2. Similarly a 75 mm hole was cut 150 mm from the ceiling in the gypsum board covering stud space 3 and two holes, one 150 mm from the floor and one 150 mm from the ceiling were cut in the gypsum board covering stud space 4. Each of the holes was covered with coarse copper wool. The gypsum board covering stud space 1 was left intact. The interior of the test building was maintained at 20°C and 40% RH from the end of October to the beginning of the following May. The plywood weather screen was raised periodically and the exterior of the waferboard examined for condensation. At the end of the observation period pieces of the insulation along with the attached sheathing were cut from the top and bottom of each stud space and the insulation was examined for moisture both gravimetrically and by scanning in a gamma spectrometer [2].

RESULTS AND DISCUSSION

There were distinct differences observed among the three types of cellular plastics in the rate at which they accumulated moisture under a temperature gradient (Figure 3). The phenolics accumulated moisture most rapidly, while the XEPS displayed the lowest rate of moisture accumulation. Within the XEPS the rate of moisture accumulation had an inverse dependence on the density within materials from the same source, e.g., XEPS 1, 2 and 3 in Figure 4, but material of the same density from different sources had different rates of moisture accumulation, e.g., 1 and 4. The sensitivity of the PUR's to moisture accumulation varied from sample to sample and was probably dependent on their composition (Figure 5).

The temperature dependence of the water vapor permeance of two of the XEPS and the two phenolics were determined and compared to those found for the PUR and

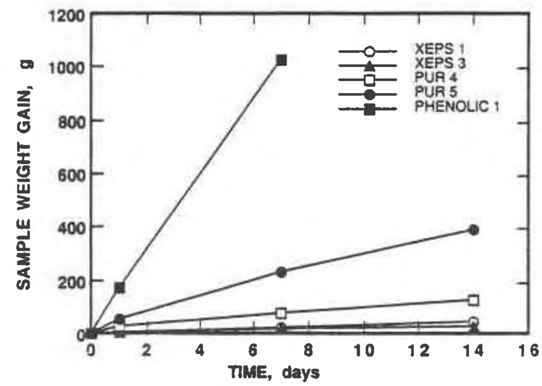

Figure 3. Moisture accumulation of cellular plastics under a temperature gradient of 5°C on the cold side and 50°C on the warm side.

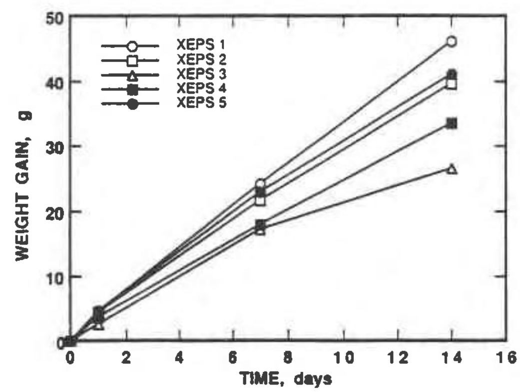

Figure 4. Moisture accumulation in XEPS's under a temperature gradient of 5°C on the cold side and 50°C on the warm side.

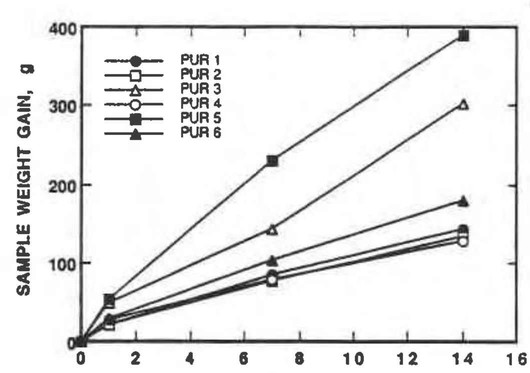

Figure 5. Moisture accumulation in PUR's under a temperature gradient of 5°C on the cold side and 50°C on the warm side.

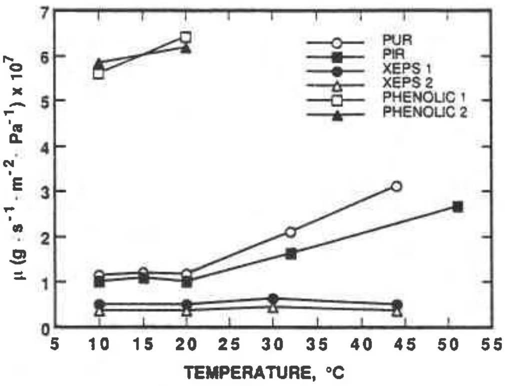

Figure 6. Temperature dependence of the water vapor permeance of cellular plastics.

PIR reported earlier [1]. The results are shown in Figure 6. The materials with the higher rates of moisture accumulation also had the higher permeance values. It is also interesting to note that the water vapor permeance of the XEPS does not change much with temperature unlike the two isocyanate-based materials, and the phenolics. The rapid rate of moisture accumulation of the phenolics is reflected in their relatively high water vapor permeances.

In the field test of the sprayed-in-place PUR it was observed that frost build-up occurred on the outside of the waferboard sheathing under the plywood weather screen. This frost was likely the result of moisture moving through the PUR, and occurred in roughly oval shaped patches at the top of the four stud spaces. This condensation was most pronounced on the exterior of stud spaces 2, 3 and 4, i.e., the stud spaces with the holes in the gypsum board. When samples of the foam and sheathing were removed it was found that the waferboard from the top of stud space 4 showed some delamination but the others were unaffected. No significant moisture was found in any of the foam samples, however.

The absence of moisture accumulation in the PUR in the field while PUR exposed to temperature gradients in the laboratory accumulate considerable moisture can be explained, at least partially, by referring to Figure 6. In the laboratory experiments the temperature gradient was from 50°C on the warm side to 5°C on the cold side. This range includes the temperature region in which the water vapor permeance of the PUR rises rapidly with temperature. Moisture entering the foam from the warm side can move through the first few layers relatively rapidly but as lower temperatures are encountered the permeance decreases and the moisture does not move out as rapidly and hence accumulates. In the case of the PUR in the field the temperature gradient ranged from 20°C on the room side to as low as −25°C on the weather side. In this temperature range the water vapor permeance of the PUR is fairly constant at the low value and the potential for moisture accumulation is low.

CONCLUDING REMARKS

In contrast to the water vapor permeance of PUR and PIR, the water vapor permeance of the XEPS changes little with temperature up to 45°C. The rate of moisture accumulation of the various cellular plastics studied is higher for materials with higher permeance values. Under service conditions, sprayed-in-place PUR insulation in a wood stud wall did not accumulate any moisture over a winter heating season when the sheathing on the cold side of the insulation was fairly permeable, allowing transmitted moisture to escape.

REFERENCES

1. Schwartz, N. V., M. Bomberg and M. K. Kumaran. "Water Vapor Transmission and Moisture Accumulation in Polyurethane and Polyisocyanurate Foams," ASTM Symposium on Water Vapor, Bal Harbour, Florida (December 1987).
2. Kumaran, M. K. and M. Bomberg. "A Gamma-Spectrometer for Determination of Density Distribution and Moisture Distribution in Building Materials," *Proceedings of the International Symposium on Moisture and Humidity*, pp. 485–490 (1985).

BIOGRAPHY

Norman V. Schwartz

Norman Schwartz received his B.A. and Ph.D. in chemistry from the University of Toronto. In 1960– 1961 he was European Research Associates Fellow at Oxford University. Between 1962 and 1985 he was a Research Chemist then Senior Scientist at Dunlop Research Centre in Mississauga, Ontario. He became the SPI Fellow at the Institute for Research in Construction, National Research Council of Canada at Ottawa in April 1986.