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Publisher's version / Version de l'éditeur:

Solplan Review, September 118, pp. 16-17, 2004-09-01

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NRCC-47618

A version of this document is published in / Une version de ce document se trouve dans :
Solplan Review, no. 118, September 2004, pp. 16-17

High-performance insulation materials

By Phalguni Mukhopadhyaya

The space heating and cooling of buildings consumes a substantial amount of energy. Over the past thirty years, big improvements have been made to reduce building energy use, but further improvements are possible and necessary. Some high-performance thermal insulation materials can be up to *ten times* more efficient than materials currently in use.

Researchers at NRC's Institute for Research in Construction (IRC) have been working with European partners to advance the technology of new generation insulation materials for building applications. Micro- and nano- porous materials, vacuum technology and special gas-filled porous structures are all viable solutions. This article explains the characteristics of vacuum insulation panels (VIPs) and presents some preliminary results of IRC research on their thermal performance.

Although VIPs are being used in Europe to a limited extent in buildings, their use in North America is still limited to specialized applications like refrigeration and pharmaceuticals. By conducting more research on these promising materials, IRC and others will be able to assist manufacturers and the construction industry to overcome any limitations regarding the use of the technology in building applications.

Benefits

In addition to delivering substantial energy savings and a consequent reduction in CO_2 emissions, VIPs offer several other important advantages. With the development of insulation materials that are ten times more efficient than contemporary products (Figure 1), the thickness of building envelopes can be reduced. In cases where the size of framing members is governed by their ability to contain insulation materials rather than by structural strength, the size of insulation cavities can be reduced, with a saving in materials, a maximization of usable building space and a reduction in waste and recycling needs at the end of the building service life.

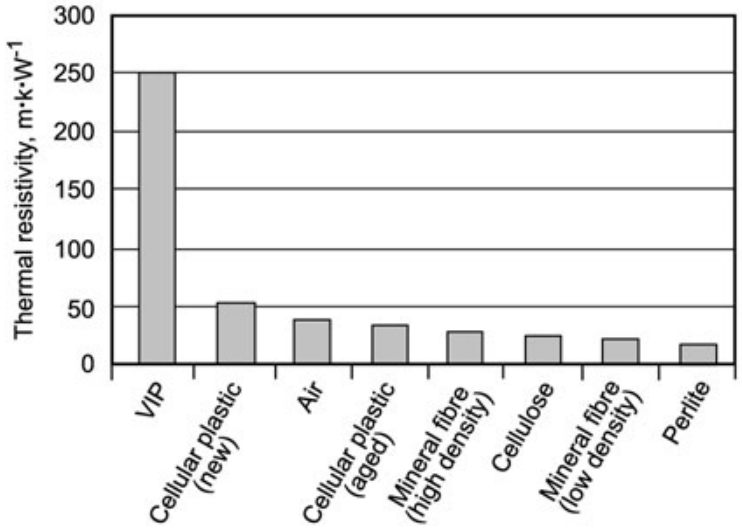

Figure 1. Thermal resistivity of VIPs compared to common insulating materials

The compactness and insulating properties of VIPs are particularly valuable in situations where space is at a premium, such as in building retrofits and in heaters, chimneys, pipe-work and wall assemblies. Their use in Canadian construction could potentially reduce the thickness of building envelopes and substantially reduce energy costs.

What is a Vacuum Insulation Panel?

A vacuum insulation panel is composed of two components: a micro- to nano- porous material called the "core" that is evacuated and sealed using a thin membrane called the "foil" (Figure 2).

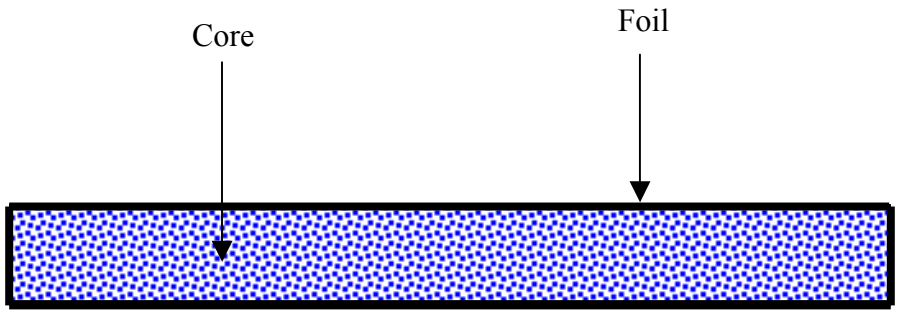

Figure 2. A schematic representation of a vacuum insulation panel

VIPs make use of the fact that the absence or reduction of gaseous pressure inside a porous material increases its thermal insulating potential. This effect becomes even greater in materials that already have high thermal insulating values, and can be increased still further by applying the latest scientific and technological developments in other fields such as nanotechnology.

The initial thermal conductivity of a VIP depends on the pore dimensions of the core and the level of the vacuum retained within the sealed panel. Air molecules and water molecules that permeate the foil and the seams causes a loss of vacuum and thermal resistivity. Thus, the long-term thermal resistance of VIPs depends on the integrity of the foil and its seams. Even one pinhole in the foil or the seam destroys the vacuum and the high performance of the VIP. Ensuring the integrity of the insulation is obviously a challenge in building applications.

IRC Test Program

IRC researchers initiatally tested twelve 30-cm x 30-cm x 30-mm VIPs for thermal resistance. Various batches of panels were subjected to different environmental loads (temperature, relative humidity, and pressure) for more than a year and their thermal resistance was repeatedly determined. In addition, the water vapour permeability of the foil bags and seams was tested.

Samples aged in the laboratory, under standard laboratory conditions, (21 ± 1) ºC and approximately 50 % RH, had an initial 6% drop in resistivity; the resistivity then remained constant for the remainder of the year. Other samples exposed to higher temperatures (up to 32°C) and higher relative humidity (up to 90%) showed a similar initial drop in resistivity but were not otherwise affected. Samples exposed to high pressure (5 bar for 30 days and 3 bar for 15 days) resulted in shrinkage of the test specimens and a reduction in resistivity of one half.

Edge Effects. Four specimens were tested edge-to-edge to make one 60-cm x 60-cm test assembly to examine edge effect. The effective resistivity of the assembly was about one quarter the resistivity of an individual VIP specimen. Further work is needed to find ways of reducing thermal bridging at the edges of adjacent panels.

Conclusions from IRC Testing

Based on the information available to date from IRC's investigations, the following conclusions can be made about vacuum insulated panels:

- They exhibit thermal resistivity up to ten times greater than current building insulating materials.
- Damage to the foil bags affects resistivity and thus the methods of providing protection during construction and service need further investigation.
- As found in this study, environmental loads such as high relative humidity and higher than normal indoor temperatures have no measurable effect on performance. However, further investigation is necessary.
- Over-pressure may cause VIPs to shrink but does not totally degrade the high thermal resistivity.
- The thermal bridges at the edges of VIPs reduce effective resistivity, but still leave them with resistivity several times higher than current insulation materials.

IRC is undertaking a new phase of research on VIPs. The work will focus on:

- Confirming and expanding upon the findings of the study reported here;
- Using the latest advances in micro-porous and nano-porous materials to improve VIPs;
- Developing guidelines for the application of VIPs in the field.

The initial project attracted substantial funding for three years from a number of organizations. However, to ensure representation from all interested parties, IRC would also like to include industry partners willing to take an active role in the research and development of VIPs.

Readers interested in learning more or how to become involved may contact Dr. Phalguni Mukhopadhyaya at (613) 993-9600, or e-mail phalguni.mukhopadhyaya@nrc-cnrc.gc.ca.

Acknowledgement
IRC wishes to recognize the financial and professional support of Natural Resources Canada, Icynene, Enbridge Consumers Gas, Lexcor Industry Supply, Rideau Construction Inc., Canada Mortgage and Housing Corporation, BASF Canada and Plastifab.

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