VACUUM INSULATION PANELS (VIPs): Five Years of Field Performance

The Use of VIPs as a Next-Generation Insulation Material in Roofing Systems

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PREAMBLE

This article presents the continuation of a study by the National Research Council of Canada (NRC) that was first published in *Interface* in August 2014. The 2014 article, entitled "Vacuum Insulation Panels (VIPs): An Historic Opportunity for the Building Construction Industry," presented the concept of using VIPs in roofing systems to complement conventional insulation materials. The current article presents the ongoing performance assessment of the VIPs for five years of in-field monitoring.

BACKGROUND AND SIGNIFICANCE

The reduction of energy consumption in every aspect of life has become a major focus of global warming mitigation strategies and environmental considerations. The benefits of reduced energy use include a decrease in the use of resources such as fossil fuels, and improved energy costs. The energy requirements for buildings in Canada—including commercial, institutional, and residential—account for over 30% of the national energy use, which presents a significant opportunity to implement energy improvement strategies. Targeting the building envelope is a key element for improving overall efficiency and reducing energy consumption. A significant aspect of the building envelope is the roofing system, especially in commercial and institutional buildings, where the roof surface area is particularly large and subject to major energy losses.

Energy code upgrades have recommended higher insulation requirements in building envelopes to provide the necessary thermal performance for the respective climatic zones. The challenges of meeting increased R-values include the need for increased thicknesses of insulation, providing constraints on physical building space, which may be possible for roofing sites but may not be favorable for walls and floors. Furthermore, increasing the insulation thickness can allow for additional movement between the various building layers, which can compromise the durability of the system.

An alternative to increasing the insu-

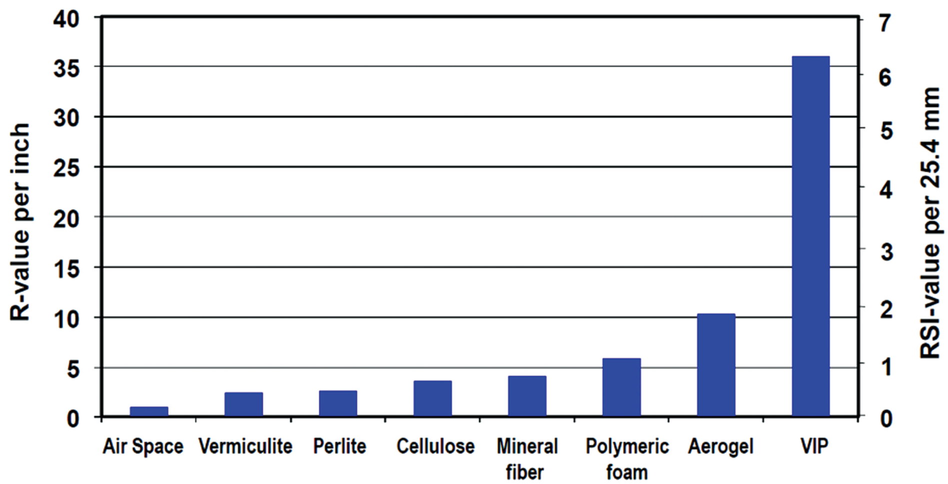

Figure 1 – R-value of VIP in comparison to other insulation materials (Mukhopadhyaya, Kumar, Ping, and Normandin, 2011).

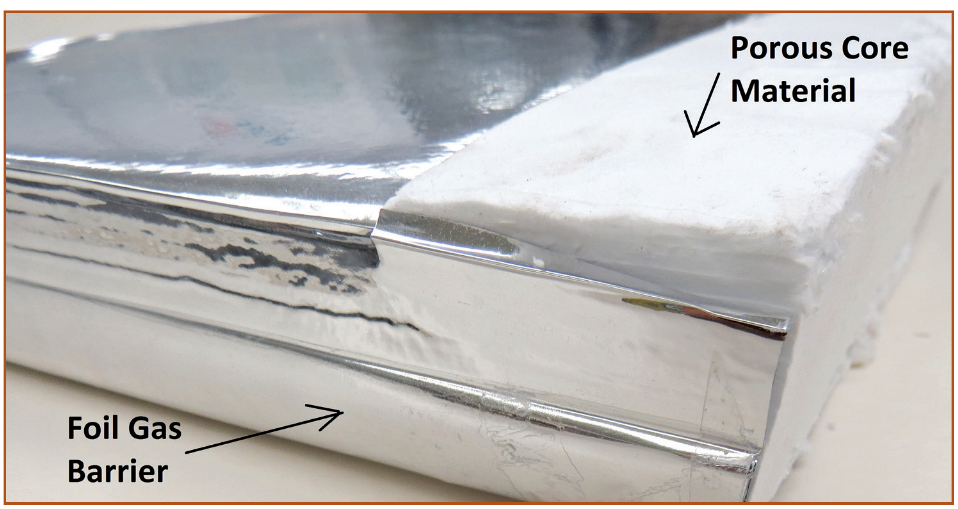

Figure 2 – Components of VIP insulation. The dessicant is located as a patch at one end of the panel.

Figure 3 – Modified-bitumen roofing system installed on Building M-24 at NRC.

Figure 4 – Installation of polyiso and VIP composite side by side as a point of comparison.

lation thickness is to use a material with a higher thermal performance (namely, a higher R-value) to complement the existing insulation system. To achieve this goal, research is being conducted by the NRC to investigate VIPs to complement current insulation use. VIPs have a thermal resistance of five to ten times that of conventional insulation, as shown in *Figure 1*; and, therefore, they have the potential to be used as a next-generation material in roofs, floors, and walls. VIPs can be incorporated into new or existing insulation systems to provide a significant thermal barrier to achieve building R-value requirements. The NRC has been performing in-situ monitoring of VIPs over the past five years to assess their long-term performance.

WHAT IS A VIP?

VIPs consist of three components, which include a porous core material, a Getter®/desiccant, and a gas barrier, shown in *Figure 2*. The core material provides both mechanical strength and thermal insulation properties, and commonly consists of fumed silica powder. The main requirement for the core material is to maintain the desired quality of vacuum and to be able to withstand the external force applied as a result of the internal vacuum pressure. It is desirable to have a core material with very small pore diameters, as this reduces the gas conductivity and increases the thermal resistance. The Getter®/desiccant is added inside the core material to adsorb residual or permeating gases within the VIP barrier. The gas barrier is a foil facer, which is required to provide air-vapor tightness and maintain the vacuum environment within the

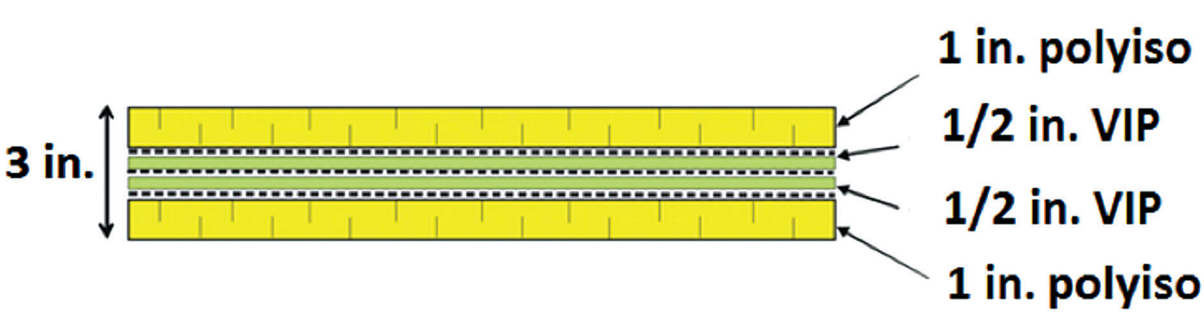

Figure 5 – Schematic representation of the VIP composite insulation.

Figure 6 – Roofing adhesive used to integrate layers of roofing system around the installed instrumentation.

Figure 7 – Installation of heat flux meters and thermocouple instrumentation to monitor VIP composite and polyiso performance.

VIP. The vacuum pressure is essential in providing the superior R-value, as reducing the air pressure further reduces the air conduction. Special precautions must be taken to ensure that the gas barrier is not punctured during installation, as this would compromise the vacuum environment and the overall thermal behavior.

The implementation of VIPs in the construction industry is primarily dependent on the material cost, integration, and long-term performance. Limited in-situ monitoring of VIP performance has been conducted on a short-term basis for both walls and roofing applications.[2-8] However, the need for actual in-field long-term performance

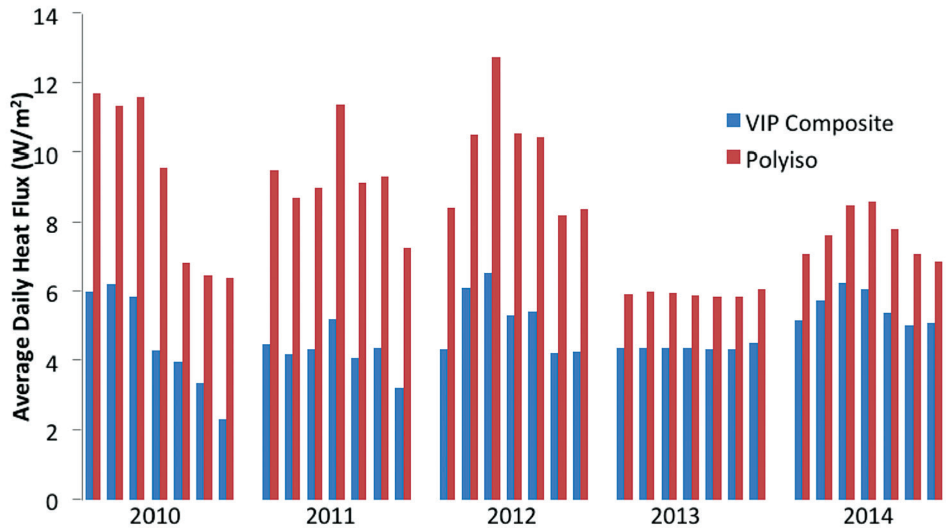

Figure 8 – Average daily heat fluxes of polyiso and VIP composite insulations for a typical winter week for 2010-2014.

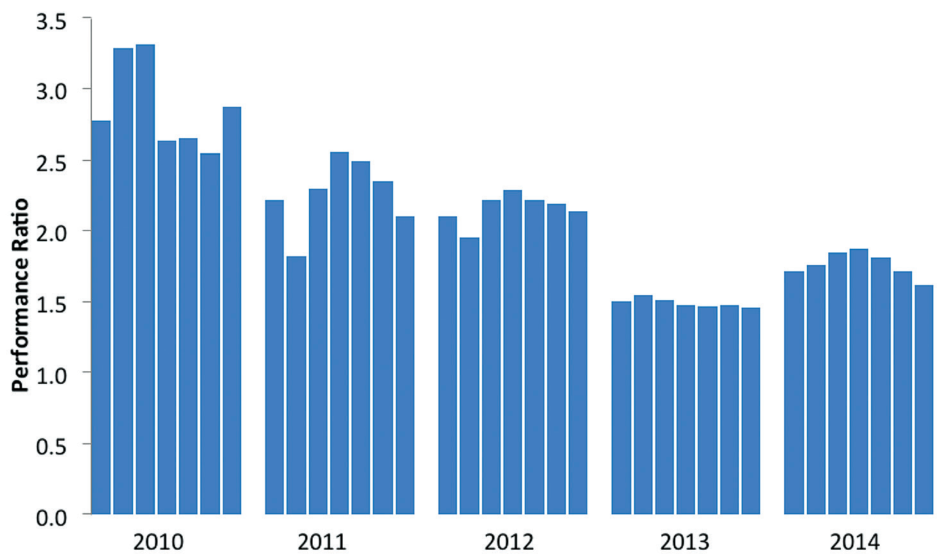

Figure 9 – Ratio of VIP composite performance to conventional polyiso performance for a typical winter week for 2010-2014.

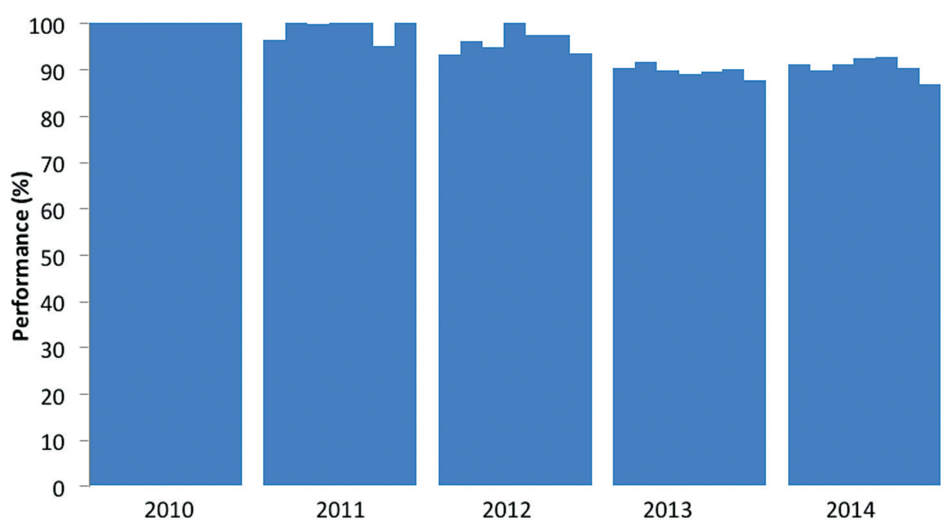

Figure 10 – VIP performance with respect to its initial performance at the time of installation for a typical winter week for 2010-2014.

evaluation of VIPs has motivated the current study by NRC that is presented here.

APPLICATION OF VIPs IN ROOFING SYSTEMS

In this study, the intended use of VIPs is to complement current roofing insulations, such as polyisocyanurate (polyiso) insulation, to provide an improved thermal barrier. VIP composites, which consist of VIP boards inserted between polyiso boards, were constructed and installed on Building M-24 at NRC in Ottawa as a thermal barrier in a modified-bitumen roofing system, shown in *Figure 3*. In order to assess the performance of the VIP composite, conventional polyiso insulation was installed beside the VIP composite to provide a point of comparison, as shown in *Figure 4*. The VIP composite was comprised of two layers of ½-in.-thick VIPs sandwiched between two layers of 1-in.-thick polyiso insulation, giving a total thickness of 3 in., as shown in *Figure 5*. The conventional polyiso was installed with the same thickness of 3 in.

The roofing system consists of a concrete deck, vapor barrier, insulation, asphalt cover board, modified-bituminous membrane base sheet, and modified-bituminous membrane cap sheet—all integrated with a solvent-based roofing adhesive, shown in *Figure 6*. Both the polyiso insulation and the composite VIP were equipped with heat flux sensors and thermocouples to monitor the roofing performance, as seen in *Figure 7*. The VIP panels were 18 x 22 in. and were installed with an offset of 150 mm (6 in.) between the two layers to reduce thermal bridging from the panel gaps. The M-24 roof has a conditioned indoor environment maintained at 20°C (68°F) and 50% relative humidity. The data monitoring has been ongoing since November 2010, when the installation was completed.

LONG-TERM PERFORMANCE OF VIPs IN ROOFING SYSTEMS

The instrumented roofing insulation panels have been monitored and analyzed for five years at the NRC facility. The VIP composite insulation has outperformed the conventional polyiso insulation in all seasons and years monitored. *Figure 8* presents the average daily heat fluxes for a typical winter week from 2010 to 2014. The conventional polyiso insulation has consistently had a higher heat flux, which allows for a substantial amount of heat loss to the building exterior. The VIP composite, on average, allowed for 40% less external heat flow, resulting in significant energy improvements. *Figure 9* shows the performance ratio, which is defined as the ratio of the thermal resistance of the VIP composite compared to that of the conventional polyiso, during a typical winter week from 2010 to 2014. The thermal resistance of the VIP composite insulation is on average twice that of the conventional polyiso, which demonstrates the potential for achieving higher R-values through complementing polyiso insulation with VIP panels.

In order to assess the long-term performance of the VIP composite insulation, the resulting R-values were compared to the initial R-value at the time of installation to determine the VIP behavior as it ages. *Figure 10* shows the performance of the VIP composite in reference to its initial performance for a typical winter week from 2010 to 2014. The VIP composite has, on average, performed within a 10% margin of its initial thermal performance, providing an effective long-term thermal barrier.

CONCLUSION AND FUTURE WORK

VIP insulation was installed and monitored at NRC in conjunction with regular polyiso insulation panels to assess its performance in an in-field roofing system. Based on the monitoring results, it was shown that VIP insulation can be incorporated into existing roofing systems to provide high thermal resistance. The VIP composite provided a significant barrier for heat flow in comparison to conventional polyiso insulation and consistently gave high performance and R-values for consecutive winters within a 10% margin. The monitoring is ongoing to determine the future long-term performance of VIP insulation.

Although VIPs have shown excellent thermal performance, several challenges need to be addressed, including the sensitivity to puncture, material cost, and thermal bridge effects. The best practices for VIP installation also need to be determined, including whether the VIPs are required to be adhered, or whether they could be incorporated with a different insulation system at penetrations and along the roof perimeter for mechanical fastening.

Regardless of the system attachment method selected, the most important consideration is the sensitivity of the VIPs to puncture during installation, which can reduce the thermal resistance performance of the panels by over 50%. Thus, the way in which VIPs are incorporated into a roof assembly will determine their effectiveness and, ultimately, their acceptance within the roofing community.

The heat flow behavior at the VIP seams is also being monitored at the NRC to determine whether significant thermal bridges exist with this next-generation insulation material. The NRC is expanding the scope of work for the investigation of VIPs and is seeking industrial partners to perform lab-scale/full-scale experiments for the commercialization of VIP insulation.

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Lad-Saf™ Sleeve Recalled

3M has issued a recall of its original DBI-SALA Lad-Saf™ sleeve after receiving reports of serious injuries or deaths that occurred while using the sleeve. The recall stated, "Although our review did not reveal product hazard or risk scenarios that would arise in the ordinary and proper use of the product, it did reveal potential misuse scenarios that could result in serious injury or death. The potential misuse scenarios include interference with the braking mechanism (such as entanglement with cords, lanyards, clothing, or other materials; or grasping the sleeve prior to or during a fall), or result from the user attaching the sleeve upside down (user inversion). No safety regulator has made a finding that the design of the original Lad-Saf sleeve is defective." The carabiner was manufactured for more than 30 years. For more information, visit http://api.capitalsafety.com/api/assets/download/1/44877916.

