Side-by-Side Study Proves SIP Advantage

Brock University study quantifies superior thermal performance of SIPs

The thermal qualities of Structural Insulated Panels (SIPs) have long been argued and are generally accepted, but true comparison to traditional stud wall systems often gets bogged down by misleading R-value ratings. Furthermore, many field studies are partially flawed because they compare different structures in different environments.

That's why a recent study by Dr. Tony Shaw of Brock University was a refreshing change from much of the existing research on the thermal performance of SIPs. Dr. Shaw's work involved a side-by-side evaluation of nearly identical residential buildings – one constructed with SIP exterior walls and one conventionally framed with studs and batt insulation.

The detailed study, which was supported by the National Research Council of Canada (NRC), provides tremendous insight into the energy efficiency properties of SIPs. But before getting into the findings, a bit of background is warranted.

Thermodynamics 101 and the limitations of R-Values

When two bodies with different temperatures are brought into contact with one another, heat always transfers from the hotter object to the colder one. This is fundamental to our discussion: minimizing heat transfer within a wall system is the key to energy efficiency.

There are three different types of heat transfer: conduction, convection and thermal radiation. Conduction is where heat transfers between two bodies through actual physical contact. For example, heat from a stove element is conducted to the frying pan. Convection involves the transfer of heat through the movement of a fluid (e.g. air), which is easy to comprehend when you sit too close to a campfire. Finally, radiation involves energy radiated from hot surfaces through electromagnetic waves, similar to a light bulb emitting light and heat.

When we're talking about the energy efficiency of a wall system, it's conduction and convection that matter most. Conduction of heat occurs through sheathing, studs and insulation. Convection occurs through cracks, gaps and openings within the wall, as well as air cells in batt insulation.

This paper highlights the findings of recent research by Dr. Tony Shaw of Brock University. Supported in part by the National Research Council of Canada, the year-long study measured heat loss and energy efficiency of two nearly identical residential buildings, one framed with stud and batt exterior walls, the other built with Structural Insulated Panels (SIPs). Using several methodologies, the research quantified the superior thermal performance of SIP construction.

The problem with using R-values to gauge the energy efficiency of a home is that insulation is typically rated in a laboratory under controlled conditions. But in an actual stick and batt wall, heat conducts not just through insulation, but more significantly through studs, reducing the overall efficiency of the system. And gaps in the wall – sill plates, top plates, electrical outlets, window jambs and even nail holes – further reduce the true R-rating of the wall because of convective heat transfer.

A SIP wall's ability to perform closer to its rated R-value is a result of its tightness as a system, which minimizes convective heat loss. The rigid EPS insulation of SIPs eliminates air circulation and moisture that is often prevalent in stud walls.

Furthermore, the structural high-density EPS insulation of a SIP ensures less surface area for conductive heat transfer than conventional walls, which require studs every 16" or 24" for structural support – prime vehicles for conductive heat loss.

The Brock University study: comparing identical buildings

When it comes to quantifying actual heat loss in different wall systems, the Brock University study provided an excellent opportunity for accurate comparison between SIP and stick construction in the real world.

The two structures involved in the study were rental housing units, located immediately adjacent to one another. Both buildings were identical and had similar east-west orientations, ensuring the same exposure to outdoor temperature and wind conditions. Except for brief periods both houses were occupied throughout the course of the study, which took place over a 12-month period from February 2000 to January 2001. Both units were heated with a natural gas / forced air system.

One unit was constructed with 4.5" SIPs, while the other used 2x6 studs with batt insulation. Both houses were constructed according to the Ontario Building Code (OBC). The units were built by the same crews, with no one being aware that scientific tests would be conducted afterwards.

The study incorporated several test methods to analyze different determinants of energy efficiency: thermographic imaging, hourly temperature readings and air leakage measurement.

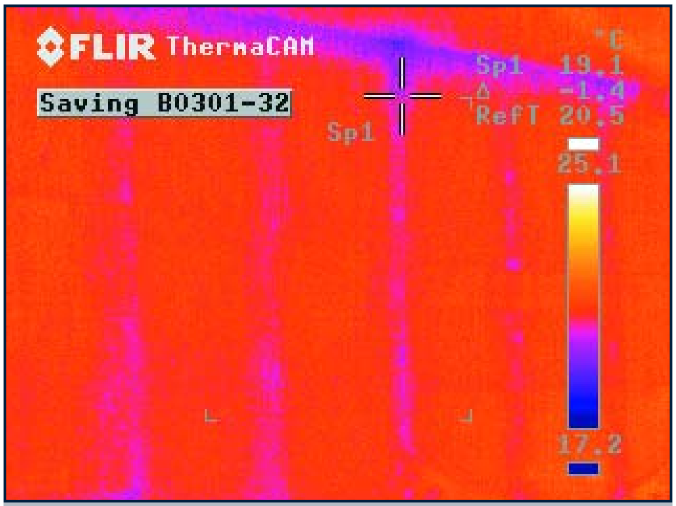

Figure 1a: Thermal photography of stud and batt wall
This thermal photograph of a stud wall reveals multiple points where heat can escape – primarily along studs themselves.

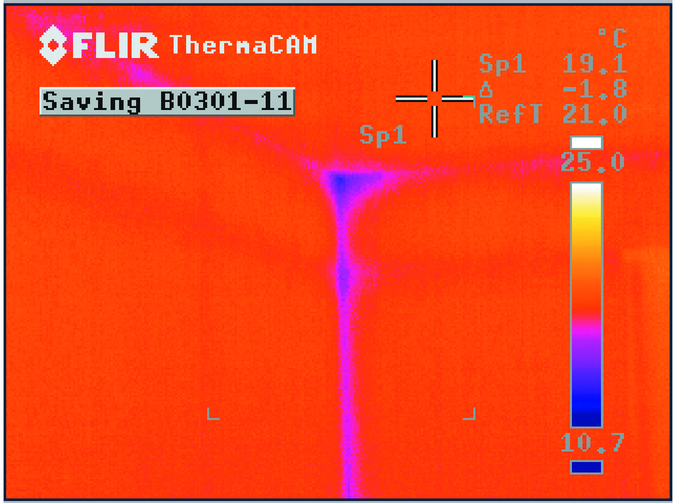

Figure 1b: Thermal photography of SIP wall
The SIP wall allows for minimal heat loss along the wall surface. The only heat loss evidenced here occurs in the corner area.

Thermographic Analysis

The deceiving nature of R-values was illustrated by infrared imaging on the two structures on a day in early March. Energy loss measured at the conventionally framed building, which used insulation rated at R-20, performed at an R-4 equivalent. By comparison the SIP home, performed at a true R-17 level. Thermographic analysis, at an outdoor temperature of -10.5 °C (13.1 °F), also demonstrated that the stud home consumed nearly four times as many BTUs as the SIP home.

Furthermore, thermographic photographs provided visual confirmation of areas of thermal weakness in the 2x6 wall, where *thermal bridging* (i.e. conduction) is visible around each stud, along with pockets of air leakage (see figure 1).

Temperature Trends

This imaging evidence was supported by temperature data recorded hourly by a series of sensors located within the walls of each building (see figure 2). Temperatures recorded in the middle wall (T3) and inside the exterior wall surface (T2) of the stud construction showed the greatest fluctuation, corresponding closely to the variation in outdoor ambient temperatures, especially during the cold months of December, January and February. In comparison, the SIP wall sensors recorded significantly higher and more stable temperatures at those locations. The temperature of the middle wall sensor (T3) averaged 1.95 ºC (35.5 ºF) for the stud wall, while the SIP wall averaged 15.61 ºC (60.1 ºF) in the month of January.

These variances are key because, once again, heat will always move from the hotter body to the cooler one. The higher temperature at the T3 sensor demonstrates that the SIP wall experienced less heat loss than the stud wall, and consequently, is more energy efficient.

The Brock study involved thermal photography, hourly temperature readings over the course of a year and air leakage tests. In each case, the SIP house outperformed the stud house in energy efficiency.

Also of notable significance are the temperature differentials recorded between the inside interior wall surface (T4) and the inside exterior wall surface (T2). Over the course of the year, lower differentials were recorded for the SIP wall (an average of 6.51 ºC (43.7 ºF) as compared to 12.31 ºC (54.2 ºF) for the stud wall), further demonstrating it's reduced susceptibility to heat loss. Figure 3 shows the overall daily thermal performance of the two walls in the cold month of January. The T3 measurement for the stud wall was consistently close to the actual exterior wall surface temperature while the SIP wall demonstrated a steady and sizeable gap.

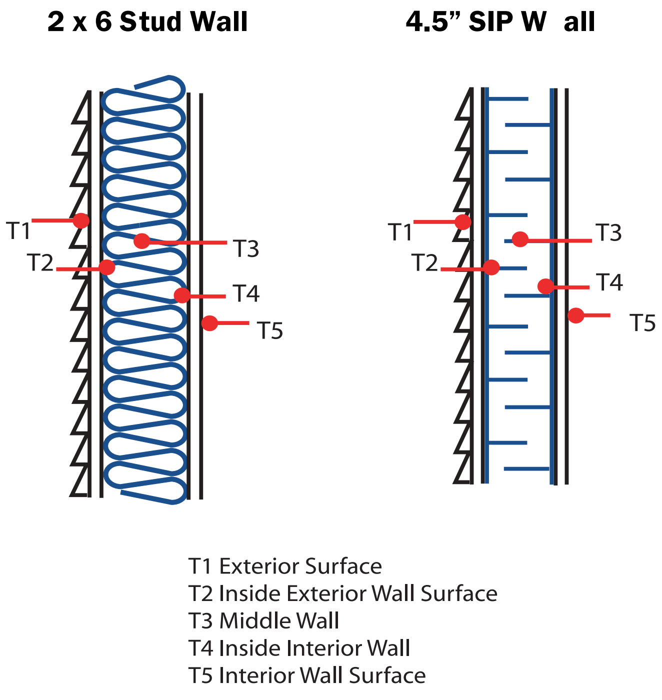

Figure 2: Sensor locations
This cross-section shows the positioning of the temperature sensors used in the Brock University study, comparing the thermal performance of stud and SIP wall systems.

Air tightness comparisons

In addition to the thermal performance and thermography components of the Brock study , air leakage tests were conducted to compare the tightness of the two units. This analysis shows the relative convective properties of each, a key determinant of overall energy efficiency.

The results of the air leakage tests showed the SIP house to be much tighter than the stud house. The SIP house had 1.55 ACH (air changes per hour) at a pressure differential of 50 Pa, while the framed wall house had 2.60 ACH at 50 Pa, or a 68% more leakage. This means that, all other factors being equal, the SIP house would use less energy for heating, would be more comfortable, have better heat retention and be less drafty.

Conclusion

The U.S.-based Oak Ridge National Laboratories 1998 study under laboratory conditions stands out among the most authoritative work on the subject, and Habitat for Humanity has provided several opportunities to compare different wall systems under similar conditions. Likewise, Dr. Shaw's research is a very insightful analysis on the thermal properties of SIP and stud construction. Studies such as Brock University's SIP/stud comparison are relatively uncommon, but they are generating tremendous interest by government, industry and consumers alike.

As awareness builds surrounding the environmental impact of buildings on greenhouse gas emissions and urban air quality, the construction industry will be under increasing pressure to adopt new standards and practices to reduce energy consumption. Regardless of the Kyoto Protocol, where signatory governments agree to take concrete measures to reduce greenhouse emissions – inevitably rewarding environmentally friendly technologies at the expense of less efficient ones – the economics of energy costs and natural resources availability will make non-traditional building materials such as Structural Insulated Panels more and more attractive.

Based on the heat loss data collected in the Brock University study, a natural-gas heated, 2,000 sq. ft. SIP house would save $88 on a monthly heating bill in an average winter month.

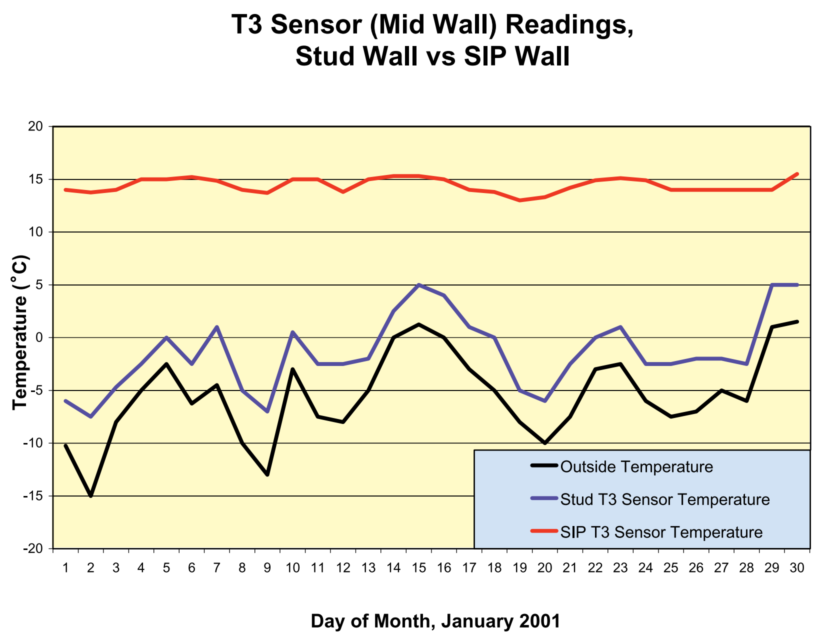

Figure 3: Thermal performance of stud and SIP wall systems
Data from the temperature sensors in the stud and SIP walls demonstrates the relative energy efficiency of the two systems. This graph is based on measurements throughout January 2001. Temperatures at the middle wall sensor for the stud construction are very close to the exterior temperature. In contrast, data shows how the SIP wall maintained much higher temperature at the same sensor locations – an indication of superior energy efficiency.