Concept of Thermal Bridging in Wood Framed Construction

Shawn P. Kelley
Moment Engineering + Design

Mike Blanford
U.S. Department of Housing and Urban Development

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Abstract

Thermal bridging through wood framing accounts for significant energy loss in an insulated wood-framed wall assembly. The Model Energy Code has been silent on thermal bridging in wood-framed construction and instead has focused on the R-value of the insulation within the wall cavity. For the first time, the 2021 International Energy Conservation Code (IECC) will now require continuous insulation as a part of the wood-framed wall requirements in colder climates. A common solution to this requirement is to place a layer of rigid foam insulation on the exterior of the wall assembly; however, the code allows for alternative methods, providing an opportunity for innovation.

Introduction

The second law of thermodynamics specifies that hot things cool unless something is done to stop it. Some people may have experienced this with their morning cup of coffee. If using a thin-walled cup without a lid, the coffee cools rapidly. If one wishes to keep the coffee hot until later in the day, using a double-wall insulated thermos with an airtight lid will keep the coffee hot. The thermos is much more energy efficient—it keeps the heat in place.

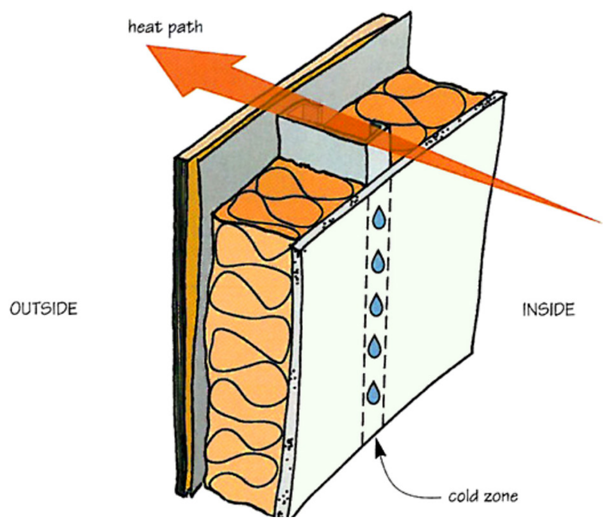
Likewise, the walls, floors, roof, and foundation surrounding homes are all potential sources of heat loss. Reducing the migration from hot to cool (i.e., improving the energy efficiency of homes) is especially important when considering the impact homes have on total energy usage. According to the U.S. Department of Energy, energy use in residential homes accounts for about 21 percent of total U.S. energy consumption, and more than one-half of that energy is spent heating and cooling homes (EIA, 2015).

Using the coffee analogy, when the thin-walled cup holding the coffee is too hot to the touch, the heat of the coffee is transferred directly through the cup into one's fingers. To reduce this effect, one can slip a cardboard sleeve around the cup or use a Styrofoam cup (except in those states where Styrofoam has been banned for decades already), and the cup can be easily held without feeling the heat of the liquid inside. The Styrofoam cup and the cardboard-sleeve-wrapped cup have more thermal resistance than the unwrapped paper cup. In home construction, thermal resistance is measured by R-value. The higher the R-value, the greater the insulating power.

Understanding these concepts is the first step in improving energy efficiency in our homes (exhibit 1).

Exhibit 1

Diagram of Thermal Bridging



Source: Civil Engineering

Concept of Thermal Bridging in Homes

Most people are familiar with cavity insulation (typically fiberglass batt) that is used in the walls and ceilings of wood-framed construction, but it is the wood framing that tends to conduct the heat out of the house because of the poor insulative value of wood. In wood-framed construction, the R-value of wood studs is R1.25 per inch, whereas fiberglass insulation is R3.3 per inch (Bres, 2009). The heat seeks the path of least resistance, and the path of least resistance—where the heat tends to flow—is called a thermal bridge. Thermal bridges develop where the wood studs are located because the wood is more conductive to heat than the other materials around it, resulting in higher heat loss. The wood frames are like the coffee cup without a sleeve. The thermal bridging of wood framing is evident in an infrared photograph (exhibit 2).

Exhibit 2

Infrared Photograph of a Wood-Framed House

Source: Applied Building Technology Group

How many thermal bridges are in a typical wall? Building scientists developed the term *framing factor*, which is the ratio of the area of the wall made up of wood studs to the total wall area (Kosny et al., 2006). A typical wood-framed home might have a framing factor as high as 25 percent (Lstiburek, 2010). For an energy-efficient home built using advanced framing techniques, the framing factor might be 15 percent. In fact, heat loss through framing members such as studs, headers, and sill plates could account for as much as 30 percent of the total heat loss in a wood-framed wall assembly. Minimizing or eliminating thermal bridging presents a substantial opportunity for energy savings for heating or cooling.

New Energy Code Requirements

To address thermal bridging, Section R402.1.2, Insulation and Fenestration Criteria, of the 2021 International Energy Conservation Code (IECC) now requires continuous insulation in addition to wall cavity insulation in colder climates (ICC, 2021). Continuous insulation provides a thermal break over all framing members on either the interior or exterior of the wall assembly. This process is similar to adding a cardboard sleeve or a layer of Styrofoam insulation to the coffee cup. Most commonly, a 1-inch layer of rigid foam insulation (R5) is applied on the exterior of the home, a method known as continuous foam insulation. The exterior insulation minimizes the effects of thermal bridging by preventing heat flow through the wood stud directly to the outdoors; however, as discussed below, continuous foam insulation is not the only solution.

Current Solutions Using Continuous Foam Insulation

Several insulated sheathing products on the market incorporate a foam layer as part of the structural wall sheathing. With these products, the structural sheathing and continuous insulation layer are all incorporated into one product and installed like typical plywood or oriented strand board (OSB) sheathing on the exterior face of the stud wall (exhibit 3).

Exhibit 3

Insulated Sheathing Boards

Source: Huber Engineered Woods

Structural insulated panel (SIP) construction is another method that satisfies continuous insulation requirements (see Blanford, 2009). SIPs are sandwich panels constructed with a core of expanded polystyrene foam insulation between an interior and exterior layer of plywood or OSB. SIP walls do not have studs within the wall cavity; instead, they are composed of continuous panel segments connected with a few wood studs at panel joints.

Both construction methods are examples of continuous sheets of rigid foam that create a thermal break. The methods comply with the prescriptive R-value insulation requirements of the code.

Alternatives to Continuous Foam Insulation

The 2021 IECC Table R402.1.2 allows an alternative method of compliance to prescriptive R-value insulation. This method looks at the overall effectiveness of a wall assembly by quantifying a maximum U-factor for compliance. U-factor is often expressed as the reciprocal of the R-value; a lower U-factor is more effective in reducing thermal transmittance. The U-factor of a wall assembly is determined by measuring the relative contribution of thermal transmittance, considering the different R-values of the individual materials. In the case of a wood-framed wall, the thermal properties of each construction element (the drywall, studs, cavity insulation, exterior sheathing, house wrap, air sealing, and siding) are all added up and considered a part of the overall thermal effectiveness of the wall assembly.

Using the more detailed approach of determining the U-factor for a wall assembly, builders can use innovative new building components to comply with the energy code without the need for continuous sheets of foam insulation material. One such innovation is the use of insulated studs, headers, and sill plates to replace conventional wood material when constructing exterior walls. Insulated stud products such as Insul-Stud™ help to create a thermal break within the wall cavity, thereby eliminating the need for added foam layers outside it. The insulated studs are constructed using two pieces of wood separated by a dense core of closed cell insulation, forming a structural composite material. A 2-inch by 6-inch Insul-Stud™ has an R19 insulation value, whereas a conventional wood stud is about an R7. In addition to the higher R-value, these studs use 40 percent less wood and are 60 percent lighter than a wood stud while still having the same strength as a regular wood stud (exhibit 4).

Exhibit 4

Insul-Stud™ Brand of Insulated Studs

Source: Insul-Stud™

Comparative Analysis of Insulated Studs vs. Continuous Foam

One drawback of using continuous foam insulation on the exterior of a building is the cost associated with the additional material and labor required to install it. In one example, the cost to install a 1-inch layer of continuous foam insulation on the exterior of an average single-family dwelling was approximately $2 per square foot. In addition to the material and installation costs for the insulation, builders have to consider door and window moldings that would be required for the increased wall thickness.

Depending on the product used, the foam layer could also affect the lateral strength of the building and require specialty fasteners that are long enough to extend through the added insulation layer into the framing. These fasteners penetrate the insulation layer, causing thermal bridging through the continuous insulation layer at stud locations, thereby reducing the effectiveness of the wall assembly.

With insulated studs, the need for expensive exterior rigid foam is eliminated, and exterior sheathing and finishes can be installed as they would with wood studs. Another benefit is that the metal fasteners used to install exterior sheathings and finishes will not create a thermal bridge at stud locations because the core of the studs creates a thermal break. The insulated studs are an easy replacement for wood materials, with no additional installation costs, and are much lighter and straighter than a wood stud, making installation easier. In addition, the web material is easy to drill through, simplifying the installation of electrical and plumbing lines, and because the continuous insulation is accomplished with the wall cavity, using this product to meet code requirements provides no added wall thickness.

Another use for insulated studs is in net-zero construction. Using insulated studs in combination with other enhanced insulation products (such as continuous exterior foam insulation and closed-cell spray foam in the wall cavity) can yield a high-performance, energy-efficient exterior wall using a minimal wall thickness.

Conclusion

At the time of publication, less than 10 percent of jurisdictions in the United States have adopted the 2021 IECC code. The authors encourage builders and homeowners unfamiliar with the new code requirements to learn more about them since exterior finish details and construction costs may be affected. Using alternative products such as Insul-Stud™ offers a drop-in solution that is interchangeable with wood studs and would require no extra steps for code compliance. In general, the new thermal bridging code requirements are a step in the right direction toward improving energy efficiency and creating a more comfortable living environment for homeowners.

Authors

Shawn P. Kelley is a professional engineer and president of Moment Engineering + Design in Vienna, Virginia. Mike Blanford is a research engineer at the U.S. Department of Housing and Urban Development.

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Additional Reading

This U.S. Department of Energy webpage provides an excellent introduction to insulation and other concepts discussed in this article: https://www.energy.gov/energysaver/insulation.

For more on the physics of heat flow through a wall assembly, see the research report by John Straube, *Thermal Metrics for High Performance Enclosure Walls: The Limitations of R-Value*. https://www.buildingscience.com/sites/default/files/migrate/pdf/RR-0901_Thermal_Metrics.pdf.