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The Dow Chemical Company
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Exceed Prescriptive R-Value Requirements With Continuous Insulation

"ci" Defined

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) standard 90.1 defines continuous insulation ("ci") as "insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior, exterior, or is integral to any opaque surface of the building envelope."

While "ci" is not a new concept, design and construction professionals and even building owners are becoming increasingly aware of the value of "ci" in helping to achieve desired thermal and moisture performance. This is in large part due to emerging standards – and state and local energy codes based on those standards – placing a greater emphasis on "ci" and its ability to reduce thermal bridging and associated issues.

The topic of continuous insulation is relevant for all types of construction. Building scientists consider it a *best practice*, whether the building in question is a commercial structure or a home.

Continuous insulation applies to all manner of structural methods, too – wood frame, steel stud, precast or poured-in-place concrete, and blends of many methods. Insulation materials and systems that meet "ci" requirements are varied, as well.

This white paper focuses on commercial steel stud construction and the dramatic effect exterior continuous insulation can have on overall building energy efficiency by controlling two key variables: thermal performance and moisture.

Continuous insulation alone can achieve specified R-values and optimum moisture control.

Continuous insulation moderates temperatures inside the wall cavity, reducing the potential for convective heat loss – and increasing the insulation value of the wall system.

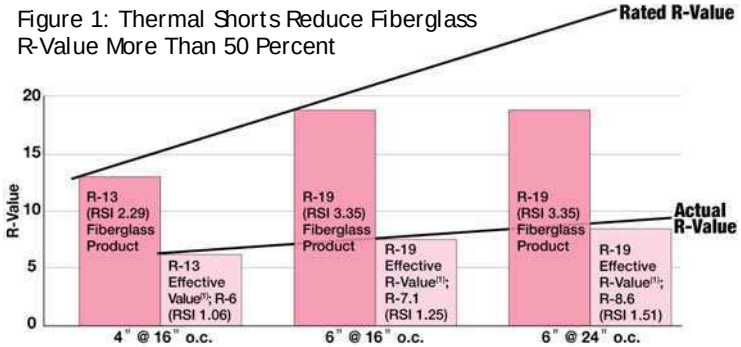
Continuous insulation covers entire surfaces, providing R-value where cavity insulation cannot.

The Deal on Steel

As a structural material, steel is valued for its strength, economy and versatility. But steel studs act like an enormous heat exchanger in a building, providing fast and dramatic heat transfer across and through the wall. This is because steel is an exceptionally good conductor of heat. The R-value of steel varies with its precise makeup, but a representative value is about R-0.003 per inch.[(1)] The very low R-value of steel means that it is often the path of least resistance for heat flow in a wall assembly.

Typical steel stud wall design places cavity insulation (such as fiberglass batts) between the studs, which are then sheathed with other low R-value materials, like gypsum board. This results in an uneven thermal distribution over the wall. The highly conductive steel studs act as thermal short circuits, where heat moves rapidly around the cavity insulation, reducing the system's thermal performance. These thermal shorts can reduce the R-value of fiberglass batts by more than 50 percent of their rated value (Figure 1).

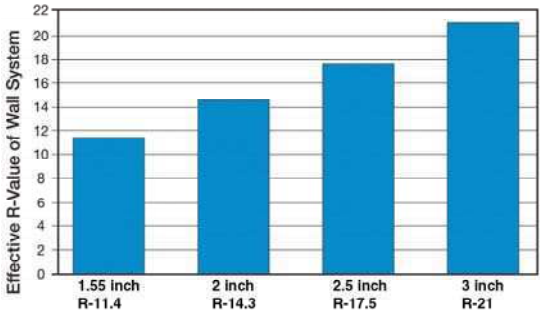
Figure 1: Thermal Shorts Reduce Fiberglass R-Value More Than 50 Percent



(1) Effective R-value (RSI) calculations based on ASHRAE 90.1-2004 Table A9.2B for effective R-value of batt insulation and cavity. All cases have 1/2" interior gypsum with R-0.45 and no air films or exterior finishes.

Highlights:

Figure 2: Wall Assembly With "ci"
(Polyisocyanurate Rigid Foam; R-6.5 at 1")



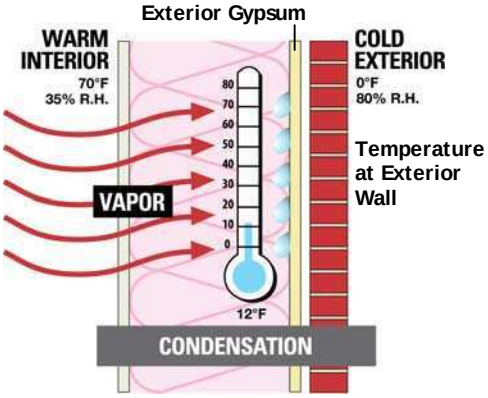
What's more, adding thicker insulation *between* the studs will not significantly improve thermal performance, nor will increasing stud size or spacing – making it physically impossible to design a steel stud wall system with a system R-value over R-10 using typical assemblies. Or, stated in terms everyone who purchases cavity insulation will understand: It is physically impossible to achieve an R-19 steel stud wall with R-19 rated batt insulation by itself.

Exterior continuous insulation is the only way to overcome the immense thermal deficit created by steel studs. For example, installing polyisocyanurate rigid foam insulation (R-6.5 at 1") dramatically improves the wall assembly's effective R-value (Figure 2).

"ci" to Simplify Condensation Control

In a cold climate, fiberglass batt insulation in the stud cavity keeps the exterior gypsum cold between the studs. When heat transfer occurs through the steel studs, it has the potential to create condensation on the face of the exterior gypsum, behind the fiberglass, thus creating a wet environment. For a closer view of this phenomenon, see Figure 3.

Figure 3: Typical Steel Stud Wall Assembly



Based on a 2x6 assembly with batt insulation and exterior gypsum at conditions of 70ºF and 35 percent R.H. on the interior and 0ºF and 80 percent R.H. on the exterior. Note that the interior of the surface of the gypsum is 12ºF with the potential for condensation very high. The system R-value is R-11.1.

You have likely observed this "ghosting" effect on buildings, too (Figure 4). Not only does condensation reduce the effectiveness of the insulation, but if the moisture that forms in the cavity does not dry out, additional moisture-related problems can develop.

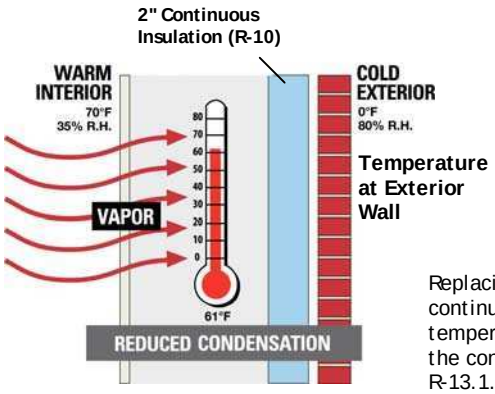
Figure 4

Non-insulated sheathing is no different than covering a wall with metal for condensation control. The dark areas outline stud locations.

Minimizing this condensation potential is one reason vapor barriers were designed. But a moisture management strategy that relies on controlling the perm rating of the wall must be executed perfectly – with location of the vapor barrier adjusted according to climate – in order to work.

However, applying a temperature gradient strategy enables a simplified wall assembly that can work in any climate, where only the thickness of the insulation is changed. Placing continuous insulation on the exterior of the building, similar to wearing a zipped-up coat in the wintertime, warms the cavity and reduces the potential for condensation (Figure 5). This is why continuous insulation, not a vapor retarder, is the ultimate way to eliminate the condensation potential inside the wall altogether.

Figure 5: Assembly With "ci" (Extruded Polystyrene Rigid Foam; R-5.0 per inch)



Temperature has a very strong effect on drying potential, too: The warmer the surface, the more rapidly it will dry. Continuous insulation provides a conditioned cavity, which allows any moisture, such as that from vapor drive, to evaporate faster.

Replacing the batt insulation and exterior gypsum with R-10 continuous insulation increases the insulation's interior surface temperature to 61ºF. The cavity is now a conditioned space with the condensation potential near zero. Plus, the system R-value is R-13.1.

Go Beyond the Code With "ci"

The prescriptive path to meeting the ASHRAE 90.1-2007 standard and the 2009 IECC (International Energy Conservation Code) requirements outlines specific configurations for the various U.S. geographic regions or zones that must be used to meet the code requirements for walls, roofs and fenestrations.

By simply varying continuous insulation thickness to maintain prescribed U-factors, it is possible to meet both ASHRAE 90.1-2007 and 2009 IECC Commercial Building energy standards for steel-framed walls for all U.S. climate zones with continuous insulation alone (Figure 6).

Given the important role of energy efficiency in reducing greenhouse gas (GHG) emissions, today's higher ASHRAE standards have raised the bar for energy efficiency targets. Code bodies, voluntary rating systems such as the U.S. Green Building Council's LEED (Leadership in Energy and Environmental Design) program and the federal government now base code compliance, certification and tax incentives/ funding opportunities on meeting – even exceeding – ASHRAE standards.

It is worth noting that in LEED 3.0, the Energy and Atmosphere (EA) credit category now uses ASHRAE 90.1-2007 as its baseline, and the range of points for EA Credit 1 has increased from 1-10 to 1-19. Continuous insulation increases a building's energy-efficiency level, which in turn contributes to LEED points.

Keep in mind that ASHRAE 90.1 represents the minimum code requirements. Meeting minimum requirements alone may not result in eliminating dew point within the wall or achieving high energy efficiency.

Figure 6:

ASHRAE 90.1-2007 Building Envelope Requirements for Above-Grade, Steel-Framed Walls

Climate Zone	Nonresidential Requirements	Residential Requirements
1	R-13; U=0.124; R=8.06	R-13; U=0.124; R=8.06
2	R-13; U=0.124; R=8.06	R-13 + 7.5 ci; U=0.064; R=15.63
3	R-13 + 3.8 ci; U=0.084; R=11.90	R-13 + 7.5 ci; U=0.064; R=15.63
4	R-13 + 7.5 ci; U=0.064; R=15.63	R-13 + 7.5 ci; U=0.064; R=15.63
5	R-13 + 7.5 ci; U=0.064; R=15.63	R-13 + 7.5 ci; U=0.064; R=15.63
6	R-13 + 7.5 ci; U=0.064; R=15.63	R-13 + 7.5 ci; U=0.064; R=15.63
7	R-13 + 7.5 ci; U=0.064; R=15.63	R-13 + 15.6 ci; U=0.042; R=23.8
8	R-13 + 7.5 ci; U=0.064; R=15.63	R-13 + 18.8 ci; U=0.037; R=27.0

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References

(1) ASHRAE Fundamentals Handbook, www.ashrae.org
(2) www.architecture2030.org
(3) www.buildingscience.com
(4) www.iccsafe.org
(5) www.mckinseyquarterly.com
(6) www.recovery.gov
(7) www.usgbc.org

STYROFOAM™Brand Extruded Polystyrene Foam Insulation
CAUTION: This product is combustible. Protect from high heat sources. A protective barrier or thermal barrier may be required as specified in the appropriate building code. For more information, consult MSDS, call Dow at 1-866-583-BLUE (2583) or contact your local building inspector. In an emergency, call 1-989-636-4400.

Dow Polyisocyanurate Insulation
CAUTION: This product is combustible and shall only be used as specified by the local building code with respect to flame spread classification and to the use of a suitable thermal barrier. For more information, consult MSDS, call Dow at 1-866-583-BLUE (2583) or contact your local building inspector. In an emergency, call 1-989-636-4400.

WARNING: Rigid foam insulation does not constitute a working walkable surface or qualify as a fall protection product.

Building and/or construction practices unrelated to building materials could greatly affect moisture and the potential for mold formation. No material supplier including Dow can give assurance that mold will not develop in any specific system.

"ci" for a Sustainable Future

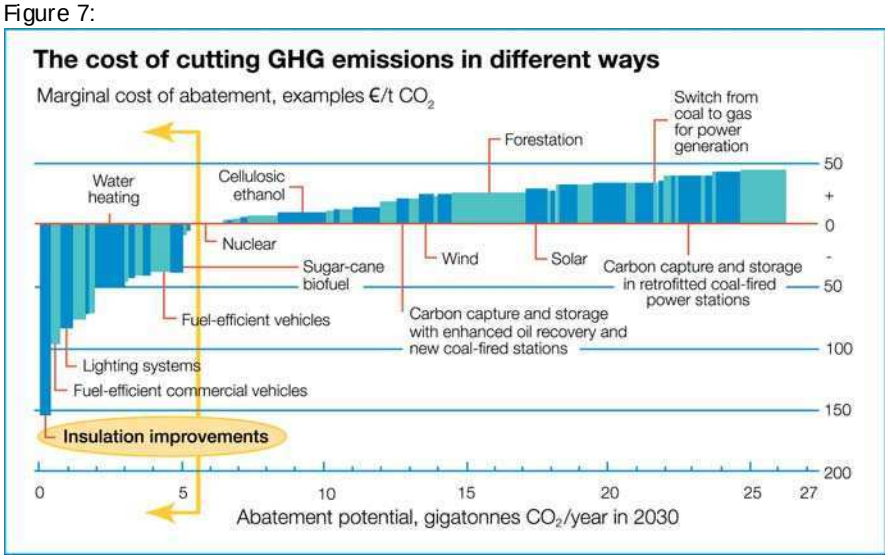
Building and construction accounts for almost half (48 percent) of all energy consumption and greenhouse gas emissions in the United States.
www.architecture2030.org

Today, sustainable, environmentally responsible design means shifting an initial emphasis on recyclability and biodegradability to materials and methods that can help a building operate more efficiently year after year.

As shown in Figure 7, "insulation improvements" is among the more economical measures at the left of the arrows that provide the fastest payback and should be implemented before doing any of the other measures. And as the graph shows, "insulation improvements" is by far the best measure in terms of a negative marginal cost.

Continuous insulation has the potential to reduce a building's energy consumption more than changing HVAC systems, lightbulbs or water heating systems. With greater energy efficiency, the building uses less energy for heating and cooling, resulting in reduced fossil fuel consumption and greenhouse gas emissions, helping move closer to a goal of achieving carbon neutrality and a more sustainable future.

Figure 7:



Source: Study conducted by McKinsey & Company, and Vattenfall. McKinsey & Company studied the costs of implementing various GHG abatement options. This graph represents only a few of the abatement options researched. For the graph in its entirety, visit www.mckinseyquarterly.com/A_cost_curve_for_greenhouse_gas_reduction_1911.

Dow "ci" Solutions

Learn more about Dow products and systems that meet "ci" requirements for commercial construction:

- Rigid foam insulation – extensive line of STYROFOAM™Brand Extruded Polystyrene Foam Insulation and Dow Polyisocyanurate Insulation products for a wide range of applications
- THERMAX™Wall System – innovative commercial steel stud wall insulation system that provides continuous insulation, air barrier and flashing

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