LASTING THERMAL CONTROL FOR BUILDING FAÇADES

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The LEED Platinum home for Zurich North America, in Schaumburg, Ill., employs a soaring three-story double wall to control heat gain and daylight quality in the office and amenity areas.

To keep interior spaces warm this winter (and nice and cool next summer), Building Teams report adopting more advanced approaches to envelope design and construction, whether for big-ticket cladding choices, window edge details, or meticulous mockup and installation practices. Fortunately, a confluence of product innovations, creative assemblies, and improved project delivery techniques are helping improve performance and reduce first costs and long-term energy use.

New findings run the gamut. Modeling of enclosures is expanding, as seen in the recently developed sensitivity analysis tool (tinyurl.com/y8ct6xfl) for quantifying the impact of thermal bridging and corresponding efficiency measures for high-rise residential buildings, according to Brad Carmichael, PE, Assoc. AIA, Senior Building Science Specialist with JRS Engineering.

Improved insulation and cladding systems are enhancing performance as they simplify construction and installation. Methods for mitigating energy losses—including thermal bridging, which experts like engineer Joseph Lstiburek, PhD, say can account for the most uncontrolled heat loss and gain in buildings—have turned the glazing discussion to edge-of-glass performance. In that vein, new breaks and edge spacers dramatically boost performance as compared to treating glass with additional coatings.

In addition, super-green and resilient building concepts are now seen as more available, attainable, and dependable. “Buildings are constantly getting tighter and more energy efficient as technology improves,” says architect Andrew Franz, AIA, LEED AP, noting that successful designs apply strategies drawn from the voluntary Passive House standard and incorporate natural means, including shading devices to manage heat gain.

LEARNING OBJECTIVES

After reading this article, you should be able to:

+ **DESCRIBE the general principles of building siting, orientation, and overall design that contribute to energy efficiency and enclosure integrity.**
+ **DISCUSS continuous insulation and the methods of selecting and applying thermal protections.**
+ **LIST key systems and components for mitigating solar heat gain and unwanted glare.**
+ **EXPLAIN how design and construction practices can affect enclosure performance.**

ALBERT VECERKA / ESTO

An undulating masonry façade highlights the exterior of a five-story addition to P.S. 70, a primary school in Astoria, Queens. The design melds with the neighborhood's mid-block residential setting.

Zoning and code issues also factor into environmentally responsive façade designs. "We also have zoning issues such as city mandated setbacks that are often to the face of the cladding, not to the face of the structures," inhibiting the thickness of walls to preserve real estate value, according to engineer John Straube, PhD, Principal at RDH Building Science. Some codes offer more optimistic outcomes, he adds, such as California Energy Code's comprehensive appendix of "enclosure assembly variations and their impact on typical thermal bridges" (tinyurl.com/y7ooo3x9).

Says the architect Franz, "In short, as states improve their energy codes, more manufacturers step up their standards across the board and the costs come down for end-users."

BUILDING DESIGN PRIORITIES

For sustainable, energy-efficient, and durable commercial and institutional buildings, the key considerations in effective envelopes start with location, enclosure and cladding concept, and system approaches for thermal, air, and moisture control. In schematic design, building siting and orientation are essential starting blocks to meet climate needs and performance expectations. Other factors, such as window-wall ratios (WWRs) and variables like shading from existing trees, can play a role in effective U-value, a measure of the heat transmission through a building component.

"Orientation, the effects of which vary by each site, is a significant player in reducing exposure to solar and wind effects," says Mark Sullivan, AIA, NCARB, LEED AP, Studio Director with architecture firm JZA+D. "The amount of heat gain can be diminished by orienting the building to lessen the effects and by providing shade, whether natural or built, to reduce heat gain and glare. Although natural shading from trees, for example, is less than ideal because it can be affected by disease and seasonal issues." Also, project teams report much more difficulty in mitigating heat exposure when the amount of glazing exceeds 50% of the façade, though that depends on the glass design performance, according to JZA+D's Sullivan, who works on varied commercial and institutional buildings including reconstruction projects.

A key factor in many projects is designing for optimized daylighting, ventilation, and cooling, adds the architect Franz, depending on the use and climate zone. "It also depends on whether the building will have operable windows and take advantage of natural ventilation and prevailing breezes, although daylighting is a primary goal and sometimes northern fenestration provides more uniform, diffused interior light," he says.

For opaque façade areas, the envelope system design and detailing—and installation—are critical to successful interior comfort and operating conditions. "We design building envelopes by combining air barrier systems, moisture protection, and thermal insulation, so that the combined performance is optimal year-round and under varied weather conditions," says Alex Brito, AIA, Architect with RKTB Architects, which works in the Northeast and Mid-Atlantic climate zones. "Because both heating and cooling seasons are fairly intense, we ensure the integrity of the envelope to mitigate air infiltration, which causes significant energy loss. We use continuous insulation systems and thermally broken window frames so that bridging and 'hot spots' are sufficiently addressed in the construction documents."

Even more so, project teams tend to respond to project needs based on factors outside of pure performance calculations. "While there sometimes is a push for more glass area in commercial and multifamily residential buildings, we believe that designs should relate to their context and community," says Brito. That often means a fenestration pattern with wall-to-window ratios similar to neighboring buildings, such as a recent school expansion by the firm. Where context is more open, as at the Zurich North America Headquarters on a large expressway site in Schaumburg, Ill., the project team led by architect Goettsch Partners and Clayco employed an all-glass wrapped façade, optimized for solar orientation and articulated with varied sunshades.

AIRTIGHT AND INSULATED

In addition to thermal bridging, envelope function is closely correlated to the control of air infiltration, "to control moisture damage, reduce energy losses, and to ensure occupant comfort and health," according to Straube. Variables impacting airflow across the building enclosure include wind pressure, stack effect, and mechanical air-handling equipment like fans and furnaces, he says, requiring "a continuous, strong, stiff, durable, and air impermeable air barrier system."

System choices often reflect this priority, says Wendy Wisbrun, RA, LEED AP, Associate with Spacesmith. "Airtightness of the building enclosure is one of the most critical components of a wall's performance in terms of energy efficiency," says Wisbrun, whose work is focused on sustainable design and building science findings. "Self-adhered, water-resistant air barrier membranes at the exterior sheathing can be positively sealed to the glazing systems for continuity of the air barrier to limit air leakage." In addition to airflow, Wisbrun emphasizes the importance of continuous exterior insulation and additional insulation between façade structural members.

Where these different products and trades must interface, including façade openings and penetrations and at the foundation and roof assembly, Building Teams must be especially vigilant, according to RKTB's Brito. Air barrier details must allow for positive and negative wind pressures, and the designs must allow for movement, he says. Adding to that, the architect and enclosure consultant Richard Keleher, AIA, CSI, LEED AP, recommends "careful attention to interconnection details for all systems, field inspection of the work, and testing of typical conditions." These safeguards are especially valuable in later project phases, since products and manufacturers may not be identified in the schematic and design development. Keleher recommends coordination drawings of the interfaces by the general contractor, though this step is frequently skipped.

When the air barriers are installed, they must be confirmed to be free of even pinholes and minor gaps, according to Taylor Gonsoulin, PE, LEED AP, Senior Associate with Pond Robinson & Associates, which assesses buildings for IAQ and HVAC issues. Gonsoulin notes that specially made fasteners offered by many manufacturers should be used to secure barrier material to the sheathing. As for liquid-applied barriers, they must be installed with no gaps in coverage and at the minimum specified thickness, he explains. In the construction phase, joints and seams must be inspected and completely covered, with attention to sealing of service penetrations.

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CONTINUOUS AND BRIDGE-FREE

Project teams also describe obstacles arising in the selection, detailing, and installation of thermal insulation. Examples include thermal bridging and the continuity of continuous insulation, even in the smallest details.

"Continuous insulation is a must for eliminating thermal bridging of exterior assemblies," says Spacesmith's Wisbrun, who compares system alternatives based on insulating value and integration and installation advantages, but also embodied carbon of the materials, which is a factor in climate change. Another factor for energy consumption and greenhouse gas emissions is operational energy use by buildings, which accounts for roughly 40% of total U.S. energy consumption and 38% of CO_2 emissions. Continuous insulation (CI) is a means to lower that pattern.

Environmental considerations are important in this context. For example, increasing availability of recycled polystyrene has led to more EPS and XPS products with minimum recycled content of 20% or more. The rigid foam materials can be reclaimed, melted, and reused multiple times without degradation, according to researchers and trade groups like the Styrene Information & Research Center.

"Mineral wool exterior insulation is another excellent choice, but can be trickier to install, especially in thicker insulation values, due to its compressible nature," says Spacesmith's Wisbrun. She adds that project teams routinely install up to eight-inch-thick continuous mineral wool in an exterior cavity, using the correctly engineered mechanical fasteners, which can be highly effective.

Other novel insulating systems are finding more use, such as silica aerogels in translucent panel

COURTESY GOETTSCH PARTNERS (MODEL) AND LESTER ALI PHOTOGRAPHY (PHOTO)

Advanced modeling of the Abu Dhabi Global Market Square project, by Goettsch Partners, revealed the benefits of the building's ventilated double-skin facade (above) and active and passive shading systems (opposite page). The complex became the first in Abu Dhabi to be pre-certified LEED-CS Gold.

products faced in polycarbonate or acrylic—and in recent research on single-glazed windows with aerogel fill (tinyurl.com/ybul5789). New closed-cell spray foam insulation formulas use hydrofluoro-olefin (HFO) blowing agents, which have a global warming potential (GWP) of about 1, a vast improvement over many hydrofluorocarbons commonly used in the past. Another insulating solution combines raw materials such as natural wood fibers, polyolefin fibers, and ammonium sulphate to produce a flexible board that can act as both thermal insulation and water-resistive air barrier, or WRAB, according to Wisbrun.

In addition to insulation for the opaque wall areas, RKTB's Brito points to the window frame and the glass edge—portions of insulating glass units (IGUs) that significantly affect total U-value. "To reduce cold spots and thermal bridging at window frames, there are excellent new products, including polyamide thermal breaks and warm-edge insulating glass spacer bars," he explains. "These details have an outsize impact on building performance and energy efficiency." Describing the effects of thermal transfer between glass panels, window frame, and the spacer, "warm-edge" components cut energy loss, making the interior frame surface and glass edge warmer to the touch in cold weather (and, conversely, cooler on hot days).

Insulation material choices should match both performance needs and the expected lifespan of the building. The "useful life" of insulation materials tends to describe the length of time the materials retain their material attribute and a significant portion of their R-value. According to experts like Straube, high-R-value enclosures are a long-term investment, with insulation materials typically lasting 75 years (tinyurl.com/ydddyz7q). This compares to HVAC equipment, for example, which may be changed out three or more times during a similar time period. Comparisons of various foams, boards, batts, wraps, and loose-fill products show some variation, but useful life expectancies can reach 80 years to 100 years in some cases.

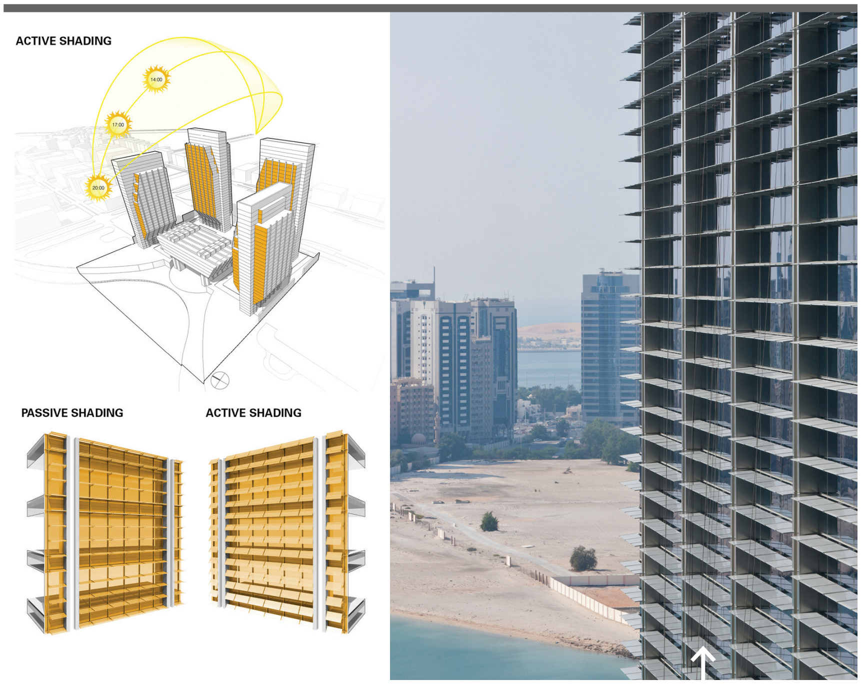
Regardless of the insulation materials and systems selected, detailing and installing for continuity and full coverage are essential. Detailing and installing façade insulation must provide for "a continuous layer between the building's conditioned inside space and the outside environment," says André Omer Desjarlais, Program Manager for the Building Envelope Systems Research Program at Oak Ridge National Laboratory. Every break in this layer is effectively a thermal bridge and an opportunity for excessive energy loss or gain.

CI is often harder to execute in the field, say Building Teams. During the construction and installation phases, "the main issues are proper detailing, especially at joints and penetrations, and ensuring the installing tradespeople and subcontractors are following the details and specifications," says RKTB's Brito.

GLASS PRODUCTS AND THERMAL BRIDGING

Increasingly rigorous energy codes are demanding better performance for façade glass systems, according to experts. U-factor requirements in jurisdictions with codes based on the International Energy Conservation Code (IECC) or ASHRAE 90.1 require vertical fenestration with thermally broken frames as well as dual-pane glazing with a low-emissivity (low-e) coating. In places like Seattle and Washington, D.C., which sit in climate zone 4, and cities including Chicago in climate zone 5, enhancements beyond those two are required to meet codes and standards. Examples include argon-filled IGUs, warm-edge spacers, enhanced thermal breaks, and applying an additional surface with a low-e coating. Further north in climate zones 6 and 7, even more of those fenestration enhancements are required on projects meeting IECC 2015, for example.

In addition, building owners and developers are looking for more opaque wall areas on projects as a way to hedge against rising energy costs. "Glass is the weak spot in the built wall, as its thermal



3D models depict the active and passive shading systems at Abu Dhabi Global Market Square.

COURTESY GOETTSCH PARTNERS (MODEL) AND LESTER ALI PHOTOGRAPHY (PHOTO)

resistance will generally be less than the adjacent opaque wall," says the architect Sullivan. Even as the thermal insulating values of glazing systems improve, says Sullivan, it is unlikely that the industry will shift toward larger glazed areas on projects, because the thermal insulating values of opaque façade systems will also improve. "It seems likely that fenestration area will continue to be a balancing act with opaque insulated wall sections," he adds.

On the other hand, many project teams see steady, incremental performance gains and reasonable costs, even in metropolitan markets. "Glazing technology has increased substantially from a thermal perspective, and the costs for superior performing glazing have become more affordable," says Franz. Add to this the market drivers for increased daylighting and occupant views, which have demonstrable impacts on productivity in some studies and foster "wellness and ultimately yielding higher patient satisfaction with their environment" in healthcare buildings, according to the Center for Health Design (tinyurl.com/y8usgpnp).

The University of Southern California's Façade Tectonics Institute has documented the trends toward larger and more complex glass apertures and dynamic fenestration products that respond to environmental conditions.

Fenestration performance can be improved by looking at both the center-of-glass U-factor and the edge-of-glass U-factor. Depending on the area of the window, less than half of its U-factor can be attributed to the center-of-glass performance. At a presentation last year during the Glass Performance Days conference in Finland, Helen Sanders, PhD, of the company Technoform stated, "To get to—or close to—net zero, we need to look more broadly at the window as a system," including frame and edge-of-glass conductance, as well as aspects related to air leakage and installation."

Building Teams are catching up with these aspects of façade thermal performance. According JRS Engineering's Carmichael, a modeling tool to assess how thermal bridging affects overall performance allows project teams to rank various building elements in terms of total potential heat flow. Created during project work for a University of Washington academic facility, the method allowed the team to see how various curtain walls, framed walls, parapets, and shade attachments would impact energy efficiency.

"As demand increases for building enclosures that have greater detail complexity and higher performance requirements, so too does the need for procedures to evaluate the impact of thermal bridging on the performance of the enclosures," according to Carmichael.

IN SHADE AND SUN

The desire for glass-wrapped buildings in many settings is a key to value for developers and investors. Yet the floor-to-ceiling views can conflict with increasingly stringent codes mandating better energy performance.

In an October 2018 presentation in Dubai for the Council on Tall Buildings and Urban Habitat (CTBUH), James Goettsch, FAIA, Chairman and co-CEO of Goettsch Partners, illuminated this issue with a comparison of energy consumption by two Chicago office towers: 150 North Riverside and 110 North Wacker. The buildings are similar in terms of height, location, and floor plate, and they were designed within five years of each other. Yet the second building met an "allowable energy consumption requirement reduced by 27.2%" in part due to enclosure design enhancements.

In these and other types of building projects, the envelope is a focus of careful study to mitigate unwanted heat gain. Smarter building systems, improved and increased low-E coatings, active shading devices, and architectural elements like overhangs and fins add articulation and function to façades of varied WWRs. Shading in general is an area of focus when the building interior areas have significant cooling requirements.

General rules of applying these systems marry common sense with environmentally responsive techniques. For example, effective shading devices that mitigate potential heat gain must be outside the glass or finished façade face, since those surfaces must be relieved of additional thermal load applied by the sun, according to Sullivan. Interior shading devices offer a secondary function and are ideal for glare control, especially when operated independently by occupants. Active shading systems require an ROI analysis, adds Sullivan, due to their cost and maintenance requirements, yet they can be attractive in their inherent function and visual appeal, providing for customization of the exterior wall.

Applications run the gamut. “We have used exterior shading elements for our school designs, including a public school in Queens, New York,” says RKTB’s Brito. “The architectural shading makes light more useful, manageable, and enjoyable in the new school addition.” The solar control scheme supports the School Construction Authority’s long-term focus on environmental stewardship and reducing operating costs, according to the project team.

In a similar vein, the LEED Platinum home for Zurich North America employs sunshades varying in depth and a soaring three-story double wall to control heat gain and daylight quality in the office and amenity areas. The overall design of the 783,800-sf complex optimizes solar orientation for amenities, according to Goettsch Partners, and responds to the regional climate in ways that benefit long-term economics, occupant comfort, and ultimately the success of the organization.

The double wall at Zurich’s HQ is a unique architectural statement that provides many environmental benefits. Designed with an interstitial cavity, double walls help improve acoustics, solar control, and ventilation, according to experts. The systems can be applied in new construction and also in reconstruction situations, in some cases as an option that may improve on over-cladding.

The cavity between the two walls provides a potential location for containing or eliminating heat gain, for shading devices, and for supplying outdoor air ventilation, according to Keleher. Experts anticipate increased use of double glass walls and other double wall designs in the future, as the push for greener and net-zero energy building designs necessitate more robust enclosures.

MOCKUP AND SEQUENCE

In general, in addition to the owner-developer’s wishes, building teams consider the following factors in the planning stage of enclosure designs, including glass wall systems: code compliance, constructability, first cost, life-cycle cost, functionality and appearance. The testing and sequencing of construction tasks is essential to the project schematic design and design development. Early in these phases, adds Keleher, building teams plan to coordinate carefully when shop drawings are being created and reviewed, owing to the fact that team members won’t know all the manufacturers and product types for insulation, air barriers and other wall, roofing and fenestration products.

The main issues in selecting insulation systems are the correlation to the sizing of building HVAC, locating the dew point within the wall so that condensation build up is avoided, and allowing the wall to breathe, according to JZA+D’s Sullivan. “Of course, there are always the flammability and flame spread requirements of the building code, too.”

The downside of a poorly executed installation is significant, adds Sullivan. “Continuous is an absolute essential type of application, because without it, thermal bridging leads to significant heat transfer and will create a dew point on the surface of the bridging element which can lead to moisture management problems and even mold,” he says.

Spacesmith’s Wisbrun agrees, giving a common example in some building projects. “Insulation is installed separately, such as with continuous exterior insulation such as semi-rigid, stone wool insulation boards designed for exterior cavity and rainscreen, coupled with mineral wool insulation between studs and structural elements,” she says. “These are commonly used materials that trades are comfortable using and can be reliably installed, and having a separate air barrier allows for quality assurance inspection before the insulation is installed over it.”

According to Keleher, “Although it’s not often done, coordination drawings of these interfaces by the general contractor are very helpful to the process.”+