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Thermal Bridging: It Can Be Done Better

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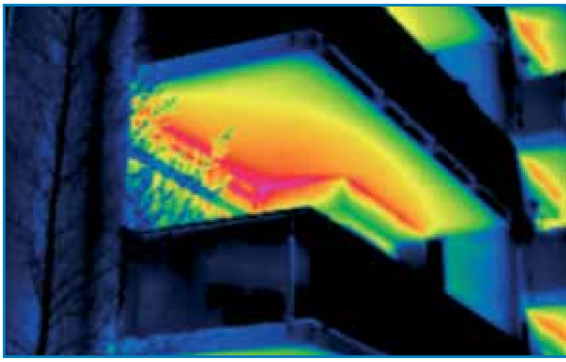

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On the cover: The Centre for Interactive Research on Sustainability (CIRS), located at the University of British Columbia, is one of the greenest buildings on earth… and provides a great example of thermal bridging done right.

Thermal Bridging: The Final Frontier of High-Performance Buildings

By Matt Capone, Assoc. AIA

MINIMIZING OUR USE OF ENERGY AND NATURAL RESOURCES are vital components of the global strategy to protect our environment and mitigate climate change. Buildings and the construction sector represent a large portion of total global energy and resource consumption. The United States has responded to this awareness with a tightening of building energy and performance standards. ASHRAE 90.1 has significantly reduced the energy that can be consumed by a building.

One significant aspect of energy loss from a building is conductive heat transfer through the building envelope. There are common improvement strategies to minimize conductive heat loss that include reducing the window-to-wall ratio, using high-performance window systems and improving façade insulation. These assemblies are largely responsible for the overall thermal performance of an exterior wall.

The focus has turned to a long-overlooked aspect of the design—thermal loss through structural components. Traditionally, not a lot of attention has been paid to the various thermal bridges that are integral to these larger envelope assemblies because they were thought to represent a relatively small percentage of the overall energy loss. As we improve the thermal performance of our overall wall systems, however, the heat loss through thermal bridges becomes a much greater percentage of energy loss and, thus, more important to consider and control.

These overlooked thermal bridges are a concerning topic. Off-the-shelf, manufactured structural thermal breaks (MSTBs) have already proven to be an attractive solution through their performance, not to mention the material and system testing being completed by the system manufacturers. These products are now considered standard building practice in Europe and are available in the United States market now too.

IDENTIFYING STRUCTURAL THERMAL BRIDGES

Thermal bridges are localized elements or assemblies that penetrate insulated portions of the building envelope with thermally conductive materials that results in high levels of heat loss. As a consequence, in cold climates, low internal surface temperatures occur during the winter that may create conditions for condensation and mold growth.

In the case of uninsulated balcony slab connections, the interaction of the physical geometry ("cooling fin effect" of the balcony slab) and the material properties (thermal conductivity of a reinforced concrete slab) can result in significant heat loss, meaning that the uninsulated balcony connection is one of the most critical thermal bridges in the building envelope **(FIGURE 1)**. Buildings that contain uninsulated balcony connections have significant incentives for adoption of thermal break technology to improve thermal comfort, energy efficiency and indoor air quality.

Generally speaking, there are many different structural elements and/or building components that penetrate the building envelope and may form thermal bridges. This includes balconies, canopies, slab edges, parapets or corbels. These components are common architectural features or essential structural elements in residential buildings, as well as in commercial buildings, such as hotels, schools, museums and gymnasiums.

Depending on the assembly design and climate zone, these structural penetrations through the building's thermal layer are providing a direct path for energy loss and premature structural damage due to condensation. Another possible effect of thermal bridges includes an uncomfortable living environment, due to differentiating temperatures within one space. During the wintertime in a cold climate, the center core temperature of the room needs to be increased to make the edges and corners bearable. While some may think that radiant flooring can combat thermal bridging, the result is an increase in energy use to constantly heat a lost cause.

AN APPROACH TO REDUCE THERMAL BRIDGES

The more efficient a building is designed to perform, the more impact thermal bridges have, as the thermal path will follow the easiest route with the least thermal resistance—structural thermal bridges.

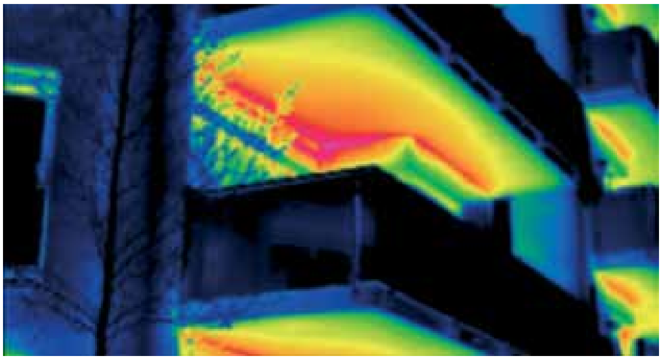

Figure 1. This thermograph photograph shows that if thermal bridges at balconies are not addressed, the balconies act as "cooling fins", conducting the heat off the building and cooling the rooms adjacent to the balconies.

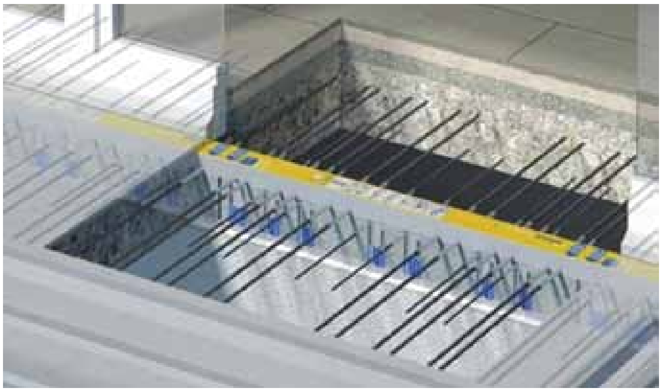

Figure 2. An illustration of balcony connections with structural thermal breaks.

Windows are often seen as the largest thermal bridge in buildings because the thermal performance is often quite low compared to the surrounding walls (for example, an R-2 metal frame window within R-20 insulation). However, exposed slab edges and balconies can have almost as large of an influence, having effective R-values around R-1.

These weak links in the building envelope reduce the efforts of insulation and air barriers. The design team should be aware of the thermal calculations of the design to ensure the entire building envelope meets the project's expectations for efficiency.

To reduce structural thermal bridges, the engineer should also be involved early in the design process. Architects deserve the freedom to explore their design and working with the structural engineer earlier allows time to find solutions to enhance or follow the design input. This collaboration between the architect and engineer is essential to energy-efficient designs, especially when dealing with structural thermal breaks.

SOLUTIONS TO STRUCTURAL THERMAL BRIDGES

Structural thermal breaks **(FIGURE 2)** reduce the heat flow, while also conserving structural integrity. At uninsulated balconies, for example, the reinforced concrete at the connection is replaced with an insulating material, while continuous reinforcement bars are used to transfer loads (moment and shear). In some instances, these reinforcement bars may be replaced by stainless steel where they penetrate the insulating material, as it is much less thermally conductive than conventional reinforcing steel. The use of stainless steel not only reduces thermal conductivity but also guarantees longevity of the structural components in the gap where no concrete protects them, through its inherent corrosion resistance.

Other materials are also used in some proprietary systems, with the aim of reducing thermal conductivity, such as concrete modules to transfer compression instead of stainless steel.

The combination of all these aspects means that structural thermal breaks can average an equivalent thermal conductivity of k = 0.19 W/mK (0.110 btu/h ft K) to connect a standard balcony with a cantilevered length of 2 m, instead of k = 2.2 W/mK (1.27 btu/h ft K) for reinforced concrete at an untreated balcony connection. This reduces the thermal conductivity at the connection by up to 90 percent and can also elevate the surface temperature in the living area up to a maximum of 63.7°F (17.6°C), depending on the nature of the structure. **(FIGURE 3)**.

The improvement in thermal performance by using MSTBs may benefit the application of green building programs, such as Leadership in Energy and Environmental Design® (LEED), by contributing to the reduction in overall building energy use. Typically, a range of MSTBs are available from the manufacturer, depending on the load requirements and deflection criteria, so that the optimal solution between structural and thermal performance can be found.

INTEGRATION IN BUILDING DESIGN IN THE UNITED STATES

To ensure that the requirements of a project are met, an integrated design process between the project architect, engineer, relevant specialty consultants, construction team and manufacturer's technical staff is recommended. For example, an appropriate design solution

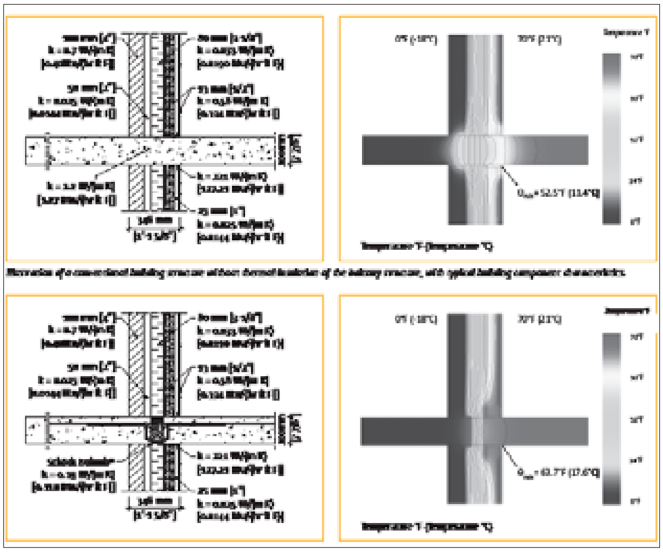

Figure 3. The diagrams illustrate the influence of an effective insulation product in a concrete construction. The heat can freely flow out via a non-insulated balcony slab but by using the product, heat loss will be reduced and the inside surface temperature will be increased.

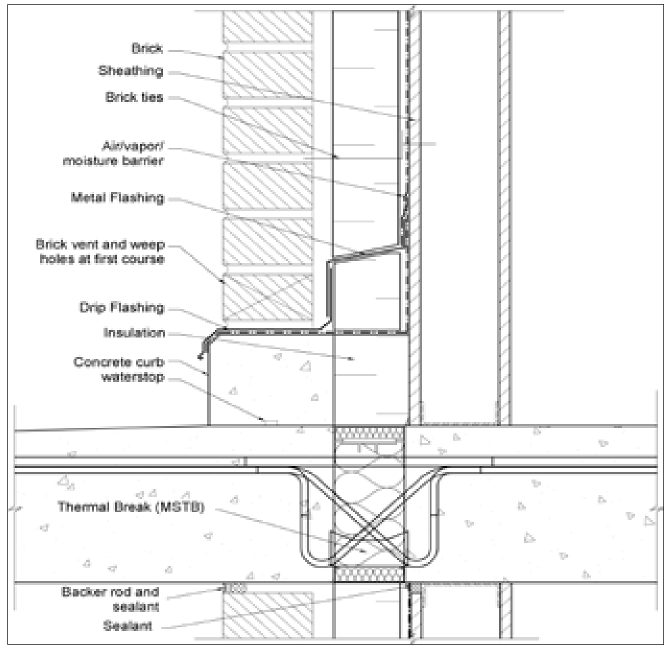

Figure 4. An illustration of a sample detail at a typical balcony with a brick wall, for reference purposes. There are several solutions possible and the shown detail should create an idea of how to integrate thermal breaks in current construction methods. The shown waterstop should solve the issue that the concrete curb is not integral with the slab.

for a high-rise residential building with cantilevered concrete balconies will vary based on regional construction practices and cladding assemblies (brick veneer, architectural pre-cast concrete, exterior insulation and finish system, painted concrete, etc.) **(FIGURE 4)**.

Therefore, the project architect will be required to determine and illustrate the location/placement of the thermal breaks, taking into account considerations from the integrated design team. This will include the code consultant to comply with code requirements for fire resistance/protection specific to the project details; the building envelope consultant to maintain continuity of the critical barriers (air, moisture, vapor and thermal); and the structural engineer in order to avoid interference with the structural attachment of other elements (glazing, framing, etc.).

Additionally, the structural engineer should also take into account: slab rotation at the slab extension, primarily due to the elongation of the unbonded bars in the MSTB; expansion joints in the exterior structure, due to thermal elongation of the exterior element; and lap reinforcement to ensure the transmission of the loads into the slab. The manufacturer's technical staff may also offer support with those previously noted, based on project experience and research/testing completed by individual manufacturers. Some manufacturers provide recommendations for these considerations in their technical manuals, based on structural calculations for ensuring code compliance.

To summarize, the following key points should be discussed among the design team prior to the project architect illustrating the integration of structural thermal breaks in design drawings:

- Desired thermal performance;
- Structural demand versus capacity of the MSTB;
- Minimum clearance required for structural attachment of other elements;
- Fire protection requirements at selected details;
- Continuity of the building envelope critical barriers;
- Waterproofing transition and connection details; and
- Installation procedure and construction sequencing.

CONCLUSION

As energy efficiency requirements in the United States building construction market continue to become more stringent, greater emphasis and attention is likely to be required at thermal bridge locations in design. In addition to the energy use benefits of thermal breaks, there are also other benefits, such as reduced risk of condensation and mold occurrence and improved user thermal comfort. Manufactured structural thermal breaks provide an attractive option because the system testing has already been completed to facilitate ease of adoption in design and construction.

The integration and installation of MSTBs has various considerations that require collaboration among the project stakeholders to ensure that the project requirements are met. This is no different from any quality construction project. Adoption of this building technology is growing and providing a knowledge base specific to the United States construction market. Owners and developers can also facilitate project specific adoption of this technology by utilizing design professionals and preferred product suppliers already experienced with the integration of MSTBs in building construction in the United States. ■

Matthew Capone, Assoc. AIA, is the United States Sales Manager for Schöck USA, Inc. Capone is an architectural designer with a wealth of experience in design-build projects and implementing energy-efficient strategies. His project experience extends from initial design development to construction practice. With a drive to create a lasting positive impact on our communities and environment, Capone applies techniques and industry insight to bring realization to the table. He is both proficient in building information modeling (BIM) and in energy-efficient strategies, such as Passive House. Capone holds a B.Arch. from Roger Williams University.