Steel Framing & Building Envelopes

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Attending to thermal bridging can make a big improvement in the building envelope.

HOW MUCH OF A BUILDING'S heating and cooling energy demand is attributable to thermal steel bridging? Probably much more than you think. Have you ever calculated it, and do you even know how? I bet not—most people don't. I didn't, until recently.

For years, I thought that the continuous steel angles and plates that extend across a building's wall and roof insulation didn't transfer enough heat to worry about. After all, no one complained. And we had developed a set of details that seemed to work well—they were economical, allowed dimensional adjustment where needed, and most importantly provided good structural support. Details that provided thermal breaks were simply not part of our design repertoire. Unfortunately, I was very wrong in my assumption that those insulation-bridging plates and angles didn't matter. They do.

Turn R-Values On Their Heads

My mistake was in thinking only in terms of relative *R*-values, which describe a material's resistance to heat flow. Sure, I thought, the *R*-value of steel is very small, but even if it's nearly zero, the algebraic sum of the areas of the materials times the *R*-values means that a small area of steel reduces the overall *R*-value of a wall by only a small amount. But this approach is incorrect when there are parallel heat paths.

The way to determine the potential thermal energy flux through an area of building envelope with one material "bridging" across another is to use the inverse of the *R*-values—the *U*-values—which is a measure of a material's heat transfer capability. Comparing *U*-values, carbon steel conducts heat about 1,200 times better than rigid expanded polystyrene (EPS) insulation. This means that if the EPS insulation in an exterior building wall is "bridged" by a steel plate across an area that is just one tenth of one percent of the wall's total area (that's a ¼-in.-thick continuous steel plate at 16 ft 8 in. on center), more heat can potentially flow through the steel plate than the entire rest of the wall. That means the wall's total effective *R*-value could be less than half of a similar wall with no steel bridging across the insulation. For the steel to transfer that amount of heat would require a very good thermal connection to both the interior conditioned elements and the exterior temperatures. But this is not too far from reality for steel in building envelopes: A brick relieving angle, for example, is well connected to the interior building structure, and the continuous contact with the brick wythe provides an efficient thermal coupling to the external ambient air.

Improving Building Energy Efficiency

From a sustainability perspective, structural steel has a lot going for it. Its high recycled content, its recyclability, and its ability to make durable, adaptable structures makes steel a good choice for buildings. But architects and owners gradually are becoming aware of the importance of the design and detailing of the thermal envelope on a building's demand for heating and cooling throughout its service life. Structural engineers, who are frequently sidelined during discussions about a project's sustainability opportunities, can and should play a bigger role.

The industry is getting feedback about building energy loss through thermal steel bridging in three important ways:

- ➜ The use of infrared thermal cameras. This is becoming more common and reveals warm surfaces in the wintertime at bridging locations, including masonry lintels, relieving angles, and roof edge angles (see photos).
- ➜ The use of accurate thermal energy modeling software, which correctly accounts for the effect of thermal bridging. However, although such programs exist, the actual modeling of the types of detail-based conditions like thermal bridging frequently are approximated, and not always accurately. It is fairly rare to have a building modeled to such a level of detail during the design phase, with feedback from the results brought back to the design team for making changes to improve the performance of the details.

➜ Data from actual building energy use. Beginning with LEED 2009 projects, the U.S. Green Building Council will be collecting and analyzing energy usage data from all buildings that obtain LEED Certification. This feedback will identify which types of buildings perform well, in terms of energy use, and which do not. It will likely result in a real push to make changes to the poorly performing buildings.

The energy performance of a wall or roof system depends on a variety of things. For example, thermal mass can play a significant role, especially under conditions where there are wide swings in temperature from day to night. Also, any discontinuities in a building's air barrier can create convective heat transfer, which can overshadow the energy lost by conduction. But the main point should not be ignored: Steel that bridges across building envelope insulation can cause a significant increase in building-related energy use, in both heating and cooling conditions.

It's time to develop some new details. We can modify existing details to incorporate thermal separation that blocks the thermal steel bridge. However, in some cases completely new details will be necessary. In Europe, manufacturers have developed proprietary thermal bridge isolators—packages, similar to a pack of shim plates—that span across a thermal envelope, with rated capacities for shear, moment, and axial forces. Such products are not yet readily available in this country. Certainly, developing new details represents additional design time and possibly an increase in construction costs over traditional installations. But there is an ongoing financial payback in energy savings over time.

Solutions

This issue begs the question: Who should be responsible for the calculation of the effect of thermal steel bridging on a building's insulation? If a project has a building envelope consultant, this should be part of that person or firm's work. For other projects, it is unclear who the responsible party should be. Most structural engineers assume that the architect would provide them with feedback if they are doing anything that compromises the thermal envelope, but this is frequently not the case. Because steel is detailed and specified by the structural engineer, that person should understand the thermal implications, and work to minimize the bridging, or at least inform the architect or client about the magnitude. We certainly do not want non-engineers revising steel support details.

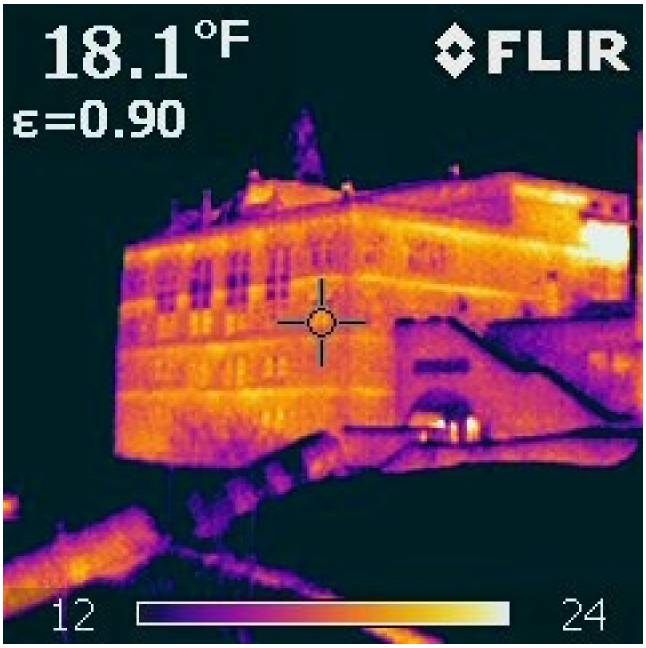
Here are a few suggestions:

➜ Work with the design team, especially the architect, to accommodate insulation and an air barrier completely around the structural steel, on all sides. This includes columns that extend outside the envelope, projecting roof canopies, overhanging roof edges, and floor structures over unheated spaces.

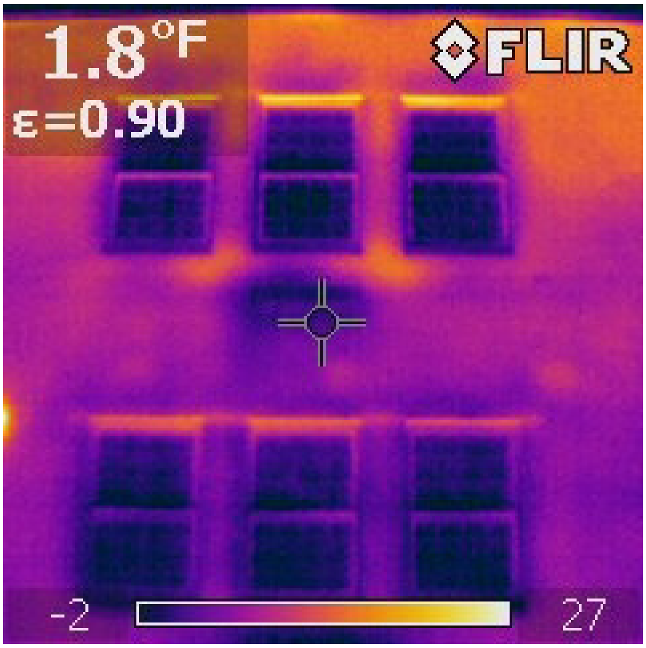
➜ Consider supporting exterior elements such as balconies and canopies completely externally to the main building structure, so that the interior and exterior steel structures do not connect to each other, or are connected as minimally as possible.

➜ Reduce the area of steel that passes through the building envelope insulation to no more than what is structurally necessary. Although this will help to a degree, especially for overly conservative details, the resultant reduction in energy loss is not linear: A 50% decrease in the area of steel bridging across the insulation results in significantly less than a 50% reduction in potential thermal transfer. In most cases, this has the potential to reduce the amount of energy loss by slight increments.

➜ Use stainless steel whenever possible for steel bridging the insulation. The thermal conductivity of stainless steel is about



An infrared thermal image of a steel-framed brick building reveals heat loss at the bright yellow lines corresponding to the locations of the relieving angles.



Heat loss through steel lintel plates in a masonry wall is clearly visible in this infrared thermal image. The darker areas show lower temperatures and lighter areas indicate warmer areas.

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Photos: Using a fiberglass reinforced plastic (FRP) angle as a shim in this hung lintel detail, seen from above and below, is one way to significantly reduce thermal bridging.

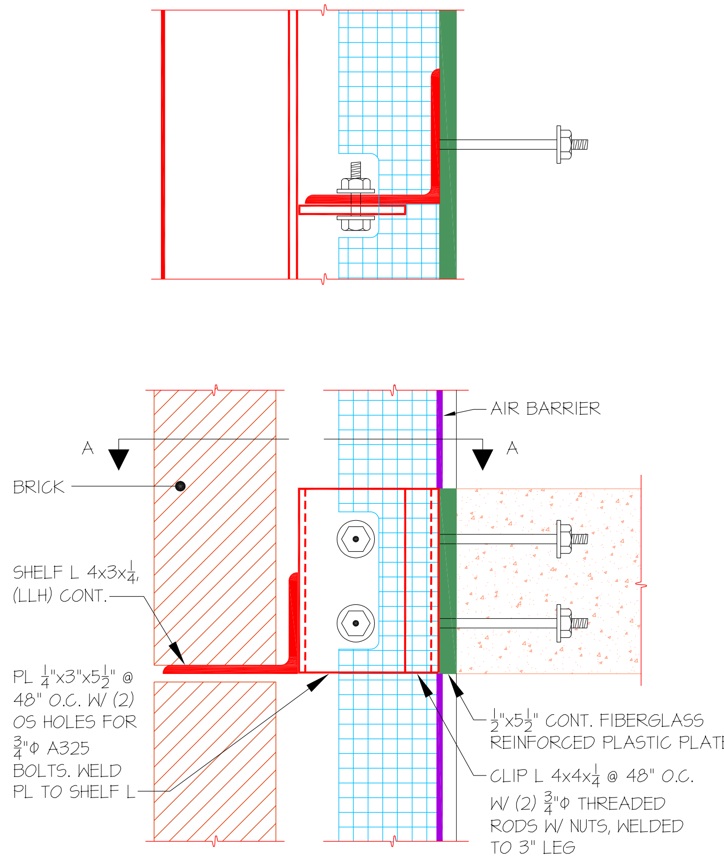

Figure 1: FRP plate used as shim and edge form at relieving angle for thermal break.

a third that of carbon steel. However, this is also only an incremental improvement. Plus, stainless steel is significantly more expensive than carbon steel.

- Develop details that introduce thermal breaks across the steel.

Our office has developed some initial prototype detail concepts for roof edges, rooftop grillage supports, facade relieving angle supports, and masonry lintels. Figures 1 through 4 show some of these conceptual details.

We have found the discrete use of fiberglass reinforced plastic (FRP) elements to be most promising. In addition to having a low rate of heat transfer, they are a proven structural material that is readily available throughout the country. Although they have significant structural properties, we do not use them to resist flexural or tensile loads, because plastic creep over time can be a problem. Instead, their structural role is similar to a shim pack. Also, the capacity of the bolted assembly should be very carefully reviewed, because introducing any non-steel element between steel plies is a departure from the connections covered by the Research Council on Structural Connections' *Specification for Structural Joints Using ASTM A325 or A490 Bolts*.

As of this writing, we have successfully implemented the FRP angle shim concept in hung lintel details at three small school building additions in upstate New York (see photos above). For these three projects, the amount of masonry supported was small, and therefore the loads on the bolts were fairly low.

Although adding an FRP element in the middle of a fabricated steel assembly certainly introduced a challenge, taking the time to

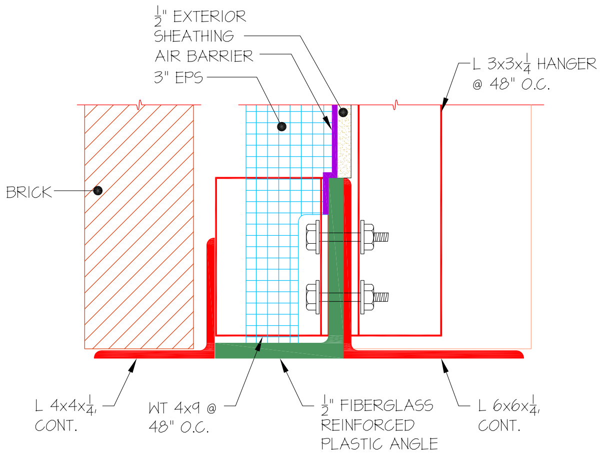

Figure 2: FRP angle used as shim in hung lintel for thermal break.

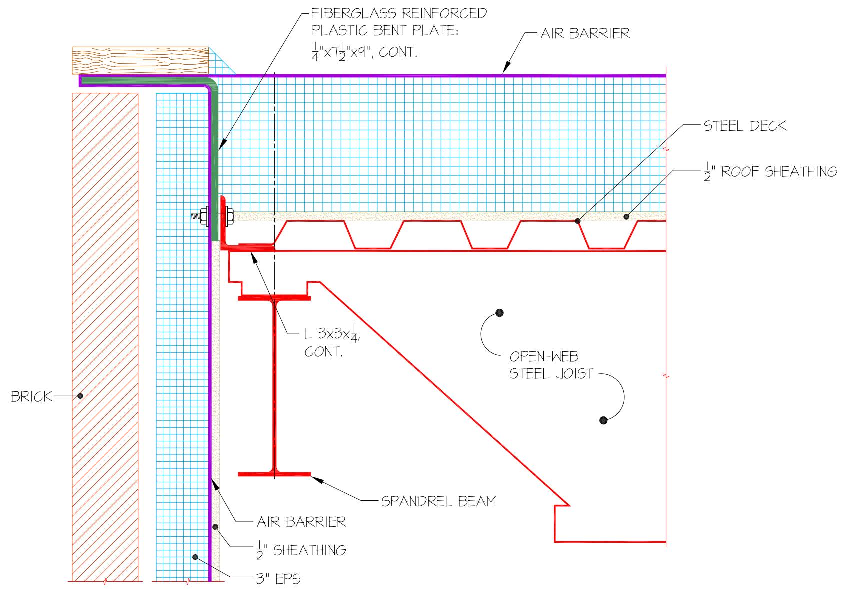

Figure 3: FRP angle used for roof edge angle support.

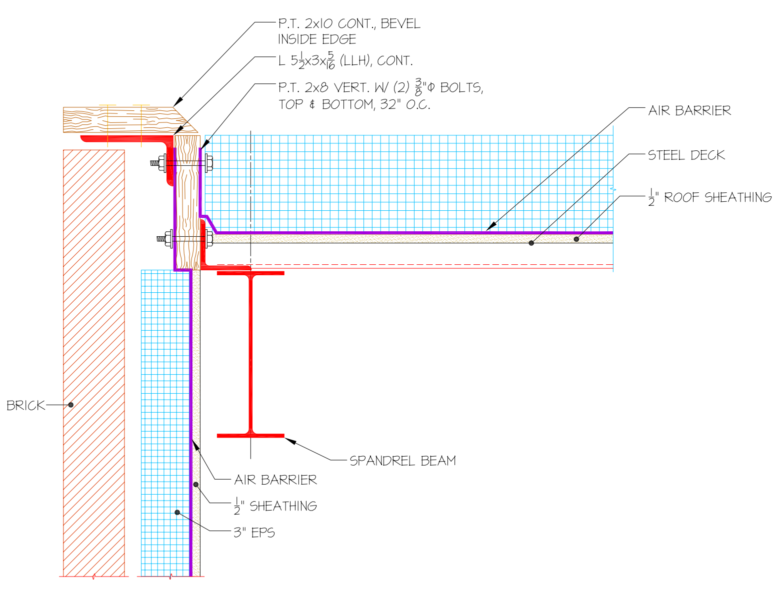

Figure 4: Wood support for roof edge angle.

explain the rationale of breaking the thermal bridging nearly always resulted in buy-in and acceptance. We have found that, especially with any new system or procedure, good communication among all members of the design and construction team is critical for smooth implementation. One crew made us promise that we would come back with our infrared camera after the building was finished and being heated to see how well the detail performs. We'll be interested, as well.

In other countries, manufacturers have developed proprietary systems that can be integrated into building envelope details to block thermal bridging. These systems, which might be thought of as structural shim packs, have defined performance parameters to resist structural loading with defined deflection limits. To the author's knowledge, no such systems are available in the United States—yet.

Closure

In addition to the sustainability impact of the use of structural steel material itself, the steel design and construction community must acknowledge the need to minimize the potential building energy that can be lost through thermal steel bridging. This change is coming quickly. We need to develop and refine a set of solutions now, before our options are limited by others. We shouldn't wait until building codes are introduced in this country incorporating specific limitations for the amount of thermal steel bridging that will be allowed in buildings depending on their use. It's time for structural engineers to understand this problem and develop solutions. That's what engineering is all about. MSC