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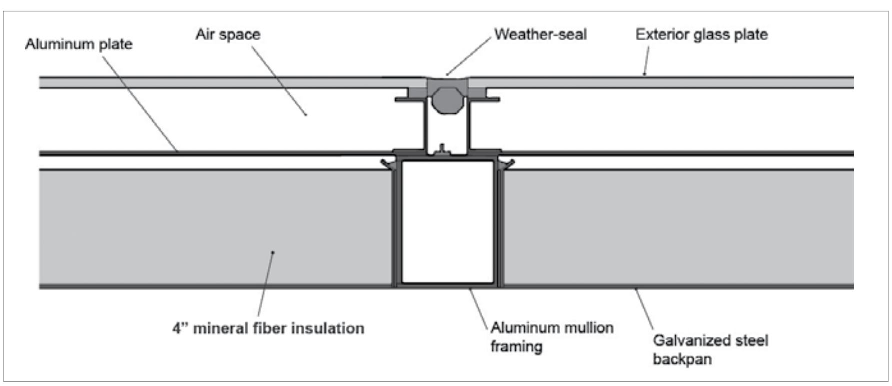
SPANDREL THERMAL PERFORMANCE

BY STEFAN ELSHOLTZ, B.APPL.SCI., DANNY HARVEY, PH.D. AND PAUL DOWSETT B.E.S., B.ARCH.,OAA. MRAIC

A high-performance sustainable building will require a high-performance thermal envelope – one that retains interior heat during the winter while minimizing unwanted heat gain during the summer.

The ease with which heat travels across an envelope element is represented by the element U-value, given in Watts per square meter of envelope area per degree of temperature difference between the inside and outside of the envelope (W/m^2K). As an example, a single-glazed window has a U-value of about 5 W/m^2K, while the now-standard double-glazed window with an argon gas fill and a low-e coating will have a U-value of about 1.5–2.0 W/m^2K, and the best triple-glazed windows have U-values of about 0.5 W/m^2K – meaning that they have 1/10 the heat loss of a single-glazed window. An R30 wall corresponds to a U-value of about 0.2 W/m^2K, while U-values in single-family houses that meet the Passive House standard in Canada will be in the 0.10–0.15 W/m^2K range (R40-R60).



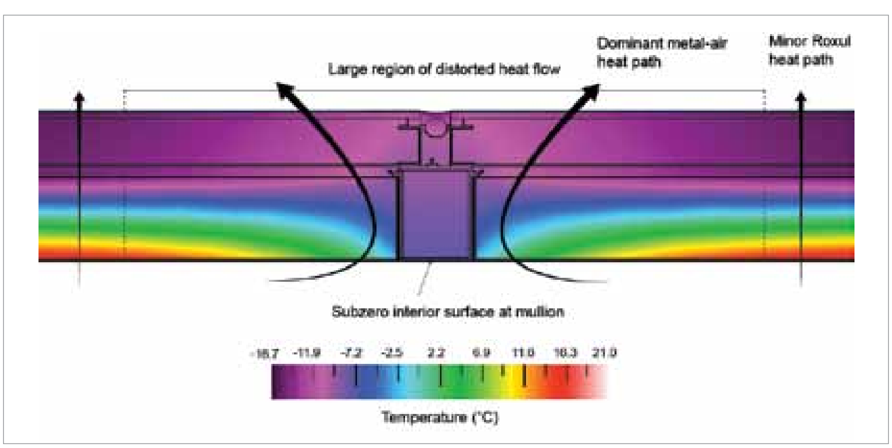


FIGURE. 1: Temperature variation and two-dimensional heat flow through a mullion within an insulated spandrel. IMAGES BY THE AUTHORS

Currently, walls in many commercial buildings consist of a glazed area (frequently accounting for 60 per cent or more of the façade) and an opaque spandrel panel. Traditional spandrel panels consist of an exterior cladding material (typically glass) and an interior layer, or "back-pan," that is made of steel or aluminum, with mineral fibre insulation between.

Most architects know that very narrow elements that cut through an insulating layer can conduct an amount of heat that is disproportionately larger than their cross-sectional area. These conductors need to be meticulously avoided in buildings that are meant to be high-performance. An example would be the 38-mm. span across standard 2 x 6 wood framing, or the less than 1-mm.-thick metal in steel stud framing. In framing systems and other features with complex geometry, the U-values of the various elements, even if averaged according to their percentage contribution to the area of the façade, are no longer reliable indicators of the overall heat loss. This is because the U-value concept assumes that the heat flow through adjacent elements moves, exactly perpendicular to the wall, without crossing laterally from one element to the next.

However, the winter coldness in a thermal bridge, such as a wood or metal stud or the mullion in a curtain wall, protrudes from the outside deep into the wall insulation, thereby drawing heat laterally into the stud and then to the outside. This is illustrated in Figure 1, which shows the temperature contours and direction of heat flow (from warm to cold) around a mullion thermal bridge.

Two-dimensional heat flow through geometrically complex building elements can be readily simulated using the THERM software program that is freely available from Lawrence Livermore National Laboratory. We used this software to calculate the effective U-value for various commercially-available spandrels (that is, a single U-value that, when multiplied by the total area of the spandrel and the indoor-to-outdoor temperature differences, gives the same heat loss as that simulated with the THERM software). The metal around the edges of a spandrel unit of course serves as a thermal bridge, increasing the effective spandrel U-value above that associated with the insulation within the spandrel. However, we found that the thermal bridge is significantly worsened by the presence of a metal backpan, such that the resulting effective U-value is almost as high as for a spandrel with no insulation at all! This is because heat is transmitted to the exterior along the backpan, and then through the thermal bridges at the edges of the spandrel unit, such that the backpan draws heat from the interior air along the entire surface area of the spandrel unit. This heat is then effectively transmitted to the outside through the narrow metal edges of the spandrel unit.

These effects are illustrated in Table 1, which gives the effective whole-spandrel U-values for cases with metal edges and a metal backpan, and metal edges with a non-conducting fibreglass backpan, as well as the average U-value obtained from a simple area-weighting of the one-dimensional spandrel and mullion U-values.[1] The effective (overall) U-value of the standard spandrel (including the mullion) is almost three times the area-weighted average of the spandrel and mullion U-values. A little over half of the increase is due to the lateral conduction of heat on the backpan that faces the interior of the building, as can be seen by comparison with the effective U-value for the hypothetical spandrel with a fiberglass backpan.

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TABLE 1. Overall U-values for the spandrel and vision-glass portions of a curtain wall consisting of 10 per cent mullion area and 90 per cent spandrel or vision-glass area, and simple area-weighting of the 1-D spandrel and mullion or vision-glass and mullion U-values.

	Standard non-thermally-broken mullions	Improved mullions with minimal thermal breaks
Spandrel portion of curtain wall		
Standard steel backpan	2.25 W/m^{2}K	1.80 W/m^{2}K
Fibreglass backpan	1.40 W/m^{2}K	1.08 W/m^{2}K
Simple area weighting	0.84 W/m^{2}K	0.81 W/m^{2}K
Vision-glass portion of curtain wall		
Effective U-value	1.75 W/m^{2}K	1.22 W/m^{2}K
Simple area weighting	1.35 W/m^{2}K	1.20 W/m^{2}K

The discrepancy between the effective overall U-value and the area-weighted average U-value is much greater for the spandrel than for the vision glass. As a result, the effective U-value for the standard backpan is substantially greater than the effective U-value of the vision glass (1.75 W/m^{2}K, including the effect of its mullion), even though the area-weighted spandrel U-value is less than the area-weighted vision glass U-value.[2] Use of a thermally-broken mullion modestly improves the effective spandrel U-value (from 2.25 to 1.80 W/m^{2}K), while use of a hypothetical fibreglass backpan would improve the spandrel U-value to 1.08 W/m^{2}K. However, this last value is still not impressive.

There are two solutions to this poor performance: (1) opt for a punched window construction within a well-insulated, thermal bridge-free building envelope, or (2) insulate on the inside surface of the backpan (in place of insulation on the outside surface of the backpan, which – as the analysis here shows – does little good), in either case sufficient to bring the overall wall U-value down to the value of about 0.3 W/m^{2}K that is now required for non-residential buildings under the Ontario Building Code.[3]

The key conclusions drawn from this analysis are (1) the performance of curtain-wall components (vision glass, spandrel, mullions) normally used in Canada is not good; (2) counter-intuitively and surprisingly, lower performance can be associated with common building envelope details; and (3) it is important to develop in-house expertise in the use of THERM or similar two-dimensional heat transfer modelling software, so that the performance of proposed building envelope details can be tested and modified as necessary.

NOTES

1. These 1-D U-values are as follows: centre-of-spandrel, 0.36 W/m^{2}K; spandrel mullions, 5.11 W/m^{2}K if not thermally-broken and 4.84 W/m^{2}K if thermally broken.
2. The 1-D U-values in this case are: vision glass, 1.05 W/m^{2}K; vision glass mullions, 4.05 W/m^{2}K if not thermally-broken and 2.53 W/m^{2}K if thermally broken
3. See *Supplementary Standard SB-10 Chapter 2*, Tables SB5.5-5 to SB5.5-7, available at http://www.mah.gov.on.ca/AssetFactory.aspx?did=8827

Stefan Elsholtz *is a Master of Architecture student at MIT. He holds a Bachelor of Applied Science in Engineering Science from the University of Toronto, with a major in Energy Systems.*