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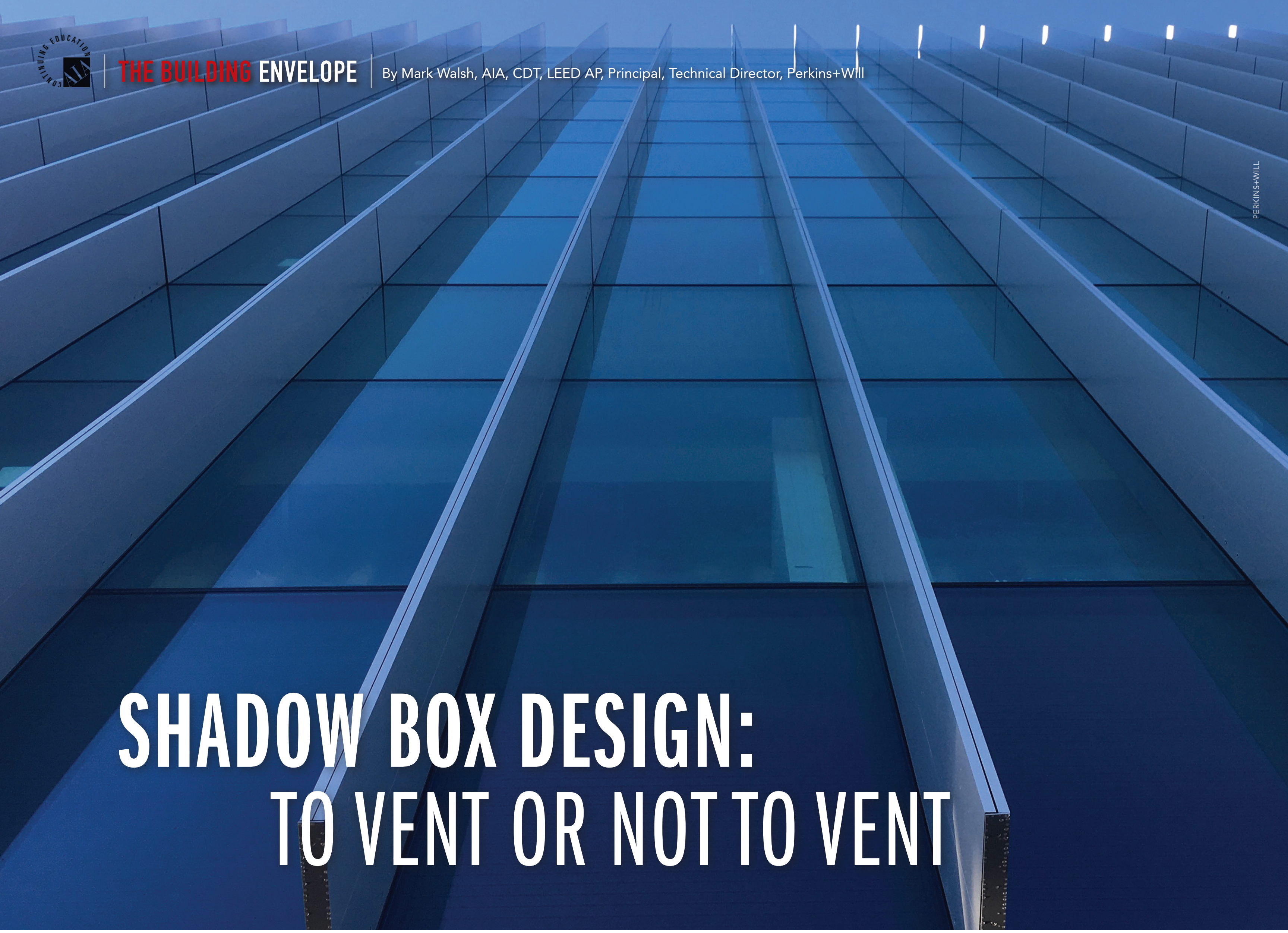


PERKINS+WILL

SHADOW BOX DESIGN: TO VENT OR NOT TO VENT

A curtain wall shadow box is a spandrel assembly consisting of vision glass at the building exterior and an opaque infill at the interior side of the curtain wall system. Shadow boxes are generally used for one of two aesthetic reasons: to maintain the visual continuity of a curtain wall system as it crosses from vision glass to spandrel areas; or to give the spandrels the quality of having visual depth.

Shadow boxes are often preferred over opaque-fritted spandrel glass because they use the same glass as adjacent vision areas and render the opaque areas of the curtain wall nearly indistinguishable from the vision areas.

SHADOW BOX FAILURE

In 2017, we conducted a comprehensive review of literature related to the design of shadow boxes, including their failure and subsequent remediation. For a summary of the literature review and salient points, go to BDCnetwork.com/SBappendix.

The literature review revealed four categories of shadow box failure:

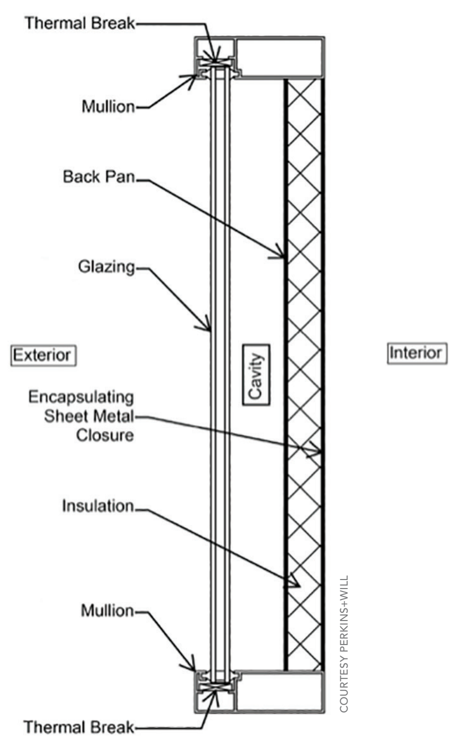
- Condensation in the shadow box cavity
- Dust and debris infiltration into the shadow box cavity
- Thermal transfer (either excessively hot or cold) from the shadow box cavity to the interior surfaces of surrounding curtain wall mullions
- Structural failure of the exterior glass or shadow box back pan.

Condensation can form inside a shadow box cavity when moisture-laden air in the cavity is cooled to the dew point. In cold and temperate climates, winter interior building air is typically warmer and has a higher relative humidity than outside air, so infiltration of interior building air into the cavity can become a source of shadow box condensation. In warmer climates, daytime outdoor air that is introduced into the shadow box can be a source of condensation when temperatures drop at nighttime.

Condensation itself is aesthetically objectionable but tends to be transient and dissipates. It can, however, have long-term consequences that affect shadow box performance and appearance. The condensation can leave visible deposits on the interior surfaces of the shadow box cavity that cannot be easily cleaned. Additionally, the condensation can deposit solvents or particulates from finishes, adhesives, or sealants that can deteriorate other finishes and seals inside the cavity.

Since the exterior glass of a shadow box is vision glass, the presence of dust or debris in the cavity is aesthetically undesirable. Shadow box cavities are generally inaccessible after they are installed, so dust or debris that gets inside the cavity is difficult and costly to clean or remove.

FIGURE 1
MODES OF SHADOW BOX FAILURE



Components of a typical shadow box

Dust and debris can enter the shadow box cavity during assembly of the units, while they are stockpiled on site, during installation of the curtain wall or by way of cavity vents after the shadow box has been installed.

The shadow box cavity is typically located to the interior of the curtain wall mullion thermal break and, therefore, allows thermal conductivity between the cavity and the interior surfaces of curtain wall mullions at the perimeter of the shadow box. If the shadow box cavity is excessively hot, it can heat the interior surface of adjacent mullions to temperatures that can be painful or scalding in extreme conditions. If the shadow box cavity is excessively cold, surfaces of adjacent mullions that are exposed to the building interior can be cooled below the dew point, causing uncontrolled condensation inside the building.

Excessively high or low pressure inside a sealed shadow box cavity, due to very hot or cold (respectively) air trapped inside the cavity, can deform the shadow box back pan, damage seals, or break the exterior glass.

The primary means to combat these failures is some form of cavity ventilation, or a complete and deliberate lack thereof. Shadow boxes can be: vented directly to the exterior; vented indirectly to the exterior by way of the mullion cavities; vented to the building interior; or sealed.

VENTILATION STRATEGIES

Ventilation directly to the exterior. Shadow box cavity ventilation directly to the exterior is commonly done by leaving gaps in the glazing gaskets of the vision glass and putting porous baffles in the resulting openings. Typical practice is to provide vents in the vertical mullions near the top of the shadow box unit and in the horizontal mullion at the bottom (figure 2). This arrangement prevents the direct infiltration of liquid water (rain) and insects through the vents and promotes a convective flow of air through the cavity.

There are several potential benefits of venting the cavity directly to the exterior. The direct connection equalizes the pressure between the cavity and the exterior environment, preventing pressure buildup inside the cavity. The introduc-

LEARNING OBJECTIVES

After reading this article, you should be able to:

- **+ DESCRIBE the primary applications for shadow box assemblies in curtain wall systems.**
- **+ DISCUSS the most common reasons why shadow box assemblies fail.**
- **+ IDENTIFY the primary ventilation strategies for curtain wall shadow box assemblies.**
- **+ UNDERSTAND the pros and cons of different ventilation strategies for curtain wall shadow box assemblies.**

FIGURE 2
VENTILATION STRATEGIES

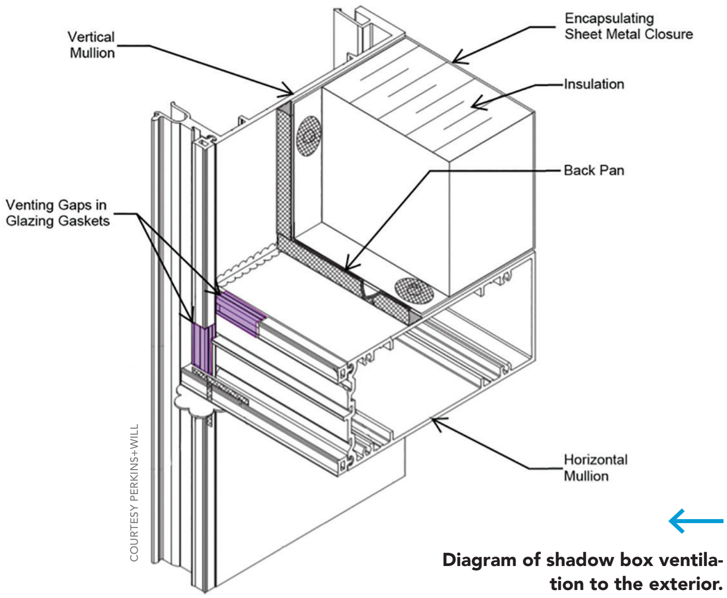


Diagram of shadow box ventilation to the exterior.

tion of unconditioned exterior air also discourages condensation inside the cavity as long as the flow of air through the cavity is sufficient to ensure that the air inside the cavity has similar temperature and relative humidity to the exterior environment.[1] In the event that condensation does form inside the cavity, the convective flow of air promotes drying and dissipation of the condensation.

There are, however, potential drawbacks to direct ventilation to the exterior. In temperate or cold climates, the introduction of very cold exterior air into the cavity can cool the mullions at the perimeter of the shadow box to a point where uncontrolled condensation can form on mullion surfaces inside the building and result in water damage to adjacent materials.[2] Exterior air that enters the cavity can also carry particulates that can collect on the inner surfaces of the shadow box. This is of particular concern in sandy or heavily polluted environments.[3]

Finally, it is very likely that intermittent condensation will occur in any climate that experiences moderate-to-large temperature swings in a short period of time, as with the passing of a cold front or at nightfall. This condensation is likely to dissipate in relatively short order, but is aesthetically objectionable in the meantime and can leave deposits on the cavity surfaces that can accumulate over time.

Ventilation to the mullion cavities, indirect to the exterior. Ventilation to the mullion cavities is done by providing baffled holes in the vertical mullions bounding the shadow box. In most curtain wall systems, the mullion cavities are used as a weeping system and have holes to the exterior to drain any water that gets inboard of the primary water seal. The weep holes provide a connection between the exterior environment and the mullion cavity, and since the shadow boxes are ventilated into the mullion cavity, they have an indirect connection to the exterior.

Indirect ventilation provides pressure relief for—and airflow through—the shadow box cavity without a direct connection to the exterior that can introduce very cold air or dust and debris. A small amount of dust may make its way through the mullion cavities and to the shadow box, but the baffled vent holes prevent the vast majority of that dust from entering the cavity. The mullion cavity is typically on the interior side of the curtain wall thermal break, so it will be tempered by the interior environment. The shadow box ventilation air has to pass through this moderately tempered zone and is, thus, brought closer to the interior building temperature before it is introduced into the shadow box cavity. This tempering mitigates the likelihood that the cavity, and the surrounding mullions will become excessively hot or cold.

There are no significant drawbacks to this approach, but there two important limitations. First, this approach is impractical in stick-built curtain wall systems due to the difficulty of ensuring complete separation of the interior mullion cavities from the interior building environment. Joinery and assembly of stick-built systems introduce a multitude of potential paths for infiltration of interior building air into the mullion cavity through splices, screw holes, or other openings in the mullion walls. This necessitates the use of a unitized curtain wall system, which has its own issues.

Second, many unitized curtain wall systems have a water and air barrier at the outboard split mullion joint that is near, or in line with, the plane of the glass (figure 3). This barrier prevents the mullion cavity from having a direct connection to the exterior. There is, however, an inboard split mullion connection, which, if not sealed, would provide a direct connection between the mullion cavity and the interior building environment.

There are also potential paths for interior air infiltration at the intersections of horizontal and vertical mullions and at stack joints or sills. It is possible to seal these during shop fabrication, but care must be taken by the designer in specifying these requirements and by the manufacturer in the subsequent fabrication. In the absence of a complete seal between the mullion cavities and the building interior, ventilation into the mullion cavity would provide an environmental connection between the shadow box and the interior building environment, which is not desirable (see below).

Ventilation to the building interior is usually accomplished by leaving gaps between the shadow box back pan/insulation/closure assembly and the adjacent mullions (figure 4).

There are serious risks in ventilating the shadow box cavity to the building interior, especially in cold or moderate climates. First, the shadow box cavity and its interior surfaces tend to be colder than the interior building environment in the winter. When warm, moisture-laden air from the building interior is allowed into a cooler shadow box cavity, the risk of condensation is very high. Since the relative humidity of the interior building air will be fairly stable, dissipation of the condensation through introduction of interior building air will likely be slow. Also, the interior building environment is likely to have significant particulate matter in the air that can get into the shadow box cavity and leave aesthetically unappealing deposits.

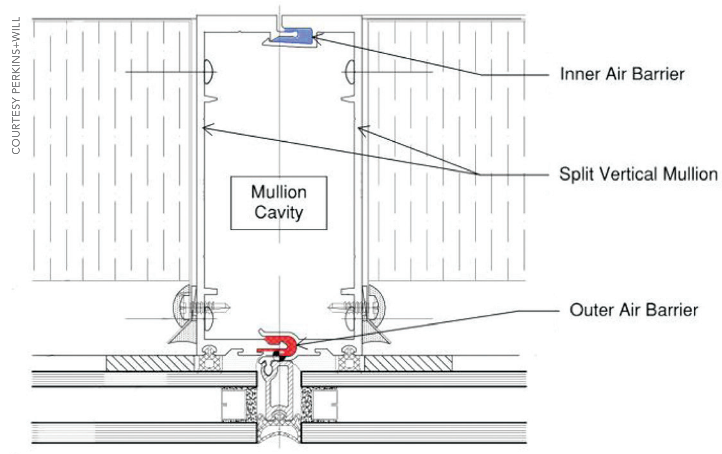
The only real benefit of ventilation to the building interior is that it offers pressure relief for the shadow box cavity.

Sealed cavity. The final ventilation strategy is not to provide any ventilation at all. In this case, the shadow box cavity is completely sealed from both the interior building environment and the exterior.

The lack of any airflow into or out of the cavity can lead to elevated temperatures and pressures, especially on hot days and at times where there is direct sunlight on the shadow box. Excessive heat can degrade sealants and finishes inside the shadow box cavity to the point where they fail.

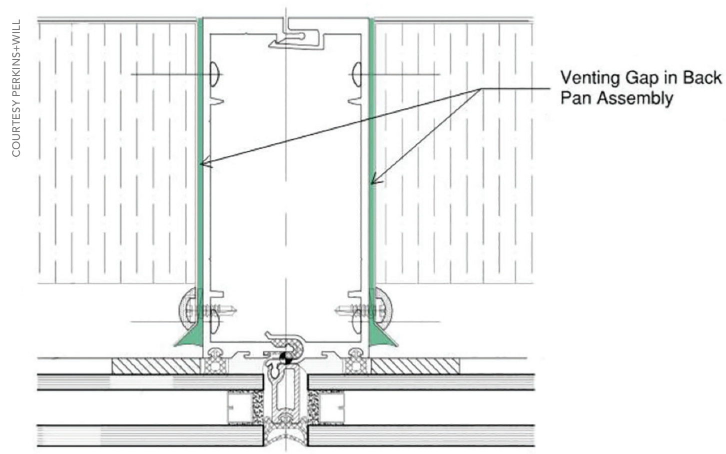
FIGURE 3

VENTILATION TO THE BUILDING INTERIOR



Unitized curtain wall split mullion showing the air barriers required for ventilation to the mullion cavity.

FIGURE 4



Shadow box ventilation to the building interior.

If a sealed cavity is the chosen solution, the designer must ensure that all finishes, sealants, and other materials in or adjacent to the shadow box cavity are stable at high temperatures. In similar fashion to the direct ventilation to the exterior, extreme temperatures inside the shadow box cavity can transfer to the mullions bounding the shadow box and result in interior mullion surfaces that are hot, or even scalding, to the touch.

There is some evidence that heat buildup in the cavity can induce elevated pressure inside the shadow box. The pressure can build to a point where an annealed (rather than heat-strengthened or tempered) glass light can break. There is little evidence of this mode of failure in completed buildings, however, the party responsible for engineering the curtain wall system should calculate potential pressure buildup (based on design criteria) and verify that both the vision glass and the shadow box back pan can withstand anticipated pressures without failure.[1]

The other major risk of sealing the cavity is that dust, debris, or very humid air is trapped inside during the fabrication process. If dust or debris is trapped inside, there is no way to remove it other than disassembling the shadow box (usually from the building exterior). If very humid air is trapped inside the cavity, it can condense during cool weather or at nighttime after installation, leaving condensation and the resultant debris on the inside surfaces of the shadow box. This risk can be mitigated by specifying that the cavity be protected from the infiltration of dust, debris, and moisture throughout fabrication, delivery, and installation. Please note that protection from dust, debris, and liquid moisture infiltration is readily achievable with established quality assurance and quality control processes, but the control of humidity requires careful climate control at the fabrication facility that may be difficult for some manufacturers to achieve. This should be taken into account in the selection of acceptable manufacturers.

RECOMMENDATIONS

Having considered the benefits and drawbacks of the ventilation strategies identified above, it is this author's primary recommendation that shadow box cavities be ventilated indirectly to the exterior through the mullion cavities. This recommendation does come with the caveat that the curtain wall must be a unitized system and that careful specification and fabrication ensure a complete seal between the mullion cavities and the interior building environment, and that the shadow box cavity be protected from infiltration of dust, debris, and moisture throughout its fabrication, delivery, and installation.

If a unitized system is not feasible, or if the chosen unitized system does not allow a complete seal between the mullion cavities and the building interior, the alternative recommendation is to specify a completely sealed shadow box cavity.

When specifying a sealed shadow box cavity, it is critical that all materials inside the cavity are suitable for high-temperature applications. It is also recommended that the shadow box glass be tempered or heat strengthened and that the specifications require the curtain wall contractor to determine the highest anticipated temperature inside the cavity and verify the ability of the glass and the back pan to withstand the resultant pressure. Finally, if the shadow box can be anticipated to receive direct sunlight, some consideration should be given to the possibility that the interior surfaces of the bounding mullions can get hot to the touch. It is recommended that the mullions adjacent to the shadow box not be in highly trafficked areas or in locations where they can be touched by children or others who are heat-sensitive.+

FOOTNOTES

[1] Michno, Michel (Enclos). "Analysis and Design of Spandrel and Shadowbox Panels in Unitized Curtain Walls." Glass Performance Days 2009 [2] Apogee Advanced Glazing Group. "A.A.G.G. 'Shadow Box' Design Guidelines." Technical Bulletin 505 (May 23, 2005) [3] Kragh, Mikkel, Stanley Yee and Larry Carbary (Dow Corning Corporation), and Neil McClellan (HOK). "Performance of Shadow Boxes in Curtain Wall Assemblies." CTBUH 2014 Shanghai Conference Proceedings

For the full appendix: BDCnetwork.com/SBappendix