Unlike traditional gutters that hang from the edge of a building to collect water, internal gutters (also known as built-in gutters and box gutters) are hidden from view, typically behind a parapet or an ornamental cornice, or they form the valley between two sloped roof assemblies. Internal gutters are generally connected to a drain body and an internal downspout, similar to a drainage system for flat roofs (Figure 1).

Because internal gutter systems are often located directly above occupied spaces, careful and specific considerations for material selection and detailing can lead to the successful use of these gutters on a project. Similarly, proper installation and appropriate maintenance programs can also impact performance and overall function. These parameters will be discussed in greater detail below, and relevant case studies will be presented. Guidelines in the Sheet Metal and Air Conditioning Contractors’ National Association’s Architectural Sheet Metal Manual, 7th Edition, 2012 (SMACNA Manual), as well as on the Copper Development Association’s website, copper.org, are also discussed.

**GUTTER MATERIAL SELECTION**

Corrosion resistance is a typical driver of material selection for the gutter system. The most common materials utilized are stainless steel, copper, aluminum, and coated steel, each of which can have varying benefits. Stainless steel and copper are the predominant materials used in the industry and also offer minimal maintenance needs when installed correctly. Aluminum and coated steel can be prone to adhesion and coating issues and are, therefore, more limited in use.

**GUTTER SIZING AND SHAPE**

The size and shape of a gutter can also impact performance. For example, in canopy installations, wide, shallow gutters are sometimes incorporated in the design. However, a wide, shallow gutter may not have the cross-sectional area to handle the volume of water that can cascade off the sloped roof. This may cause the water level to rise to a height in the gutter that results in unintended stresses placed on the sealant joints between the gutter and the canopy material.

To avoid these types of concerns, SMACNA states that the quantity of water that the gutter is expected to handle is based upon the roof area, slope, and rainfall intensity. This information will provide the basis for determining the minimum size of the gutter that is capable of handling the expected rainfall. This also includes a minimum depth and width, which can be determined in Chapter 1 of the SMACNA Manual.

**DOWNSPOUT SIZING**

Along with gutter sizing, downspouts should also be sized to accommodate the expected rainfall. SMACNA indicates that a downspout should remain constant in diameter from the gutter to the outlet. Therefore,
any accessories or additions to the system—such as drain covers or heat-trace lines that may reduce this cross-sectional area of the drain bodies and downspouts—should be accommodated with a proportional increase in the flow area or avoided to prevent blockage or gutter overflow.

**DOWNSPOUT LOCATION**

For many internal gutter systems, downspouts extend through occupied space or trafficked outdoor space. With this configuration, potential leakage associated with the downspout may warrant additional measures for the backup and access systems. Effective access to the downspouts is also a worthwhile consideration to permit the extraction of items that may cause a backup, fix leaks, or perform other maintenance items. Therefore, a discussion among the project team members should be considered so that maintenance strategies can be understood.

**DRAIN LEADERS**

The drain leader is the component that transitions from the gutter to the downspout. Since this feature will likely come into contact with the downspout, material selection for avoidance of galvanic action should be a consideration. Incorporating sealants at transition joints between materials may also present maintenance concerns due to their long-term propensity for failure and the difficulty in replacement. Drain covers are often incorporated to assist in the prevention of a downspout clogging, but drainage capacity should be considered. Covers with holes that are too small may clog quickly and cause a backup within the gutter.

**GUTTER SPLICES**

Watertight gutter splices are paramount to overall performance for internal gutters. Depending on the material used, there are multiple choices for how to deal with splices. Lapping, riveting, and soldering where the rivets are staggered every 3 in. along the transverse joints is the preferred option noted by SMACNA\(^3\) and copper.org.\(^4\) Where this is not possible, some guidelines for copper also allow for locking and soldering the metal splices. The third, most robust option is to lock, rivet, and solder the joint. Special attention should be given to the solder joints, as they become the barrier system to water leakage within the building.

Lapping the gutters and bedding in sealant is not recommended by SMACNA nor copper.org. Water running and possibly
ponding over the joints, coupled with small movements in the gutter, can degrade the bed joint quickly and cause leaks. Damage through these joints can happen over occupied spaces and not be noticed until damage occurs to interior finishes. Top-coating the joints with an elastomeric material can cause faster degradation than the industry-recommended approaches and requires more maintenance.

**GUTTER EXPANSION JOINTS**

Gutter expansion joints provide movement capabilities for the gutter. SMACNA recommends the installation of expansion joints within a gutter every 50 ft. maximum. Expansion joints should be placed between each downspout leader, as a leader will lock the gutter into place. SMACNA also provides recommendations for how to design and install a successful expansion joint, which typically includes a metal cap that allows movement. The thermal coefficient of expansion of the gutter material is a consideration when determining how much movement should be accounted for in an expansion joint, as well as the amount of movement at the ends of each gutter.

**GUTTER-TO-ROOFING INTERFACE**

The transition from the gutter to the roofing or canopy is also an important consideration for a watertight system. As gutter expansion joints were mentioned previously, it is also important to consider that the entire length of the gutter be able to move separately from the surrounding construction. In a sloped roof application behind a parapet wall, SMACNA recommends installing a continuous cleat on each side of the gutter. Consideration can also be given to waterproofing the cleats, as they could be exposed to water from gutter flooding and overflow. SMACNA indicates that peel-and-stick membrane over this transition should be a consideration.

When the roofing material is glass and metal construction, such as in a canopy application, one common approach for a designer to consider is to provide a sealant joint at transitions. One consideration for sizing the sealant joint is verifying that it is capable of accommodating the required shear movement of the gutter relative to the glass. If it is assumed that the gutter will fill up completely, this sealant joint will temporarily see a flood of water reaching it; therefore, the sealant joint must retain a proper profile and remain continuous through this area to provide ongoing protection from water. The sealant may also become submerged in water, which is another consideration to take into account during material selection.

**MAINTENANCE CONCERNS**

Gutter functionality is also impacted by maintenance. Owners should consider a regular maintenance plan to keep the gutters clean and prevent water backup. Safe access to the gutter is also important to allow for the implementation of a maintenance plan.

**CASE STUDIES**

While guidance on gutter design is available, issues can also occur during installation. Following are two representative studies in which the internal gutter design and construction contributed to enclosure performance issues.

**Project A**

Project A involves a 100-year-old school building that had encountered leakage—allegedly associated with the roof perimeter. The original roof consisted of a sloped asphalt shingle roof that terminated into an asphalt shingle roof that terminated into scuppers that drain to a low-sloped roof. The original roof was designed and installed.

The design documents for the new roof specified the location of the eight downspouts and the shape of the gutter to be installed. However, the number of downspouts was found to be insufficient to meet industry standards for the roof area that they serviced. During the design of the new roof, only the existing downspout locations were used without adding additional downspouts. However, in order to help mitigate this insufficient drainage, the designer chose to utilize overflow roof scuppers that drain to a low-sloped roof.

The specifications indicated that copper was to be used as the new gutter material, and the seams were to be locked and soldered. No gutter expansion joints were included in the design, contrary to industry recommendations that state a maximum of 50 ft. between joints to prevent undue stress on the metal gutter system and the joints between each piece of metal.

After the new roof was installed, leaks persisted around the perimeter of the building. The building leadership requested that an on-site investigation and document review take place to determine the source of the leakage.

During the investigation, a plywood base was observed over the existing galvanized sheet metal gutter, and a layer of self-adhered membrane pitched toward the leader was installed on top of the plywood (Figure 2). A copper gutter was installed on top as the finish material. The gutter was noted to have buckled due to the lack of expansion joints, and the seams had split open—likely due to the omitted expansion joints. Further, the soldering was very thin and cracked (Figure 3) and not in accordance with design documents. The self-adhered membrane was also not tied into the downspouts.

![Figure 3 – Open solder joint in the bottom of the gutter.](image-url)
There was also some question as to whether the observed leakage was coming from the gutters or the parapet. To isolate this condition, all downspouts were plugged, and the gutter was filled with water to a minimum depth of 1 in. During this testing, each of the areas immediately surrounding the downspouts leaked (Figure 4). The cracked joints in the copper gutter were letting water through and onto the self-adhered membrane, which was pitched towards the downspout and allowed the water to leak in. The self-adhered membrane was not terminated in a way that would drain water into the downspout.

Had the correct number of expansion joints been installed and the joints in the gutter been installed correctly, the leaks likely would not have occurred. Further, while the insufficient number of downspouts was not evaluated during testing, the lack of downspouts likely would have contributed to issues during rain events. In order to collect any water that did make it through the gutter liner, the self-adhered membrane could have been tied into the drain body and provided a backup water management system. Also, while adding the overflow scupper may have relieved some of the burden on the gutter system, it is recommended to design and install the minimum number of downspouts where possible.

Project B

Project B was a metal-and-glass canopy structure that covered the platform level of a metropolitan transit hub. It was fabricated with laminated glass panels that were supported by steel arms installed at 4 ft. on center and pitched to the center of the canopy. An inlaid, stainless steel gutter was installed at the base of the two glass-covered sides to collect water. Drainage was accomplished by incorporating circular drain leaders and downspouts that were located approximately 24 ft. on center.
The gutters were pitched to provide drainage to the downspouts, and the drain leaders within the gutter assembly were partially infilled with heat-trace wiring. The gutters were also notched to fit beneath each steel arm. Splices were installed adjacent to each notch in the gutter.

A review of the design documents revealed that the designer intended for the gutters to be lapped and sealed, which would not meet industry standards. The expansion joints were shown to be flat and lapped with no sealant. Downspout leaders were reviewed and determined to be undersized for expected rainfall intensity. The shape of the gutter at high points also did not meet the recommended minimum depth.

Stainless steel is also a material that works well as a gutter liner; however, it needs to be detailed properly. Following completion of the construction of Project B, the canopy leaked during several different rain events (Figure 5). An investigation took place to determine the cause of the leaks. Initially, when documents were reviewed, it was determined that the installed drain leaders were at capacity, assuming they had no blockages. Upon completing site observations, a flat strainer that was installed over each drain leader blocked portions of the drain body. Two heat trace lines with stainless steel strap backing were also installed into the drain. With the flat strainer, the stainless-steel straps, and the heat trace installed, the drain body and leaders were undersized for the canopy in all locations. This caused the backup of the drain leader and caused the gutter to fill (Figure 6). The owner also had not implemented a maintenance program to ensure the drain body did not clog.

The excess water in the gutter caused backup of the system, overwhelming lap seams and eventually resulting in leaks. Gutters were designed only to be lapped and sealed into place. Additional rivets or soldering of seams were neither designed nor installed. Any imperfections of the sealant allowed water to move beneath the gutter liner, where no backup system had been installed. Water was able to enter onto the platform level of the transit hub, as well as through the columns of the canopy and onto the mezzanine level of the station. After the station was opened, the contractor tried to remediate the situation by applying...
an elastomeric sealant over the splice joints, but it did not account for any movement, which led to the elastomeric sealant splitting.

The expansion joints installed in the gutter aligned with the expansion joints in the structure of the building. These expansion joints were installed a much greater distance apart than the recommended spacing. This, again, placed undue stress on the splice joints in the gutter. Along with the improper spacing, the expansion joints were poorly installed and designed. The design called for flat, lapped joints that bent along the shape of the gutter. This was not possible to construct, and the contractor installed upturned legs on either side of the joint. When the glazing contractor installed the glass portion of the canopy, they cut out the upturned leg, which caused leaks at each joint.

The arms that hold up the glass extend over the top of the notched gutter. As the overworked gutters fill up with water, these areas are expected to stop water from entering the canopy system, which was not originally intended. The underside of the glass was not sealed to prevent water backup that feeds beneath the gutter liner. The portion of the gutter that is notched is sealed using a skyward-facing bed seal. These issues combine to cause leakage on the platform and mezzanine levels (Figure 7).

Repairs to mitigate these issues would include providing a sealant joint on the top of the gutter liner that is capable of being temporarily submerged in water. New drain leaders with larger openings would be needed that allow more water to pass through, and expansion joints would be installed in accordance with industry standards. All of these items would likely help, but riveted and soldered gutter splice joints and/or a liner spliced in accordance with industry standards would also prevent future leakage.

CONCLUSION

Careful consideration must be given to all portions of a building in order to mitigate water infiltration. Internal gutters are no exception and can cause extensive water damage due to the nature of a gutter system that holds water over occupied spaces. Poor design and installation of internal gutters can cause issues that prevent the building enclosure from performing as intended. Repairs to create a successful system may be costly and cause long scheduling delays. Following industry standards and good construction practices, in addition to appropriate considerations for as-built conditions, can help prevent future issues with internal gutters and how they impact and integrate into the building enclosure performance.

REFERENCES

2. Ibid.
3. Ibid., p. 1.10
5. SMACNA, p. 1.10
6. Ibid., p. 1.23
7. Ibid., p. 1.52
8. Ibid., p. 1.55

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