BUILDING ENVELOPE TECHNOLOGY SYMPOSIUM

Common Installation Problems for Aluminum-Framed Curtain Wall Systems

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ABSTRACT

Aluminum-framed curtain wall systems are one of the most common building cladding systems. As industry professionals, contractors, and manufacturers, we understand the importance of the proper selection and design of the building s cladding systems. Even if the proper system is specified and designed, however, many aluminum-framed curtain wall systems still experience water infiltration issues and other failures due to problems during construction.

This paper focuses on common problems with the assembly and installation of aluminum-framed curtain wall systems and provisions to avoid these issues. Considerations for both unitized and stick-framed curtain wall systems will be discussed. First, common installation problems that result in improper water management for these systems and other performance failures will be reviewed, including improper support or opening conditions, adjacent cladding flashing conditions, field modification to the curtain wall systems, damage from installation and other trades, etc. Next, the paper will focus on provisions that professionals should consider during the design process to ensure proper system installation to achieve the desired performance. These considerations include field and/or laboratory mock-ups, preconstruction testing, field-testing, and monitoring of the system installation. Finally, the key elements to observe during each phase of curtain wall installation will be discussed.

SPEAKER

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Throughout her career, AMY PEEVEY has performed consulting services related to the investigation, evaluation, repair, and construction of structural, architectural, and material-related building problems. Ms. Peevey specializes in failure investigation, evaluation, and repair design; new design; peer review; commissioning; field testing; and construction observation of building envelope systems. She utilizes her extensive knowledge of building envelope components to investigate and remediate building envelope failures and to develop new integrated building envelope designs. She is an active member of several professional societies and has published in an ASTM International (ASTM) special technical publication on inspection of natural stone façades.

Common Installation Problems for Aluminum-Framed Curtain Wall Systems

Aluminum-framed curtain wall systems are an effective means of providing a lightweight, versatile, and self-supporting cladding system for today s high performance buildings. There are many types of systems and methods of construction available to suit each project and building s needs. Systems range from barrier systems that have no redundancy for incidental water, to water-managed systems that collect and evacuate incidental water, to pressure-equalized systems that prevent water infiltration by balancing the pressure within the system across the glazing plane. There are also a variety of glazing methods and elements that can be glazed within a curtain wall. In addition, system construction can vary from stick-framed, where all the individual components are fully assembled in the field; to unitized, where the system is preassembled into units and then the units are erected in the field; to hybrid systems (aka “knocked down), where a portion of the system is prefabricated and then fully assembled in the field.

All of these options make curtain wall systems versatile. But it is important that the options are carefully evaluated and appropriate systems are selected and designed to meet a project s requirements. Even when an appropriate system is selected and designed, it must be properly installed to ensure its performance. While the glazing types, methods, and construction sequencing may vary for each type of curtain wall system, they all have similar fabrication and installation issues that commonly result in performance failures. Following is a discussion of the common problems with the assembly and installation of aluminum-framed curtain wall systems and provisions to avoid these issues during the design and construction phases.

COMMON INSTALLATION PROBLEMS

There are many issues within and outside of a curtain wall installer s control that impact installation. Tolerance issues with the supporting structure, improper construction sequencing, and damage from other trades are common noninstaller-related issues that can result in failure of the curtain wall system. However, installers lack of understanding of curtain wall design can also cause performance failure. More commonly, the installers poor construction practices are the cause of failures.

Installation issues often result in modifications to the curtain wall system, adjacent systems, or the integration between systems. Modifications to the curtain wall can result in systems with a lack of relevant performance testing or successful performance history to ensure that they will meet specified requirements. If not properly addressed, these deviations from the original design can result in performance failures.

Construction “Intolerance”

Often, an installer does not have control over field conditions that impact the installation of the curtain wall system. These issues range from construction tolerances of related building systems, construction sequencing, and the impact from work of other trades.

Curtain wall systems have strict tolerance requirements in order to ensure their performance. However, the supporting structure and many adjacent systems have much larger tolerances. Even if adjacent larger or out-of-tolerance systems are modified to accommodate the curtain wall system, there are often undesirable results such as schedule delays or modifications to the original design. However, if the adjacent system s tolerance issues are not addressed, the curtain wall s supporting and surrounding conditions may not be acceptable or result in system failures. Problems resulting from construction tolerance issues include lack of adequate edge distances for the curtain wall framing or

Figure 2 – Concrete distress at mullion-head connection due to lack of adequate edge distance.

Figure 1 – Dead-load anchors placed less than 1 inch from the interior face of the mullion.

Figure 3 – Excessive shimming at unitized-system starter sill to accommodate concrete tolerances.

Figure 4 – Improvised wind clip at corner mullion to compensate for out-of-tolerance steel erection.

supporting structure (*Figures 1* and *2*), overshimming of connections (*Figure 3*), and impromptu “nonengineered structural connections (*Figure 4*).

These problems can result in structural failures of the curtain wall system. Additionally, tolerance issues may result in inadequate perimeter conditions for proper waterproofing at the curtain wall opening. For example, when concrete is out of tolerance, the jagged/irregular bush-hammered substrates that result from concrete demolition do not provide an adequate joint sealant substrate for a weathertight seal.

In addition to tolerance issues, the existing structure may not be installed or may be missing components for proper support of the curtain wall system. Missing or misaligned embeds (*Figure 5*) or support framing often require modifications to the original design so that the curtain wall can be properly supported.

Another noninstaller-related issue is construction sequencing. The building envelope components must be installed so that the systems are properly sequenced. Proper weather laps and alignment must be provided to ensure that each system performs independently and is also coordinated with adjacent systems for a continuous, integrated building envelope. Flashings are to be sequenced so that they are weather-lapped and integrated with drainage components. Sill pans, perimeter waterproofing, and other drainage components related to the curtain wall often must be in place prior to installation of the curtain wall systems to ensure that they are properly incorporated into the building envelope. If the components of the curtain wall and adjacent cladding systems are not properly sequenced, then the systems may fail to perform properly. A common result is the obstruction of drainage for the curtain wall and perimeter flashing systems.

Finally, damage from other trades can result in issues with curtain wall system performance. Other trades may improperly store materials on or against the curtain wall, modify it to remediate constructability issues with the installation of their own systems, or unknowingly obstruct the drainage components of the curtain wall system. In many instances, the result is aesthetic damage that can be repaired in place; however, contractor damage may also impact the structural, drainage, and other performance-related characteristics of the curtain wall system.

One common problem is the installation of the perimeter joint sealant to the snap cap of the curtain wall (*Figure 6*). Within a curtain wall system, ele-

Figure 5 – Misaligned embeds at corner condition preventing anchorage of intermediate wind clip.

Figure 6 – Perimeter curtain wall sealant installed from adjacent cladding to snap cap of system.

ments exterior of the glazing plane are within what is defined as the “wet zone, where drainage of the system occurs. In addition, the drainage of the curtain wall often ultimately evacuates at the snap cap. Therefore, installing joint sealants to the snap caps not only traps water within the system by obstructing the weeps but may also force the water within the drainage track back into the building at the curtain wall perimeter.

Figure 7A – Excessive sealant placed at the sill-to-mullion joinery.

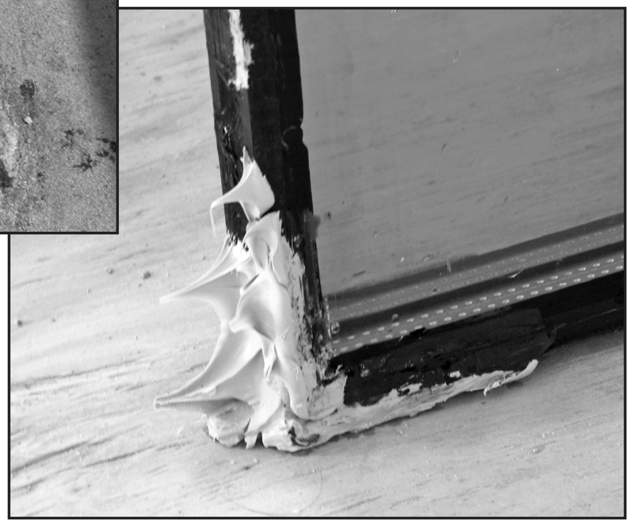

Figure 7B– View of insulated glass-unit corner after deglazing condition shown in Figure 7A.

“More Is Better” and Other “Improvements”

While there are issues with curtain wall installation that are outside the installer s control, a majority of the issues are caused by the installer during assembly of the curtain wall. Many installer problems are the result of good intention but lack of knowledge of curtain wall design. For instance, even when installers believe they are following the curtain wall manufacturer s installation instructions, they sometimes do so without understanding the repercussions of intentional “improvements. For instance, the often incorrect theory of “more is better leads to problems with curtain wall drainage (*Figures 7A* and *7B*). When excessive sealant is used within the curtain wall system, it often obstructs proper migration of water entering the system to the drainage track provided at the base of each lite where water is collected and evacuated from the curtain wall system. As a result, the water is trapped and typically infiltrates to the building interior. Another common more-is-better issue is the increase in the size, number, or frequency of the weep holes within a system. The addition of larger or additional weep holes modifies the curtain wall system from the testing that certified that the system could meet the specified performance requirements. Often, the result is that the larger or additional openings allow excessive water to infiltrate the system when the system is subjected to the negative pressures and increased rainfall commonly experienced during significant weather events. This additional water exceeds that which the system was designed to manage. As a result, water builds up within the system and infiltrates to the building interior.

Another installer issue is the substitution of materials. Utilizing nonsilicone-compatible components at structural silicone glazing (*Figure 8*) or installing ferrous fasteners at exposed locations are examples of substitutions that result in curtain wall performance issues. These can lead to staining, corrosion, or premature failure of system components.

Some installer-related erection problems are due to the inherent difficulties related to specific curtain wall systems. As an example, the units of unitized systems are large and heavy. As a result, the units can be damaged during transport and installation (*Figure 9*). In addition, they often have small tolerances to ensure proper integration of the gaskets and components so that the system can properly perform. These tight tolerance requirements can result in inadequate engagement of the gaskets between the curtain wall units

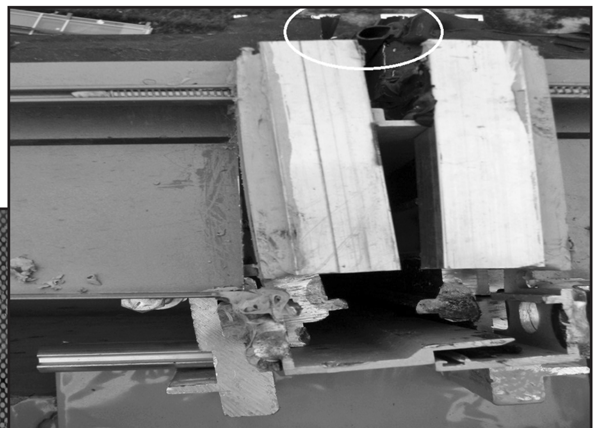

Figure 9 – Excessive vertical joint width (note lack of gasket compression) and significant damage to the curtain wall at parapet.

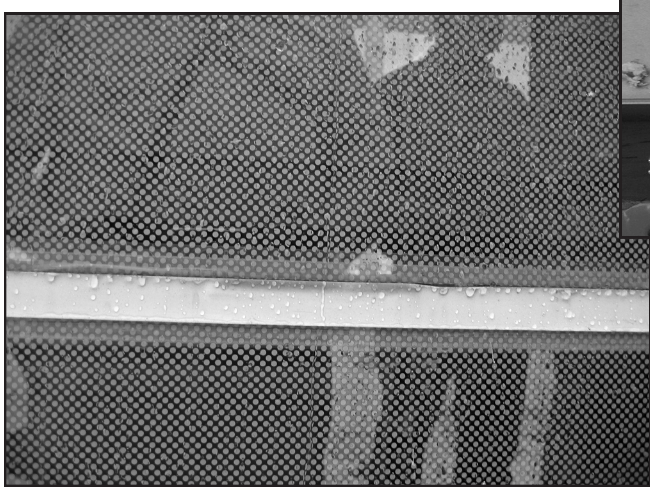

Figure 8 – Stain at incompatible setting block at a structural silicone-glazed curtain wall condition.

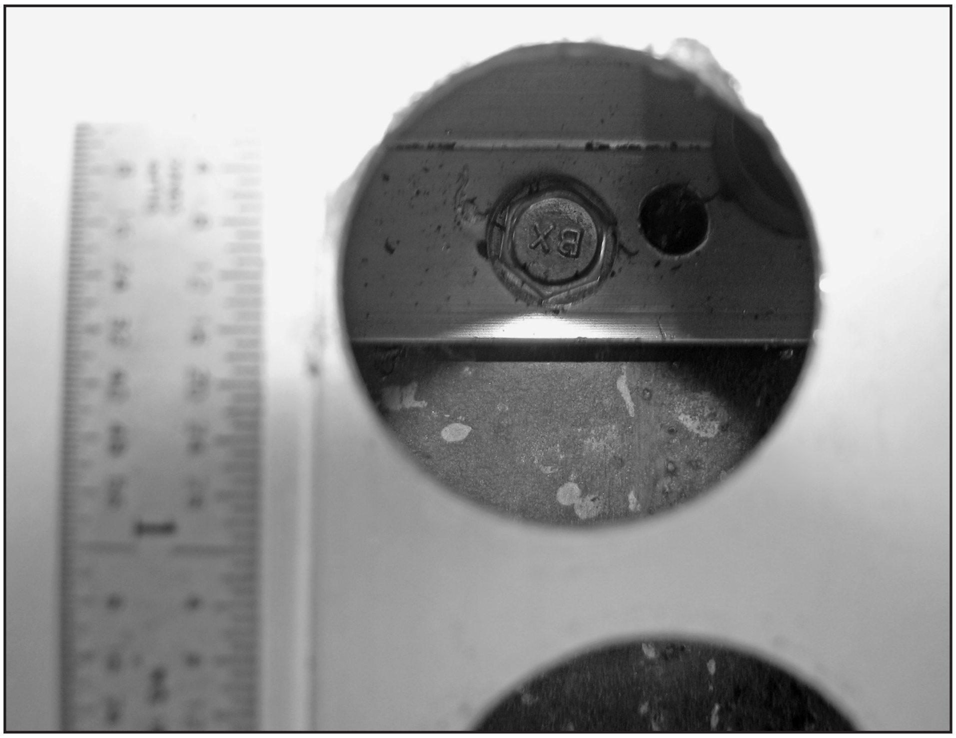

Figure 10 – Sill fastener at T clip within a bolt diameter of an abandoned fastener hole.

(*Figure 9*). As a result, water and air infiltration to the building interior can occur at the out-of-tolerance joints between unitized units.

That's How We've Been Doing It for the Past Twenty Years

Curtain wall systems are constantly evolving to meet the increasing performance demands of the market. Even systems that have been available for some time have been modified to improve their performance or overcome installation issues that have become apparent over the life of the system. In addition, different systems have special considerations and critical elements that must be properly executed to ensure the system s performance. Furthermore, there are additional measures that need to be performed for incorporation of different system options such as partial prefabrication, rotating systems so that the mullions span horizontally, or structural silicone glazing. However, it seems that many installers approach curtain wall construction with a "one size fits all approach, often missing elements unique or critical to a specific curtain wall system s construction. The results are poor construction practices that are widespread throughout the curtain wall industry.

Poor construction practices are a common installer-related issue that results in curtain wall failures. The focus of this section is to concentrate on a few select common issues that apply to a majority of curtain wall systems. These include improper framing support conditions, system modifications, and improper installation of sealants and glazing.

Improper Support Conditions

The curtain wall system is often modified from the original design to accommodate issues within or outside of the installer s control. As previously discussed, in some cases, connections are modified to overcome tolerance issues that, if left unaccounted for, result in potential structural issues for the curtain wall system (overshimming, improper edge distances, etc.). However, in many cases, the connections are modified by the installer for convenience or lack of knowledge, without understanding the ramifications. For example, often the mullion clips contain abandoned fastener holes (*Figure 10*) due to fastener conflict with reinforcement, realignment of the system, etc. An abandoned hole essentially creates a new "edge. Therefore, the edge distance requirements that apply to the anchor from the edge of the clip also apply to the anchor from an abandoned hole. In lieu of replacing a clip or setting the anchor an adequate distance from the abandoned hole locations, the modified clips are often left in place, resulting in inadequate support conditions.

Other support condition issues are purely the result of installer carelessness. For example, structural connections are to be provided to building structural elements with only proper, noncompressible shims provided at these connections. However, if sequencing is not properly coordinated, installers may carelessly install framing to nonstructural conditions such as gypsum sheathing (*Figure 11*). As another example, wind clip anchors provide vertically slotted holes to allow for movement of the system or

Figure 11 – Curtain wall mullion F bracket installed on gypsum sheathing at sill.

supporting structure due to thermal or structural loading. To allow for movement in each direction, the wind clip anchors are to be set centered within the slotted hole. However, in many cases this requirement is simply ignored (*Figure 12*). As a result, the system may bind during loading and result in structural issues, potentially resulting in glass breakage.

System Modifications

As previously discussed, installers sometimes modify the curtain wall system to "improve its performance. Additional sealant may be added to improve the ability to keep out water, or the weeps may be enlarged or additional weeps added to supposedly improve drainage capabilities. However, in many cases, installer carelessness is the cause of curtain wall system modifications that result in performance issues.

Often, for stick-framed or hybrid systems, the curtain wall elements are shipped to the installer in stock lengths. The installer then cuts the lengths to fit the project needs and punches weep holes accordingly. Without proper field measurements, cutting of curtain wall elements and punching of weeps can result in improper lengths or improperly located weeps, which impacts the system s performance. Pressure bars cut too short require additional sealant to compensate at the end conditions. This additional sealant may not be sufficient to maintain the watertight integrity of the system. Furthermore, it will most likely not be properly reinstalled during future reglazing. As a result, voids in the metal-to-metal joinery result within the sealant bridge between them, and water infiltration to the building interior occurs. Weeps improperly punched at the wrong height, profile, or size result in improper drainage of the curtain wall system. For example, if weeps are punched higher than the base of the drainage track, then standing water will result within the system, which can cause premature insulated glass unit failures.

Another common modification to curtain walls is at the glass-setting blocks. Often the setting block lengths, placement, and profile do not meet the curtain wall or glass manufacturer s requirements. The setting block length and placement are critical to the structural performance of the glass and the curtain wall system. When the length or placement is modified, the glass can be overstressed, or the curtain wall deflection can exceed the requirements. In addition, setting-block profiles should allow for drainage at the sill track. If setting blocks are installed upside down, set in a full bed of sealant, or an improper profile is used, then drainage within the sill track can be obstructed and result in water infiltration to the building interior. Another installer-related installation issue is the use of shims at setting blocks (*Figure 13*). Placement of shims between the setting block and the glass can result in stress concentrations in the glass and cause glass failure.

Figure 12 – Two adjacent wind clips, one with anchor at top of the slotted hole and one at base.

Figure 13 – Placement of shim above setting block.

Figure 14 – Improperly tooled sealant at metal-to-metal joinery resulting in a large void.

Figure 15 – Untooled sealant at an intermediate horizontal, blocking the drainage flow at mullion.

Improper Installation of Sealants and Glazing

One of the most common of poor construction practices for curtain wall installers is the improper application of sealants. The installation of sealant at metal-to-metal joinery or within the curtain walls interior drainage components is critical to ensuring its water management performance. However, these joinery sealants are often untooled or poorly tooled, allowing for voids or pinholes within the seal (*Figure 14*). In addition, the sealants are improperly tooled so that they block the flow of water within the system s drainage track (*Figure 15*). In the worst case, they are omitted all together. Even a pinhole-sized void within these seals will allow for water infiltration to the building interior.

A critical element of curtain wall systems is to limit the amount of incidental water infiltrating into the drainage track and then quickly evacuate it. To limit the amount of water infiltration, the perimeter gaskets should be properly placed and sealed. It is common practice to oversize the length of the gaskets so that once they shrink following installation, voids at the corners or between joints of the gaskets do not result. However, in many cases, the gaskets are cut to fit in lieu of being slightly oversized and/or not properly sealed at the corner joints. Water infiltrating past the gaskets should be permitted to drain quickly to the exterior. However, as previously discussed, excessive sealant at the internal joinery sealants, setting blocks, or gasket corners can obstruct the flow of water within the system, resulting in water infiltration.

Another common glazing issue is the omission of edge blocks. Edge blocks properly center the glass within the opening and prevent the glass from “walking within the frame. Uncentered glazing can come in contact with the frame, and glazing failures can result. In addition, inadequate “bite of the glass with the frame results, which can allow excessive water and air to enter the system, as well as excessive deflection of the glazing units, which may result in failure.

DESIGN PROVISIONS

While installation problems cannot be completely avoided, there are measures that a designer can put in place to help prevent and identify issues prior to and during the installation process. These measures are to be considered during the design phase and incorporated into the work. Design considerations include providing a design that can meet the actual field issues, providing for quality assurance and subsequent quality control, and taking measures to ensure proper coordination of the different components.

Constructability

While there are many design requirements that should be considered, this section focuses on a few common issues that are relevant specifically to curtain wall installation. If these elements are considered during the design, they can assist with avoiding or minimizing potential curtain wall installation issues.

First, while designers have little control over the construction, they can include provisions to help overcome common installation issues. Earlier, the tolerances between the curtain wall and structure or adjacent cladding systems were discussed. While minimizing the joints between and within cladding systems is often a goal of architects, it can further complicate the tolerance issues for a project. The tighter the joint, the more potential for issues with constructability and performance. Therefore, to assist with construction tolerance issues, the joint sealants–especially those around the curtain walls–should be one-half inch in width or greater. This will yield additional tolerance so that the joint sealants can be installed to the sealant manufacturer minimum width of one-quarter inch, helping ensure proper performance.

Another design consideration is when to use sill pans. Usually, curtain wall systems have their own means of managing and evacuating water. Typically, this is achieved at each lite. Therefore, a sill pan at the base of a curtain wall does not assist with the system s overall water management. Furthermore, a curtain wall sill pan often only results in complicating a design, as it introduces yet another element of the building envelope that must be properly integrated and constructed to achieve a weathertight condition. Another drawback of a curtain wall sill pan is that most curtain wall systems are anchored at the head and sill. Therefore, the sill pan is often penetrated by the sill connection fasteners. Each of these fasteners presents potential points of water infiltration. Finally, sill pans create thermal bridges that conduct the thermal loads of the exterior directly to the building interior. Therefore, this thermal bridging should be considered when determining if sill pans will be provided. However, sill pans or sill flashing have their function. For instance, at the base of a curtain wall above a roofing system, a sill flashing is often necessary. Other conditions also warrant the use of a sill pan, such as at projecting porous sill elements or where the cladding system construction beneath a curtain wall varies. Therefore, in the overall building design, the need for sill pans should be carefully considered and, if necessary, properly designed for proper integration with the curtain wall and adjacent cladding and flashing systems.

Additionally, system selection should be considered from an installation standpoint. Unitized systems are often preferred to stick-built systems as their prefabrication helps ensure quality, and the units can be efficiently installed in the field, accelerating the installation time so that buildings can be dried in faster. However, a designer should understand the ramifications of selecting a unitized system versus a stick-framed system. Unitized systems have large lead times because a majority of their construction is prefabricated. Often, the units are fabricated prior to the building structure s being completed. This impacts the project significantly because there is little room for modifications, should something in the construction vary from the design or should the design itself change. In addition, the unitized design and assembly occurs many months prior to the selection and shop drawing development of the other cladding systems. Therefore, the construction drawings should be well developed and more specific to the actual system being utilized, if possible, for the perimeter curtain wall conditions. This is contrary to conventional practice because the architect typically illustrates the design intent within the drawings as the actual building envelope systems will not have been selected until after the design is finalized. However, the same is the case for the unitized curtain wall. The unitized shop drawings are developed far in advance of the selection of the adjacent systems. Because the system is prefabricated, there is little opportunity for modifications to be accommodated in the future to integrate the systems with the adjacent cladding systems. Therefore, there is a need for the integration to be clear and specific in the construction documents. In summary, a unitized system should only be selected when there is adequate time to allow for the design and preconstruction of the units and where few design modifications are anticipated.

Finally, curtain wall systems are often selected or accepted based on their ability to meet the design requirements once a system is installed in the field. However, the maintenance of a system or its postmaintenance performance is often not considered. In some cases, a system must be significantly modified in order to perform the simple act of glass replacement that will occur routinely throughout the life of a building. In addition, the requirements for glass replacement may lead to unforeseen future costs for the owner. Finally, in some cases for customized unitized curtain wall systems, the need for reglazing may not have been fully developed. Therefore, the designer should require that the reglaze procedure for the curtain wall be submitted for review when considering the selection of a curtain wall system. Furthermore, incorporating preconstruction or field laboratory testing of a reglazed specimen is prudent to ensure that this procedure can maintain the original nonmodified curtain wall performance.

Quality Assurance and Quality Control

Quality assurance and control measures are essential to verifying that a curtain wall system can meet its performance requirements. Initial quality assurance will ensure that the proper system is selected for the project, and quality control will ensure it is installed as required to maintain its intended performance. The following presents quality assurance and control measures that should be incorporated into the design to help limit or avoid common curtain wall installation problems.

As previously discussed, one of the critical components of all curtain wall systems is the sealant used for the internal joinery and perimeter joints. To ensure that the proper sealants and installation methods are utilized, preconstruction compatibility and adhesion testing should be performed. Specifying such testing for all substrate conditions and including any accessories in contact with the sealants will ensure the sealants performance. The testing should be performed by the joint sealant manufacturer, and a report that indicates the recommended joint sealant and substrate preparation requirements, including the use of primers, should be provided.

For projects where the curtain wall system varies significantly from the manufacturer s tested assembly (larger spans or lite sizes, modified corner glazing or support, etc.) or where the curtain wall system is unique or incorporates unique elements, preconstruction laboratory mock-up testing is recommended. This testing will help ensure that the modified curtain wall system can meet the specified requirements while also providing an opportunity to evaluate potential constructability issues. The preconstruction mock-up testing should incorporate as much of the true project conditions as is feasible but also be representative. In addition, the perimeter curtain wall flashing or sealing conditions should be incorporated where possible. To ensure the continuity of knowledge from the laboratory construction mock-up to the field, the mock-up construction should be supervised by the superintendent and foreman for the actual project. Finally, the most critical element is to ensure that any modifications made from the manufacturer s standard installation guidelines to the mock-up are to be documented and incorporated into the erection shop drawings for the project. Often, modifications made to the mock-up are not incorporated into the final project; therefore, the performance cannot be assured.

In order to determine if the field-assembled curtain wall can meet the performance requirements and maintain them throughout installation, field-testing should be performed throughout installation. Field-testing is especially important for projects where preconstruction mock-up or initial field installation mock-up testing has not been performed. The initial field-testing serves as validation that the manufacturer s tested assembly, which has been modified to meet the project s specific conditions, can meet the specified performance requirements. Follow-up testing will ensure that future installations maintain the standards required to achieve the anticipated performance. Typically, field-testing is performed on the initial mock-up or within the first 10% of the initial curtain wall installation. Thereafter, it is recommended that at least two to three additional tests be performed on the curtain wall throughout the remainder of construction. If failures occur during the testing, evaluations to determine the cause of the failures should be performed, and all remedial measures required to ensure successful performance should be incorporated into previous, existing, and future curtain wall installations.

Unitized systems are primarily constructed in a plant, and even some stick-framed systems allow for partial prefabrication. Designers should anticipate these prefabricated systems in their specifications by requiring plant visits by the general contractor and architect and/or building envelope consultant. Their purpose is to review the prefabrication of curtain wall units, quality control procedures, storage and transportation methods, etc. While the frequency of plant visits will depend on many factors, such as the plant location and duration of unit construction, a minimum of two plant visits is advised to review the unitized fabrication.

Among the most critical components in ensuring proper curtain wall installation are site observations by the architect, building envelope consultant, and/or a third-party testing agency. These site visits are conducted periodically throughout curtain wall installation to ensure that the curtain wall manufacturer s installation and additional installation requirements determined from preconstruction or field testing are maintained throughout the project. The designer should include provisions for these inspections within the project as necessary. These provisions include that the contractor inform the architect in advance when significant curtain wall milestones are to be achieved–such as initial framing and internal joinery seals, glazing, and perimeter flashing–to ensure that the proper representatives have the opportunity to observe these critical components of the curtain wall installation.

Coordination

The final area where a designer can help ensure proper curtain wall installation is through incorporating field coordination requirements into the design. Often, the curtain wall itself is not the single cause of performance failures. In many cases, it is the improper integration with the adjacent building envelope systems. Therefore, it is important to include provisions to ensure that the trades that integrate with each other s work are properly coordinated.

Prior to construction, it is important to ensure that each of the trades understands his or her role and the sequencing of the building envelope installations. One means of establishing this collaboration among the trades is to hold building envelope coordination meetings. The purpose of these meetings is for each of the trades involved with the integration of the curtain wall and other building envelope systems to review the installation sequencing, detailing, and requirements; identify potential conflicts or issues; and coordinate their installations and required testing. This meeting should be held on site and include the general contractor, architect, building envelope consultant, and the building envelope subcontractors.

Field mock-ups are another means of coordinating work among trades. These mock-ups are often critical to evaluating constructability and sequencing the work of the trades to ensure that the building envelope components are properly installed to achieve a fully integrated, weathertight enclosure. They are especially important where preconstruction laboratory mock-up testing has not been performed, as these field mock-ups now become the first opportunity to evaluate the installation prior to full-scale installation on the building. As such, the designer should include requirements for the construction and acceptance of field mock-ups prior to installation of the curtain wall and related systems. In addition, these mock-ups can be tested as quality assurance that the curtain wall assembly and surrounding flashing conditions meet the design intent.

KEY ELEMENTS DURING CURTAIN WALL INSTALLATION

Whether the system is stick-framed, unitized, or a hybrid, there are essentially three phases of curtain wall construction. These consist of framing (including internal joinery and seals), glazing, and system integration. The differences among the various methods of assembly are essentially whether they occur in the field or in the plant. Either way, they should be monitored to confirm that the installations meet the manufacturer s and project s performance requirements. In order to perform proper monitoring, the manufacturer s installation manual and project shop drawings should be referenced for the specific curtain wall system(s). Following is a summary of the elements that should be monitored by the installer, general contractor, and other parties.

Framing

As the curtain wall connections are being laid out and installed, the proper sequencing of the curtain wall and related components should be followed. Adjacent waterproofing and flashing elements must be in place prior to installation of head and sill framing connections. In addition, the jamb flashing conditions must be properly sequenced to ensure that the flashing components are installed and properly integrated prior to curtain wall framing installation.

Once framing is in underway, the construction tolerances between the curtain wall and adjacent systems will become evident. It should be verified that the requirements for edge distances, shim tolerances, and perimeter joint sealants are maintained and that the framing is installed plumb and true. Tolerance issues should be evaluated, and remedial measures should be engineered, recorded, and incorporated into the design.

Additionally, the curtain wall anchorage conditions should be reviewed. The type, number, and size of connection elements and anchors should be confirmed. The edge distances for connection to structural elements, as well as curtain wall framing and clips, should be maintained. Wind clip anchors should be centered within the slotted holes of the connection. Finally, the separation between dissimilar metals and aluminum and alkali materials should be verified.

Reinforcement is often required to supplement a curtain wall system at high loading zones such as building corners. If reinforcing is required for the project, the type, means of connection, and location of reinforcing installation should be confirmed to meet the requirements of the engineered shop drawings.

Once the framing is in place, the waterproofing of the drainage elements should be confirmed. Specifically, the installation of the joinery seals between metal elements and critical seals at the zone dams/plugs needs to be verified. These internal sealants should be properly tooled into place so that they have a uniform profile that does not block the flow of drainage and does not contain voids or anomalies.

Special Considerations for Unitized Systems

The above framing conditions would be a phase of unitized construction conducted in the installer s plant. Upon installation in the field, unitized systems have special considerations. Unitized systems often incorporate lifting lugs that allow for the units to be raised or lowered to accommodate construction tolerances. Once the unit height is determined, the units should be permanently set so that they cannot move or "walk following final installation.

The drainage for unitized systems occurs at the stack joint horizontal at each floor. The continuity of the drainage track within the stack joint is established in the field, most commonly with the installation of precured silicone sheets placed at the head between each unit. This seal between the units must be properly installed and made weathertight to ensure proper water management within the track. Prior to stacking the next floor of units, these seals should be allowed to fully cure and be carefully inspected to ensure they are continuous and do not contain voids or anomalies. Furthermore, the stack joints should be properly terminated at the perimeter of the curtain wall opening or when intersecting with adjacent systems. End dams should be installed and verified to be undamaged and properly sealed at each level prior to proceeding with stacking the next level of units. Once the next level of units is set, it is very difficult and sometimes very costly to repair the stack joint seals and end dams, so it is imperative they are performed properly.

Glazing

Prior to setting the glazed elements, it should be confirmed that the drainage track is free of debris, that the setting blocks are properly placed so that they do not obstruct drainage at the weeps, and that foam baffles are installed at the weeps if required by the manufacturer.

During glazing, it is critical to ensure that the glass elements do not come in contact with metal elements. Therefore, the setting block type, length, and placement; the use of edge blocks; and the gasket type, size, placement, and seals should all be verified. For pressure bar systems, the fastener placement from the vertical mullions, fastener frequency, and fastener torque should all be confirmed to ensure that the gaskets have adequate pressure against the glazed units.

For structural silicone glazing, the bite between the interior face of the glazed unit and the framing is critical for structural performance. Verify that the structural silicone glazing seals are uniform and continuous and that the minimum bite thicknesses are maintained throughout the assembly. In addition, it should be confirmed that the curtain wall accessories in contact with the structural silicone glazing are compatible to prevent deterioration or staining of the sealant.

Special Considerations for Unitized Systems

As with the framing, the glazing phase of unitized construction is performed in the installer s plant. As the units are set in the field, the interface between the units must be properly integrated to ensure the system s performance. The tolerances for the unitized system permit a small amount of variance in the vertical joint width between units to accommodate construction tolerances. This joint width must be properly maintained within the system s tolerance to ensure proper integration between each unit and proper gasket alignment. Therefore, the vertical joints should be carefully inspected along their height to ensure that the widths are within tolerance.

In addition, the horizontal stack joint width must be observed. The stack joint accommodates vertical expansion and contraction within the system or of the supporting structure. The width of the stack joint should be set to accommodate vertical movement without binding the units or disengagement of the framing receptors between the units. Therefore, the stack joint widths should be verified as the units are erected in the field. Finally, the gaskets at the vertical and horizontal joints should be inspected to confirm they are not damaged and are properly placed so that they are engaged with the joint substrates.

System Integration

The final phase of curtain wall installation is the integration with the adjacent cladding elements. The perimeter of the curtain wall is often integrated with the adjacent systems by means of flashings and sealants. If the adjacent cladding systems are cavity wall systems, then integration between the cavity weather barrier, as well as the exterior cladding materials, must be provided. The following indicates considerations for the various common methods of integration.

If sill pans are provided at the base of the curtain wall, then they should be installed and properly integrated with the curtain wall and adjacent cladding systems. The jamb flashing should be integrated with or overlap the sill pan end dams. A self-supporting upturned interior leg of a height that meets the water penetration pressure requirements should also be provided for the sill pan flashings. In general, it is recommended that sill pans be prewelded at the end dam to back leg corner conditions. The sill pan should be sloped to the exterior and include provisions for drainage. The sill pan splices should be coordinated so that they do not occur at the mullion connections, and all sill pan splices and penetrations should be thoroughly sealed between overlapping sheets. The exterior terminations of the sill pan are to be flashed in with the wall flashings or sealed to create a weathertight condition.

For a curtain wall flashed with membrane flashing, it should be verified that these flashings are weatherlapped in shingle fashion with the proper lap and end-splice widths. If construction sequencing results in seams that block the flow of water, then the seams are to be sealed with the membrane manufacturer s recommended sealant. Additionally, if required by the membrane manufacturer, a continuous substrate should be provided for the membrane flashing. In addition, the terminations should extend a minimum of two inches onto adjacent substrates at transitions in plane or as recommended by the membrane manufacturer. Mechanical termination of the membrane should be provided as recommended by the membrane manufacturer or if the membrane bridges moving joints. All voids, fishmouths, or wrinkles should be repaired in accordance with the membrane manufacturer s recommendations. The flashings should extend onto the curtain wall system, or compatible joint sealants should be provided from the membrane flashing to the curtain wall framing for a weathertight condition at the full perimeter.

Perimeter joint sealants are to be continuous and properly tooled to a uniform profile free of voids, holidays, or other anomalies. The joint substrates should be properly prepared to receive the joint sealant, including the use of recommended primers, if any. In addition, the sealant manufacturer s minimum joint width requirements of   in and the recommended hourglass profile and width-to-depth ratios should be maintained. The use of proper joint sealant backings should be verified to achieve the recommended profiles and prevent three-sided adhesion. Joint sealant placement should not interfere with or obstruct drainage of the curtain wall or adjacent cladding systems. If joint sealants are used to integrate the weather barrier of cavity wall systems with the curtain wall, as well as the cladding at the exterior face, then each joint should be properly sequenced to allow for each line of sealant to properly cure. Weeps should be provided as necessary for drainage at dual joint sealant or cavity drainage systems.

There are other systems that integrate with the curtain wall that should be verified. These include but are not limited to fire-safing and smoke seals. These seals should be provided as indicated in the drawings and verified to be continuous, properly engaged, and free from defects.

CONCLUSION

While there are seemingly endless installation issues that can cause curtain wall failures, professionals can help prevent or limit these issues by gaining a better understanding of their construction and performance. Once the function and assembly of a system are understood, consultants, designers, and specifiers increase their ability to identify potential issues and initiate the proper prevention measures. Through proper design, quality assurance, quality control measures, and coordination of the curtain wall and adjacent cladding systems, the installation and performance of a curtain wall system can be assured.