Fenestration Replacement: Identifying Design Solutions for Existing Buildings

By Scott Bondi, PhD, PE, LEED AP; Leonidia M. Garbis, PE, LEED Green Associate; and Michael Colella

This paper was presented at the 2023 IIBEC Building Enclosure Symposium.

WHEN FENESTRATION REACHES the end of its service life, and after attempts to patch and repair have been unsuccessful, replacement becomes necessary. Common indicators of failure include persistent air or water leakage, inadequate reduction of solar loads, condensation, occupant comfort complaints, and compromised functionality of operable units. Upgrading the units can enhance aesthetics, reduce air and water leakage, improve energy efficiency, and acoustics. Fenestration replacement may also lower building operation costs and upgrade expenses for other systems like mechanical equipment. Changes in interior programming are also ideal opportunities for considering window fenestration replacement.

Whatever the motivation for replacement, designers and owners must be prepared to tackle various challenges. These include ensuring proper support of the new fenestration within the existing wall assembly, meeting building codes and structural design requirements, and reconciling differences between past and present construction methods. The replacement design must also account for project-specific factors such as schedule limitations, the owner's performance criteria, and minimizing disruptions for occupants during construction.

BUILDING CODE AND STRUCTURAL CHALLENGES

Building owners have traditionally replaced aging fenestration in kind with new off-the-shelf systems, often without any consideration of engineering issues. However, current building codes have added complexity to fenestration unit replacement. For example, Chapter C503 of the 2021 *International Energy Conservation Code* (IECC)[1] mandates that all new building elements used in renovations must comply with the current code requirements. Local jurisdictions may impose stricter requirements than the model codes, further increasing the differences between existing and new fenestration. Specific aspects of building codes are discussed later in this article.

When planning the replacement of fenestration units, designers and building enclosure consultants should be aware of how contemporary construction methods and materials differ from the methods and materials used originally. For example, 50 to 100 years ago, mass masonry or transitional masonry were prevalent structural systems. Transitional masonry walls typically have less masonry with the addition of steel, which limits the mass to one or two wythes of masonry. Fenestration in older buildings was typically fabricated off site but glazed in place and windows were often installed using exterior scaffolding. In contrast, many newer buildings feature steel or concrete framing with engineered backup wall construction. If a brick masonry facade is used in a new building, the facade is typically a cavity wall. Windows in new buildings may be installed from the interior with limited exterior access.

To specify a suitable, cost-effective replacement system for a particular fenestration replacement project, the designer must determine whether design approaches for new buildings can be directly applied to the existing building or need to be modified to fit with the building's architecture, structural condition, or aesthetics. Also, as noted previously, project-specific considerations, such as occupancy during replacement, affect the ease of fenestration unit installation. Thorough investigation of the project conditions is therefore a critical step toward success.

INVESTIGATION CONSIDERATIONS

Identifying air drafts or water leaks within a fenestration unit is crucial to pinpoint issues with the fenestration or its interface with the adjacent wall assembly. Field investigations can be instrumental in determining the location and severity of such leakage. The methods used in such investigations can be classified as noninvasive or invasive procedures (**Fig. 1**).

ASTM E783[2] and ASTM E1105[3] present noninvasive methods that can be used to measure air and water leakage, respectively (Fig. 1A), without disturbing existing conditions. Techniques such as tracer fog (Fig. 1B) or pressurization can identify the source of leakage from either the fenestration unit itself or the adjacent wall assembly.

Invasive field investigations offer detailed insights into structural conditions surrounding fenestration units. Invasive investigations can also be essential to understand how the existing building was constructed (Fig. 1C and 1D). Many older buildings do not have the same level of construction documentation that is expected of a modern construction project.

Careful planning for invasive investigation, especially in areas without drawings, is necessary.

Figure 1. *Invasive and noninvasive investigative procedures. (A) Water testing; (B) Tracer fog air infiltration testing; (C) Invasive opening at masonry; (D) Invasive opening at steel framing.*

Probed areas may contain hazardous materials, and prior coordination of a safety plan before the investigation begins is highly recommended.

DESIGN CONSIDERATIONS

Various design options exist for remediating fenestration issues, with no universal solution suitable for all buildings. Each option has its own complexities and considerations, warranting thorough evaluation to match project requirements. Important variables for designers to consider include the severity of problems, the project budget, and the anticipated lifespan of repairs or replacements.

Repairs and Modifications

Although this article focuses primarily on fenestration replacement, it is important to note that localized fenestration repairs are adequate for minor or limited issues. For example, deteriorated gaskets or failed sealant joints between the fenestration and the surrounding wall can be remedied with simple solutions such as new sealant joints (**Fig. 2A**) or silicone sheet patches (Fig. 2B). However, these types of repairs cannot fully resolve broad performance concerns such as insulating value or acoustic transmission. They should typically be considered as short-term solutions, and ongoing maintenance may be required. To effectively address air or water leakage problems, any repair plan should be supported by a field investigation to identify the specific leakage path and maximize the chances of resolving the issue.

In certain cases, modifying existing fenestration can be a more practical option than complete replacement. Storm windows, whether installed externally or internally, may offer a viable solution for underperforming windows (Fig. 2C). They add an additional layer of glazing, improving thermal and acoustic performance without removing the existing system. This approach is suitable for buildings where removing the current system is inconvenient or impractical due to aesthetic requirements or the need to maintain occupancy during construction.

Figure 2. *Design options for remediating fenestration issues. (A) New sealant joints; (B) Silicone sheet patches; (C) Storm window installation; (D) Window replacement; (E) Overcladding with curtainwall system.*

However, adding storm windows introduces challenges that should be evaluated on a project-specific basis. The interstitial cavity created by storm windows can lead to condensation and increased maintenance costs due to additional glass surfaces requiring access and cleaning. Also, a storm window may not provide the same thermal performance as a high-performing replacement window, and proper integration of the storm window system with the surrounding wall system is crucial for achieving a balance of thermal and waterproofing performance.

Understanding and addressing potential leakage paths is highly recommended when considering storm windows. Neglecting this step may lead to unsatisfactory performance.

Replacement

Fenestration replacement provides an opportunity to start with a new, warranted system that can be properly integrated with the surrounding wall system (Fig. 2D). Improvements may include an effective air and water barrier, reduced air leakage, and enhanced thermal and acoustical performance. However, fenestration replacement brings its own challenges, such as the need to remove existing components and, especially for older buildings, the presence of unforeseen conditions that must be addressed during the project. Detailed project-specific planning and coordination are necessary to attain the desired performance outcomes.

Overcladding is an alternative to replacement that is often used in older high-rise office buildings with curtainwall systems (Fig. 2E). It provides an opportunity to renovate the building's appearance while simultaneously achieving performance improvements. The overcladding process, which typically necessitates a custom design approach, involves placing a facade system outboard of the existing facade system, possibly requiring new anchorage back to the primary structure. Vision areas, louver areas, and spandrel areas can be incorporated into the design. This approach is often used to minimize disruption inside the building by using the existing facade as a temporary weather barrier and means of occupant protection during construction. Existing attachments and framing members may need to be worked around during the process. The project team has an option to keep or remove the existing facade in the final configuration depending on how the system is designed. Overcladding may appeal to owners because it may allow for maintaining partial occupancy inside the building during the work—a crucial factor for the owner's revenue.

Code Requirements

As noted earlier, the need to meet building code requirements may be a considerable challenge in fenestration replacement projects. For example, to meet the IECC's thermal performance requirements, new fenestration units may need to be thicker and heavier than existing fenestration, and those differences can have implications for the design of the support systems. Similarly, windborne debris resistance may be mandated by codes and insurance companies. While thermal performance can often be estimated by computation, windborne debris requirements necessitate physical testing rather than relying exclusively on analysis.

Code requirements can also influence various components of the glazing system. For example, triple glazing may be needed for energy code compliance, or laminated glazing may be specified for acoustic and/or windborne debris performance. Additionally, evolving jurisdictional requirements, such as those related to bird-friendly glass, can restrict glass coating types, locations, and fabricators. The product options that meet specific requirements may be limited, especially when physical tests are necessary, and that limitation can affect installation techniques and project costs.

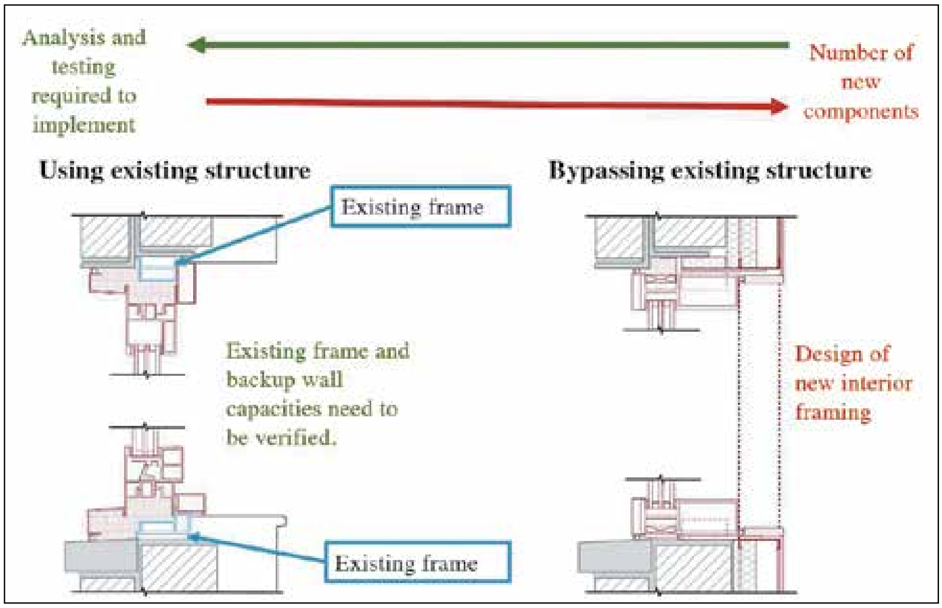

Figure 3. *Considerations when interfacing a replacement fenestration system with an existing building.*

System Integration into the Existing Building

One of the greatest challenges with a replacement fenestration system is how to best integrate it into the existing building (**Fig. 3**). Manufacturers' instructions and performance testing data are often available for fenestration systems. However, that information will not be specific to the particular project underway, so the designer will need to produce project-specific details to ensure the integration is effective.

A key design consideration is how to maintain a continuous air and weather barrier along the perimeter of the new fenestration unit. For many older buildings that rely on mass masonry, the existing masonry alone will not facilitate a continuous weather barrier.

The drainage system of both the fenestration unit and the adjacent wall assembly will dictate how to best waterproof the interface between the two systems. For example, if a new fenestration system has an internal drainage system, it is necessary to transition the waterproofing such that the drainage system is not blocked and can weep properly, while the rough opening in which the drainage system sits is fully waterproofed.

The characteristics of the surrounding wall system will considerably influence the placement of the waterproofing tie-in. Mass masonry walls may require full sill-pan flashing to catch any water that may bypass outer seals of the window-to-wall interface and drain that water to the exterior. In other cases, the replacement fenestration system is constructed of a stick-built curtainwall system and the waterproofing of the veneer cavity is directly tied into the glazing system.

Careful consideration is needed when selecting materials for waterproofing integration, with options, including sealant or sheet membrane.[4] In our opinion a membrane is typically more reliable; however, implementation requires thorough planning.

The interfaces between fenestration and the surrounding wall may need additional elements for proper integration. In traditional window replacement projects, receptors can be used to simplify interior installation. Receptors are framing pieces that shrink the window opening to facilitate installation. They can accommodate prefabrication, interior installation techniques, and construction tolerances. However, depending on their configuration, the use of receptors can complicate waterproofing integration. In some cases, window receptors are fastened into the sill of the rough opening, which may complicate a sill-pan-flashing approach that aims to avoid any piercings. Overcoming this challenge requires careful planning and creative detailing approaches.

Verifying performance is always important. Drawings may not accurately reflect the actual project challenges. It is highly recommended that project teams conduct preliminary preconstruction mockup installation and testing, as well as quality assurance testing. These tests should include air and water infiltration testing according to AAMA 501.1[5] and 501.2[6] standards. Preconstruction testing offers the advantage of a "dry run" so that the entire team can address challenges before the actual construction begins.

Coordination among all stakeholders is paramount in a fenestration replacement project.

The owner's schedule, budget, and occupancy-impact expectations will drive the design. The structural engineer evaluates primary and secondary structural members against the loads imposed by fenestration system attachments to the existing building. If the project includes interior refitment, the mechanical engineer assesses thermal performance requirements such as air infiltration, *U*-factors, and solar heat gain coefficients. The contractor implementing the design will also have input on appropriate installation methods and will inevitably discover during demolition that some existing conditions deviate from assumptions made during the planning stage. Successful outcomes depend on collaborative problem-solving by all team members.

CASE STUDIES

Senior Care Facility

Our first case study involves a senior care facility housed in a 1970s building with vertical modules of bay windows. The existing windows and surrounding metal panels were steel framed extending past the concrete building slabs. The exterior also had a textured cast-in-place concrete facade. The fenestration replacement project aimed to improve performance. The goal was to reuse the existing steel framing whenever possible.

The senior care facility needed to ensure occupant comfort and safety while remaining fully operational during construction. The project team's understanding of the installation process and its coordination with ownership and the contractor enabled a phased installation strategy (**Fig. 4**) to meet these requirements within an efficient timeline. The design process became iterative and collaborative, with the construction team influencing changes to perimeter detailing in certain areas.

The design team requested several invasive openings at the beginning of the design process to assess and verify the installed structural conditions, which varied. These openings facilitated calculations to determine the capacity of the steel framing members. To accommodate the inconsistent structural conditions of the existing building, new structural elements were added to create a uniform surface for window framing and waterproofing attachment.

For the opaque spandrel conditions of the building, the design solution involved installing new insulated metal panels with a continuous weather-resistive barrier over the existing metal cladding. Use of swing-stage access and this exterior installation method allowed the building to remain fully occupied during construction without the interior space being disturbed.

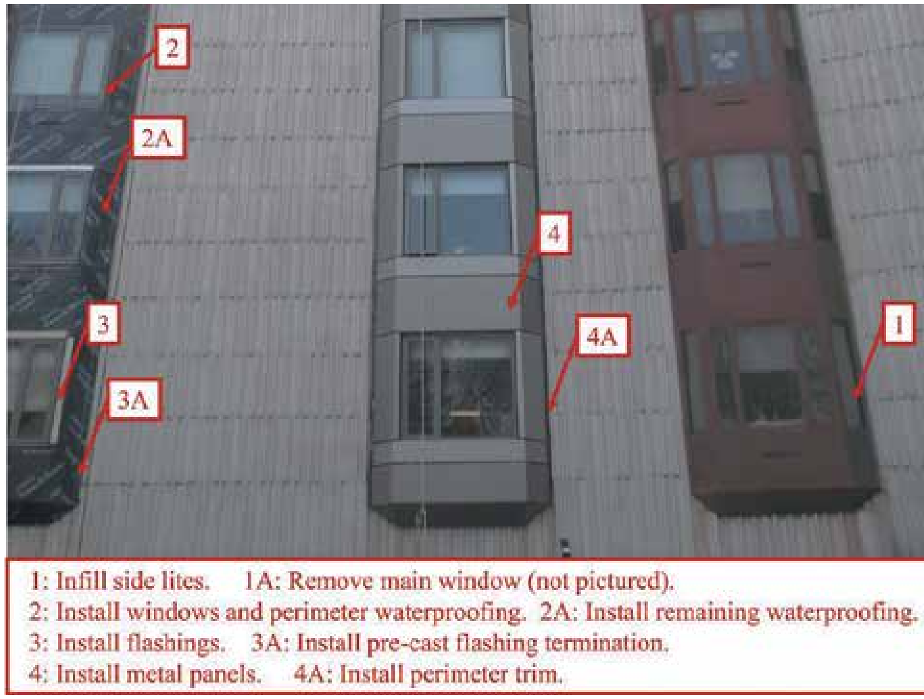

Figure 4. *Phased installation of a fenestration system at a senior care facility.*

Sheet-applied waterproofing membrane was used to create a water-resistant transition between the windows and the surrounding cast-in-place concrete facades. Precise removal of the textured concrete surface was necessary to create a flat surface for proper application and termination of the waterproofing membrane.

Unforeseen conditions in existing buildings often necessitate modifications to the project details. The design team collaborated with the contractor to create a guide for evaluating each window bay during the demolition phase. This guide helped identify and communicate conditions requiring design modifications. It included criteria such as maximum acceptable steel framing section loss, shimming heights, and minimum welding lengths. Preinstallation mock-ups were instrumental in verifying the viability of the drawn details and estimating the window replacement timeline. Successful project execution was facilitated by effective communication among the architect, contractor, and owner.

School Building

Our second case study is a 1950s school building with hung windows placed between expressed concrete fins. The spandrel areas beneath each window feature a concrete and brick masonry facade. After a thorough condition assessment and field investigation, which revealed multiple leaks and performance issues, the owner decided to replace the windows and rehabilitate the opaque exterior facades. This project involved recladding the brick and overcladding the concrete areas with an exterior insulation and finish system. The main challenge for the school was coordinating the active construction schedule within the limited time of a few months, aligned with the school calendar recesses.

Integrating replacement windows and spandrel cladding within existing concrete fins posed a design challenge. The exposed concrete fins relied on a barrier waterproofing approach.[4] To achieve the desired aesthetic, transition waterproofing had to be attached to the face of the concrete while remaining concealed. The window support design used an interior steel angle attachment to the concrete fins, allowing for waterproofing from the angle onto the concrete fin. Sheet-applied waterproofing was installed at the window jambs, concealed by the window frame, and sealed to the concrete with dual-stage sealant joints (**Fig. 5**). A metal sill-pan flashing system with end dams was used at the windowsill, and reglet-set into the concrete fins to drain any water that penetrated the initial sealant line. Between spandrel zones, new concrete masonry units were designed to support the new windows and brick exterior, while also receiving face waterproofing. This approach facilitated cavity wall construction for the reclad facade. The window's sill-pan flashing accommodated the offset between the window and the new brick masonry.

CONCLUSION

Fenestration replacement in existing buildings is a complex task requiring careful consideration and coordination. With an in-depth understanding of existing conditions, appropriate selection of replacement windows, and meticulous planning and execution, it is possible to significantly enhance the performance of the building, while minimizing disruption to the occupants and improving their comfort. The lessons learned from the projects described herein offer valuable insights for future fenestration replacement projects, contributing to the ongoing evolution of best practices in the field.

Figure 5. *Perimeter waterproofing detailing. (1) Install perimeter waterproofing flashing membrane; (2) Lap sill waterproofing flashing membrane onto cavity wall waterproofing membrane; (3) Form sill pan flashing with fully soldered upturned end dams; (4) Lap jamb waterproofing flashing membrane into sill pan flashing; (5) Install termination bar along the edge of the wall waterproofing membrane.*

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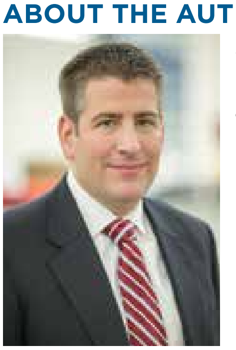
ABOUT THE AUTHORS

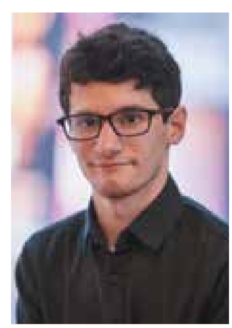


SCOTT BONDI, PHD, PE, LEED AP

Scott Bondi, *PhD, PE, LEED AP, is a principal at Simpson Gumpertz & Heger. He has extensive experience in building enclosure design and specializes in building science and numerical analysis. Bondi consults on both new construction and historic renovation projects, from conceptual design through construction administration, applying his specific expertise in curtainwall and custom glazing systems. In addition, he is experienced in providing forensic engineering services and expert witness support for both building enclosure and mechanical systems. Bondi is also an adjunct professor at Cooper Union, where he has lectured and developed courses in mechanical engineering since 2007.*

LEONIDIA M. GARBIS, PE, LEED GREEN ASSOCIATE

Leonidia M. Garbis, *PE, LEED Green Associate, is a senior project manager specializing in building enclosures at Simpson Gumpertz & Heger. With 10 years of experience, she designs and evaluates new and existing building enclosures, focusing on custom curtainwall assemblies from design through construction administration. Her portfolio includes commercial, high-rise residential, and infrastructure projects. She is also skilled in enclosure forensic engineering, including curtainwall and custom glazing system investigations. Garbis has extensive knowledge of facade, roofing, and waterproofing systems. She actively participates in the Commercial Real Estate Women Network and the Association of Medical Facility Professionals, demonstrating her commitment to professional engagement.*



MICHAEL COLELLA

Michael Colella *is a project consultant at Simpson Gumpertz & Heger and has four years of experience in the Building Technology Group. He specializes in design of new construction projects from conceptual design through construction administration. Colella uses advanced computer simulation tools, including computational fluid dynamics and finite element analysis, to support his design work. He has experience with several types of facade and roofing systems.*

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