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UNIVERSAL ACCESS for All

Ensuring Inclusivity in the Built Environment

By Kay Penn

Photo courtesy iStock

More than six million Canadians live with a disability.[1] In everyday life, they may have fewer options when accessing transportation services, communicating with others, or interacting with aspects of the built environment. Incorporating the principles of accessibility helps ensure people with disabilities can have the same experience as any other person, whether in a public venue or at home. Removing barriers and enabling universal access can create a safe and comfortable place for everybody.

Accessibility is generally recognized as an important element of architectural design practice.[2] Over the past two decades, municipalities, provinces, and territories across the country developed various policies, guidelines, and codes aiming to improve accessibility of public buildings and spaces, as well as dwellings. While there is still a lot of work to do, things like automatic doors, ramps, wider corridors to accommodate wheeled mobility devices, and universal washrooms are now common. CSA Group standards can assist stakeholders seeking to support accessibility efforts and help people with disabilities participate in their communities and live to their full potential.

Accessibility and inclusivity of the built environment

The first edition of the CSA Group standard CSA B651 was published under the title, *Barrier-free Design*, in 1990 (now published as CSA/ASC B651, *Accessible Design for the Built Environment*) and brought requirements that may seem basic today but were dramatic at the time. Installing ramps at the main entrances, widening doors, adding contrasting nosings to stairs, handrail extensions, or expanding washroom stalls were just a few features that helped improve overall access to public and private spaces for people with disabilities.

CSA B651 impacts not only how buildings are designed and built but also how various products are manufactured, so they can be used inside accessible buildings. Since its first edition, the standard has evolved significantly. For example, later updates aimed to provide better guidance on elements serving the spatial requirements of people with hearing, vision, or other communication disabilities.

New requirements and recommendations for buildings

Many requirements of the CSA B651 standard resulted from consultations with people living with disabilities, their perspectives, and experiences. These were also the case in the development of the 2023 edition of the standard, CSA/ASC B651:23. With the participation of people with disabilities and collaboration with the Accessibility Standards Canada (ASC), volunteer members of the CSA Group Technical Committee on Accessibility developed and updated numerous technical requirements and recommendations to make buildings and the exterior built environment accessible and safe for those with physical, sensory, or cognitive disabilities. CSA/ASC B651:23 supports universal design principles (*i.e.* designing environments so all people can access, understand, and use them to the greatest extent possible, regardless of their age, size, ability, or disability).

Among the important changes introduced in the 2023 edition of the standard are updates of various dimensions based on current anthropometric research. The standard's informative annex provides more details on the anthropometrics of mobility aid users, including reach ranges for a person in a wheeled mobility device, walkway width for people using crutches, walkers, or being accompanied by a service animal. The annex also provides detection space for people using a long

Photo courtesy iStock

Policymakers and consumers have identified a need to provide more housing stock that is accessible, affordable, and adaptable for older adults and people with disabilities.

white cane and dimensions of wheeled manual and powered mobility devices and their turning areas.

The new edition of the standard also provides a detailed explanation of luminance (colour) contrast and provides guidance on minimum contrast for general surfaces, glossy or shiny surfaces such as brushed stainless steel.

Further, CSA/ASC B651:23 updates guidance on functional and cognitive barriers, recommending designing spaces with simple and logical layouts with consistent features; for example, the same location of washrooms on each floor. Designers should also consider measures to avoid excessive noise interferences and implementation of improved lighting inside buildings and in the exterior environment.

Find more information about the new and updated requirements and recommendations of CSA/ASC B651:23, visit www.csagroup.org/store/product/CSA-ASC%20B651%3A23.

A new standard for accessible homes

People living with disabilities need easy access to food, hygiene, and rest areas in their homes. However, current design and construction guidelines and codes for accessible dwellings vary by jurisdiction across Canada, and their requirements tend to be limited, which can make it difficult for people with disabilities to find a home meeting their specific needs. In addition, most traditional homes were not designed with accessibility in mind, making alterations to existing homes challenging.

Policymakers and consumers have identified a need to provide more housing stock that is accessible, affordable, and adaptable for older adults and people with disabilities. The new CSA Group standard CSA/ASC B652:23, *Accessible Dwellings*, is intended to assist in the design, construction, or alteration of homes so they can accommodate the needs of their residents. The standard provides guidance for a variety of dwellings—from detached houses and duplexes, townhouses, and row houses, to apartments and condominiums. Its provisions are also suitable for short-term and visitable dwellings, such as hotels, dormitories, or care facilities.

The first edition of the standard leans on industry experts and people with lived experiences of disability to provide evidence-informed guidance and best practices for the design of various elements of accessible homes, including ramps, landscaping, parking, garages, and other exterior elements.

The standard specifies area allowances for rooms and spaces in houses to accommodate a person using an assistive mobility device, as well as knee and toe clearances and addresses accessibility features of different rooms. It also provides best practices for home operating controls, such as door handles and locks, light switches, buttons for appliances, faucets, etc. These best practices cover the position of controls, their operability, and functionality.

CSA/ASC B652 also provides requirements for floors and ground surfaces, with additional considerations for people with different disabilities, for example, people with limited vision, environmental intolerances, or those using assistive mobility devices.

Photo © Lawcain | Dreamstime.com

The initial edition of the standard relies on industry experts and individuals with disability experiences to offer evidence-based advice for designing accessible homes, covering ramps, landscaping, parking, garages, and other exterior elements.

A separate clause of the standard is dedicated to the illumination of accessible dwellings and addresses general (ambient) illumination and task lighting.

Find more information about the new requirements and recommendations of CSA/ASC B652:23, visit www.csagroup.org/store/product/CSA-ASC%20B652%3A23.

Helping designers and builders apply the standard for accessible dwellings

To help home builders, contractors, and accessibility consultants apply the requirements and recommendations of CSA/ASC B652:23, CSA

Group is developing a new interactive PDF tool. This tool will help assess the needs of individuals with physical, sensory, or cognitive disabilities and optimize the design of private homes when building, renovating, or retrofitting them.

Focusing on specific areas of the home, the tool will highlight specific requirements, recommendations, and considerations that may impact and improve its accessibility. Stay tuned for more updates on the tool by subscribing to the CSA Group newsletter.

Research identifies future standardization opportunities

Accessibility standards will continue to play an important and necessary role in building a barrier-free Canada. A report from CSA Group, "A Canadian Roadmap for Accessibility Standards," reviewed the current standardization landscape and identified areas where new standards and harmonization of accessibility provisions across Canada would help remove existing barriers to accessibility. For example, CSA Group's research recommended the development of a comprehensive national standard for accessible indoor and outdoor recreational and green spaces that would address the visual, physical, sensory, and cognitive needs of their users. Standards for wayfinding and navigation systems, especially in complex environments within transportation facilities, health care settings, and public pedestrian spaces, can also help remove barriers created by unclear signage and lack of continuous paths of travel.

To learn more about CSA Group accessibility standards, visit www.csagroup.org/standards/areas-of-focus/healthcare-and-well-being/standards-for-building-a-barrier-free-canada.

Notes

[1] Canadian Survey on Disability Report, Statistics Canada, 2018.

[2] Zallio, M., Clarkson, P.J., Inclusion, diversity, equity, and accessibility in the built environment: A study of architectural design practice, Building and Environment, Vol. 206, 2021.

Photo © Timur Malazonia | Dreamstime.com

Wayfinding and navigation standards, particularly in complex settings like transportation facilities, healthcare, and public areas, aid in eliminating obstacles arising from unclear signage and interruptions in travel paths.

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Kay Penn is the director of health and safety standards at CSA Group, leading the development of standards solutions towards building an accessible and barrier-free Canada.

Helping regulators through modular project approvals

New standard for compliance and approval process

CSA Group research and standards provide a framework for modular construction, from certification of pre-fabricated buildings and modules to their delivery and approval.

The new standard CSA Z252:23 helps guide regulators through compliance and approval processes to facilitate faster project completion:

- Guidance and best practices for review and approval of permanent modular buildings of any size and occupancy type
- What to expect at each stage of the building permit review, off-site and on-site inspections, and approvals
- Scope, roles, and responsibilities of third-party inspection agencies

csagroup.org/ModularConstructionStandards

MANAGING STORMWATER
with Bioretention Low Impact Development Systems

By Nick Mocan, M.Sc., P.Eng.

Images courtesy Crozier

Bioretention low impact development (LID) systems are becoming increasingly popular across Canada to meet stormwater management objectives for new developments, and for retrofitting mature developments. Guidance for the design and use of bioretention systems to manage stormwater varies across Canada. This article explores bioretention systems and provides a reference for design practitioners, contract administrators, and contractors including the following topics:

- An overview of bioretention systems and how they are used to manage stormwater;
- The latest bioretention system design guidelines available to design professionals;
- Myths and design oversights;
- Overcoming design challenges on sites with unfavourable conditions;
- Installation challenges that influence bioretention performance; and
- Pre-construction and post-construction monitoring to guide maintenance activities.

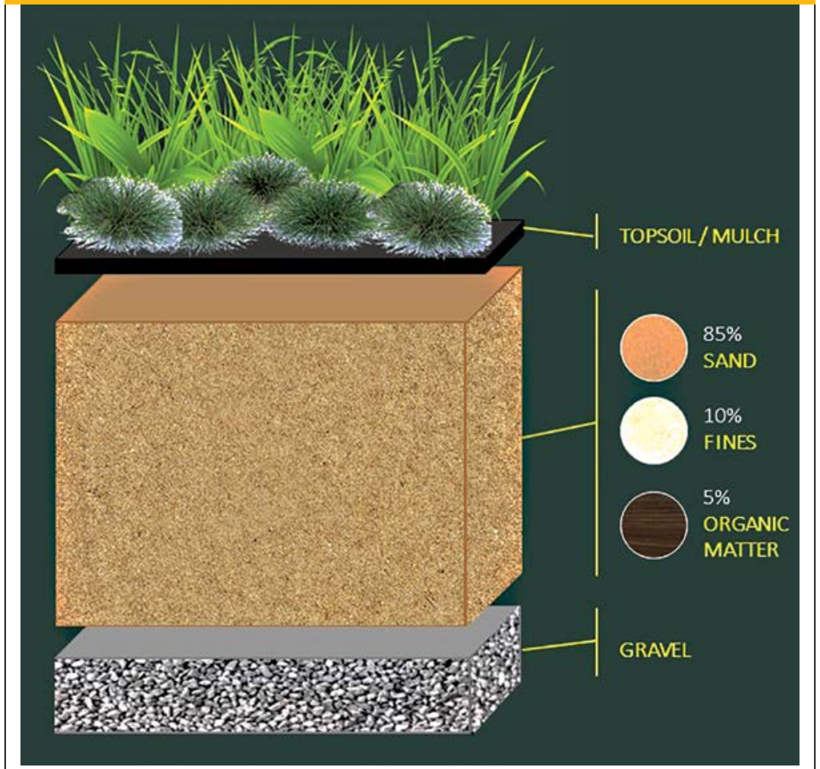
Bioretention systems are somewhat like icebergs; they are almost entirely "submerged" below ground (Figure 1, page 9).

A bioretention system is a soil and vegetation filter designed to improve the quality of stormwater runoff. They filter out pollutants commonly found in stormwater, such as suspended sediments, nutrients, and oils, among others. Some bioretention systems also provide stormwater quantity control by allowing infiltration to the

Figure 1

Conceptual bioretention system comparison with an iceberg.

Figure 2



Bioretention system composition.

subsurface and decreasing the volume of stormwater entering a sewer or watercourse. In most cases, bioretention systems manage stormwater quality and quantity from small and frequent rainfall-runoff events up to a 25 mm (1 in.) rainfall from urban drainage areas of up to 5 ha (12 acres).

A typical bioretention system is illustrated in Figure 2. In this example, a depressed topsoil and mulch layer are underlain with bioretention soil media, including a mixture of 85 per cent sand, 10 per cent fines, and five per cent organics.[1] The base layer is usually gravel with an underdrain if native soils are unsuitable for infiltration. Although most bioretention systems have a rectangular configuration, their designs are quite flexible and can be modified to suit site-specific constraints. In some cases, prefabricated bioretention systems can be specified and installed to facilitate quicker installation.

Design guidance for these systems is typically found locally with the agency having authority over watershed management. Local municipalities may also have design guidance for bioretention and other LID systems. Table 1 (on page 10 and 11) lists guidance documents primarily from Ontario agencies; however, the design principles, and construction and inspection techniques presented in these guidelines are applicable across Canada.

It is encouraging that several post-secondary institutions across Canada are conducting research to further understand and improve the design and performance of bioretention systems. One such research project with Western University[4] assesses and optimizes bioretention soil media for enhanced removal of stormwater contaminants. Ongoing research will ensure the relevance of bioretention systems in protecting the environment for future generations as development pressures continue to increase.

Myths and design oversights

Bioretention systems are relatively new in civil and water resources engineering in Canada and, as a result, several myths exist about their performance. Some of these myths are:

- Bioretention systems cannot handle large rainfall events.
- They need more care and maintenance than a traditional stormwater management pond.
- They take up more space than traditional end-of-pipe infrastructure, such as stormwater management ponds.

Traditional stormwater management ponds focus on controlling large infrequent rainfalls and bioretention systems focus more on treating smaller frequent rainfalls. Although bioretention systems are designed for smaller rainfall events, overflow pipes are included in their design to convey runoff from larger rainfall events to other stormwater storage systems. Any surface ponding on the bioretention system resulting from a larger rainfall event usually dissipates within 24 hours in systems with an overflow pipe.

Benefits aside, bioretention systems do need regular maintenance. This routine maintenance, however, is not labour intensive and does not involve heavy equipment. It involves removing accumulated sediment and debris, cleaning or replacing mulch, weeding, and trimming shrubs. Conversely, stormwater management pond maintenance may only be required every 10 years; however, it requires much more effort with pond dewatering and sediment removal using heavy equipment.

Space requirements are another reason why bioretention or other LID systems are sometimes overlooked as an option during the design process. Most bioretention and LID systems need adequate surface area to capture and filter runoff through the soil media before it discharges to the storm sewer or receiving watercourse. These systems require dedicated space on development sites to properly manage the stormwater.

Table 1 – Bioretention System Design Guidelines

Design Guidelines	Description
General Information of Bioretention Systems	
Sustainable Technologies Evaluation Program (STEP)	This program is a multi-agency initiative developed to support broader implementation of sustainable technologies and practices within a Canadian context.[2]
STEP Low Impact Development WIKI	This website contains information on low impact development. Although managed by STEP, this site allows users to edit content; therefore, please verify information found on this website before implementing it in a design.[3] https://wiki.sustainabletechnologies.ca/wiki/Main_Page
Design and Planning Guides for Bioretention Systems	
CSA W200-2018 *Design Of Bioretention Systems*, CSA Group, 2018	CSA Group has developed a standard for the design of bioretention systems in compliance with the Standards Council of Canada. This standard provides recommendations for the design of bioretention systems intended for the management of urban stormwater runoff.
Stormwater Management Planning and Design Guide, Ontario Ministry of the Environment, 2003	The Ontario Ministry of the Environment, Conservation, and Parks (formally Ministry of the Environment) is the final approval agency for stormwater infrastructure in Ontario. This manual is the foundation most of the agency's design guidelines are based.
Low Impact Development Stormwater Management Planning and Design Guide, Credit Valley Conservation (CVC) and Toronto and Region Conservation Authority, 2010 (Now found on the STEP website)	A guide for designers who want to implement low impact development practices, it includes information on the design of many low impact development (LID) techniques, including bioretention systems. This guide also includes how to integrate LID systems into a design starting from the early planning stages of a development.
Fact Sheet on Low Impact Development Stormwater Management Planning and Design Guide - Bioretention Credit Valley Conservation and Toronto and Region Conservation Authority, 2010	This fact sheet provides a useful summary of the design of bioretention systems. A fact sheet has been developed for each low impact development (LID) system which now can be found on the STEP website.

Although bioretention systems do require space on site, they can often be incorporated in landscaped areas, or as a component of a landscape feature or product. If co-ordinated properly between the civil engineer and the landscape architect, bioretention systems can take up less space than traditional end-of-pipe stormwater management facilities.

Design oversights often relate to the soil media or plantings. Organizations such CSA Group and Credit Valley Conservation (CVC) have released design standards for bioretention systems that specify soil media composition. For best results, plantings should be drought resistant, and if the bioretention system will be receiving runoff containing road salt, the plants should be salt resistant as well. Correctly specifying these design elements will help ensure the biological treatment spans the design lifetime of the bioretention system and the plant life stays healthy. Designs should also include inspection ports for ongoing monitoring.

Depending on the size and location of the proposed bioretention system, prefabricated systems can be specified and delivered to site. These prefabricated systems typically include a concrete vault with the appropriate preinstalled soil media, drainage layer, etc. Although these prefabricated systems have a higher supply cost, they often reduce installation complexity, cost, and time.

Overcoming design challenges

Bioretention systems are best placed in areas that promote infiltration, unless otherwise specified by the design practitioner. The elements one ought to look for when siting a bioretention system include well draining soils and sufficient separation from groundwater and bedrock. These factors allow bioretention systems to drain through infiltration. Options can still exist where site conditions are not ideal.

For sites that have soils with low infiltration rates, subdrains can help prevent the bioretention system from becoming water-logged. Bioretention systems typically have stone layer between 0.3 and 1 m (1 and 3 ft) deep at the bottom of the system. Depending on the design, these subdrains may be located either at the bottom of the stone layer, so that all the runoff entering the system drains out through the subdrains, or be placed at the top of the stone layer, enabling a portion of the runoff to infiltrate. If subdrains are used, the design should specify a geotextile surrounding the stone layer or a filter sock around the subdrain to mitigate the system clogging.

Table 1 – Bioretention System Design Guidelines continued

Design Guidelines	Description
Construction and Inspection of Bioretention Systems	
Low Impact Development Certification Protocols: Bioretention Practices Credit Valley Conservation, 2017	This guide help municipalities and private landowners in Ontario formalize a system for certifying low impact development (LID) systems after they are constructed. LID systems are mostly underground and, therefore, operation and maintenance personnel need a procedure to ensure the systems are working as specified.
Low Impact Development Construction Guide, Credit Valley Conservation, 2012	The *Low Impact Development (LID) Construction Guide* bridges the gap between the design and construction of LID systems. Written for design consultants, municipal engineers, plan reviewers, and construction project managers, this guide highlights common LID construction failures and how to avoid them.
Contractor's & Inspector's Guide for Low Impact Development, Credit Valley Conservation, 2014	This guide complements the CVC *Low Impact Development Construction Guide* (2012). Contractors and inspectors can use this guide daily to ensure LID projects are installed properly through all phases of the project.
Low Impact Development Stormwater Management Practice Inspection and Maintenance Guide Toronto and Region Conservation Authority, 2016	Municipalities and property managers in Ontario can use this guidance document to design an effective inspection and maintenance program for low impact development (LID) systems.
Inspection and Maintenance of Stormwater Best Management Practices—Fact Sheet - Bioretention Toronto and Region Conservation Authority, 2016	This fact sheet summarizes the inspection and maintenance practices for bioretention facilities along with cost estimates for common maintenance activities. Similar fact sheets are also available for other low impact development (LID) practices on the STEP website.

For sites with shallow groundwater, a clay or synthetic liner can help prevent the filter media from becoming water-logged. Depending on the size of the system, the installation of this liner may need to be supervised by the site geotechnical engineer. Lined bioretention systems must include both a subdrain and an overflow outlet, so they drain between rainfall events. The plants in lined systems must be carefully selected, so root systems do not damage the liner. If plant substitutions are needed, they should be approved by the system designer.

For sites with shallow bedrock, the construction challenges include both low infiltration rates and excavating around bedrock. Bioretention systems installed on sites with shallow bedrock could be designed with shallower stone and filter media layers. If the bedrock is fissured, a liner may be needed to keep enough water in the bioretention system to support the plants. If the bedrock is solid, a subdrain and overflow will be needed for the system to drain between rainfalls. Plants used in shallow bioretention systems must tolerate having shallow root systems. Any necessary substitutions should also be approved by the system designer to ensure the plants can thrive.

The requirement for LID systems in many jurisdictions lead designers to feel pressured to design bioretention systems in less-than-ideal locations. However, bioretention systems can be specified with a few design modifications to work on sites with low infiltration rates, or those with shallow groundwater or bedrock.

Communicating these design modifications to the construction team enables designers, contract administrators, site inspectors, and contractors to understand the design and be aware of the potential challenges when building a modified bioretention system. With innovative design and good communication within the project team and those in the field, bioretention systems can work well for years, even on sites with unfavourable conditions.

Construction challenges influencing bioretention performance

The industry is learning to alleviate some of the challenges of installing bioretention systems by improving communications, enhancing specifications, and working together. When designers, contract administrators, and contractors work collaboratively from the design and specification stage all the way through final certification, it results in improved long-term performance of the bioretention system.

An inlet to a bioretention system located in Mississauga, Ont.

When preparing the tender documents, all design practitioners—including civil engineers, landscape architects, and geotechnical engineers—should not only discuss the specifications for the bioretention system and its components, but also the staging necessary for a bioretention system. Before any site work begins, the area of the bioretention system must be protected with erosion and sediment control measures to avoid sediment clogging the native soil or the construction activity compacting it. If earthworks are happening onsite, the bioretention system area must be filled with high permeability soils, which may need to be imported and placed in these areas. All trades onsite, including building and utility trades, should be aware of the bioretention system, so they do not inadvertently compact or otherwise damage the area after it has been landscaped and appears as a regular landscaped area.

A bioretention system located in Brampton, Ont.

Communication between all parties is also important when adapting to field conditions. Although every effort may be taken to have records of existing infrastructure and sub-surface soil conditions during the siting and design stage of the project, actual site conditions could be different or change once construction begins. Open communication and problem solving is imperative at this stage to minimize impacts to both costs and schedules.

Even with bioretention systems becoming more popular with a shift to green infrastructure and the introduction of pre-manufactured systems, installing a system is challenging. Filter media mixes may require more testing to ensure the soil media mix meets the specifications. Additionally, if the system is not pre-manufactured, its performance relies on several contractors. For example, a civil contractor may install the geotextile, piping, and granular material; a landscape contractor may install the filter media; and a curb contractor would install any curb cuts or inlets around these systems. Each of these components are critical to the overall performance of the bioretention system. With each additional contractor involved, more complexity is introduced, which further reinforces the need for care during the installation process.

It is frustrating for contractors when inconsistencies exist in design drawings and contract documents. Designers must recognize the need to have consistent contract documents and problem solve with contractors when issues arise. This collaborative approach helps the long-term performance of bioretention systems, because it results in a better-quality installation that aligns with the design intention. Projects do better when good working relationships and open communication exists between designers, contract administrators, and contractors.

Pre- and post-construction monitoring

Although bioretention systems are low-maintenance features by design, they do require some maintenance to properly function over time. Neglecting bioretention systems can lead to poor infiltration, clogged media, flooding, overgrown vegetation, and leaks which could lead to dangerous sinkholes.[5] Sinkholes are depressions or holes on the surface caused due to a collapse of a ground surface layer. Pre-construction and post-construction monitoring can guide maintenance activities to mitigate these issues.

Before construction of the bioretention system, infiltration testing of the native soils can confirm if the proposed location is suitable or if an underdrain is required. Choosing the best soil filter media and plant material helps minimize the potential for maintenance issues that may arise over the lifespan of the system.

During construction, inspections must take place before the sewers are installed and backfilled to confirm the depths, slopes, and elevations. Erosion and sediment control measures as well as flow diversion devices used during construction need to be maintained, especially after large rainfalls. Bioretention systems can easily get clogged during construction if the sediment material from construction activities is not properly managed.

After construction, system maintenance can help sustain the bioretention system's longevity. Over time, sediment can enter the system and cause water to backup and flood the site. Twice a year, bioretention systems should be maintained by regularly removing trash, trimming vegetation, cleaning out sediment inlets and underdrains, and checking for slide slope erosion.[6] If persistent standing water is observed, it may indicate the filter media is clogged. Equipment should never be driven over a bioretention system, because it can compact filter materials and cause drainage issues. Periodically inspecting the systems every five to 15 years will determine if rehabilitation or replacement of the system is warranted. Performance monitoring options such as monitoring wells or piezometers can be installed to confirm if the system is operating as designed.[7]

Bioretention systems must be maintained. Completing pre-construction and post-construction monitoring, together with ongoing maintenance, can influence the long-term success of these systems. The long-term maintenance of bioretention system remains open to further research for input on its frequency and the signs that rehabilitation of the system is required.

Conclusion

The design and performance of bioretention systems to manage stormwater continues to evolve. Designers and specifiers can stay on top of evolving guidance by visiting the agencies who continue to publish design guidance listed in this article, as well as by staying up to date with the ongoing research conducted by institutions to improve the future of stormwater management.

***Author's note:** This article was developed in close collaboration with Crozier engineering staff including Rebecca Archer, P.Eng.; Rebecca Alexander, P.Eng.; Brendan Hummelen, P.Eng.; and Amanda Pinto, EIT.*

Notes

[1] Consult Low Impact Development Stormwater Management Planning and Design Guide, 2010, Credit Valley Conservation (CVC) and Toronto and Region Conservation Authority (TRCA). LID-SWM-Guide-v1.0_2010_1_no-appendices.pdf found at sustainabletechnologies.ca.

[2] See Sustainable Technologies Evaluation Program (STEP), which can be found at sustainabletechnologies.ca.

[3] Visit the Sustainable Technologies Evaluation Program (STEP) wiki at wiki.sustainabletechnologies.ca/wiki/Main_Page.

[4] See the entry listed on cfcrozier.ca/what-we-do/research-partnerships/low-impact-development-lid.

[5] Read Review of Inspection and Maintenance of Stormwater Best Management Practice, 2018, Sustainable Technologies Evaluation Program, Toronto and Region Conservation Authority, sustainabletechnologies.ca/app/uploads/2018/02/Bioretention-and-Dry-Swales-Fact-Sheet.pdf.

[6] See Review of Low Impact Development Stormwater Management Practice Inspection and Maintenance Guide, 2016, Toronto and Region Conservation Authority, sustainabletechnologies.ca/app/uploads/2016/08/LID-IM-Guide-7.1-Bioretention-and-Dry-Swales.pdf.

[7] Read Review of Lessons Learned: CVC Stormwater Management and Low Impact Development Monitoring and Performance Assessment Guide, 2015, Credit Valley Conservation, cvc.ca/wp-content/uploads//2021/07/Monitoring_Guide_Final.pdf.

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Helping your community adapt to climate change

Standards for more resilient infrastructure in Canada's North

Changing temperatures and precipitation patterns, permafrost degradation, and coastal erosion take a heavy toll on buildings and infrastructure in Canada's North.

CSA Group research and standards can help northern communities adapt to the impacts of climate change by addressing:

- thermosyphons and building foundations in permafrost regions
- high wind, snow drifting, and snow load risks for buildings
- climate change vulnerabilities of airports
- erosion and sediment risks for infrastructure
- fire resilient planning
- community drainage and wastewater treatment systems
- solid waste disposal in northern communities

csagroup.org/NorthernInfrastructure

FENESTRATION Testing Protocols

Essential Knowledge for Proper Specification

By Steven Gille

Photo by Tom Arban/courtesy Alumicor

In the world of fenestration, there is a wide variety of different products with a common purpose: to close the building envelope, allow light into the interior, and offer outside views. Fixed and operable windows, curtain wall, storefront, window wall, skylights, sliding doors, and hinged entrances are among the most familiar systems. Products must be evaluated to meet each project's unique requirements and goals.

To ensure proper specification, it is essential to understand fenestration products are listed across multiple MasterFormat Divisions, and subject to different standards and code requirements.

Fenestration types are grouped into two broad product categories:

- Windows – The first category includes product types defined under the scope of AAMA/WDMA/CSA 101/1.S.2/A440 North American Fenestration Standard (NAFS), *Specification for windows, doors, and skylights*. NAFS has been referenced by the *National Building Code of Canada* (*NBC*) since its 2010 edition. The CAN/CSA Standard, A440-00/A440.1-00 (A3-B7-C5), is no longer recognized by the *NBC* and shall not be used in specifications (refer to Sidebar 2, page 18).

Sidebar 1

Standards, protocols, guides, and tests methods noted in this article

- AAMA/WDMA/CSA 101/1.S.2/A440-17 North American Fenestration Standard (NAFS), *Specification for windows, doors, and skylights*.
- CSA *A440S1-19* Canadian Supplement to AAMA/WDMA/CSA 101/I.S.2/A440-17, NAFS, *Specification for windows, doors, and skylights.*
- AAMA 501-05, *Methods of Test for Exterior Walls.**
- AAMA 501.1-05, *Standard Test Method for Water Penetration of Windows, Curtain Walls and Doors Using Dynamic Pressure.**
- AAMA 501.2-09, *Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing Systems.**
- AAMA 501.4-09, *Recommended Static Test Method for Evaluating Curtain Wall and Storefront Systems Subjected to Seismic and Wind-Induced Inter-Story Drifts.**
- AAMA 501.5-07, *Test Method for Thermal Cycling of Exterior Walls.**
- AAMA 501.6-09, *Recommended Dynamic Test Method for Determining the Seismic Drift Causing Glass Fallout from a Wall System.**
- AAMA 910-10, *Voluntary "Life Cycle" Specifications and Test Methods for AW Class Architectural Windows and Doors.**
- AAMA 2604-13, *Voluntary Specification, Performance Requirements and Test Procedures for High Performance Organic Coatings on Aluminum Extrusions and Panels (with Coil Coating Appendix).**
- AAMA 2605-13, *Voluntary Specification, Performance Requirements and Test Procedures for Superior Performing Organic Coatings on Aluminum Extrusions and Panels (with Coil Coating Appendix).**
- AAMA 611-14, *Voluntary Specification for Anodized Architectural Aluminum.**
- ASTM E283-04, *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*.
- ASTM E331-00, *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*.
- ASTM E547-00, *Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference*.
- ASTM E330/330M-14, *Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference.*
- ASTM E1748-95, *Standard Test Method For Evaluating The Engagement Between Windows And Insect Screens As An Integral System*.
- CAN/CSA A440-00/A440.1-00, *Windows/Special Publication;* A440.1-00, *User Selection Guide to CSA Standard;* CAN/CSA-A440-00, *Windows** – Do not use.

Notes

* Non-mandatory standards

Photo courtesy Frontier Glass & Door and Alumicor

Ontario's Thunder Bay Regional Health Sciences Centre's 63,731 m^2 (686,000 sf) building showcases a three-storey atrium composed of aluminum-framed curtain wall. It was one of the first hospitals in Canada to intentionally bring daylight into the traditionally dark nursing stations. The architects oriented Thunder Bay Regional Health Sciences Centre's gently curving building to follow the sun's radial path.

- Other Fenestration Assemblies – The second category includes curtain wall, storefront, and window wall, called "Other Fenestration Assemblies" as defined in the appendix of the current *NBC* 2020. These products are not covered by a specific testing protocol referenced in *NBC* 2020, but must achieve the performance minimums indicated for structure, water management, and air leakage.

Categorization and the relevant specifications become complicated when multiple fenestration products are selected for a single project, for example, when a NAFS scope window type is integrated into an "Other Fenestration Assemblies" product type, as defined in the *NBC* 2020 appendix. The specifications professional then must navigate a path through building and energy codes requirements, specific project needs, compliance with different standards and consistency between divisions, and expected quality and esthetics.

What is in the code?

Canada's 2020 *National Model Codes* are currently in effect. Code updates are now the responsibility of the newly formed Canadian Board for Harmonized Construction Codes (CBHCC). Proposed changes to the 2020 editions will be open for public review. If approved, code changes will be included in the 2025 editions of the *National Model Codes*, published by the National Research Council of Canada (NRC).

As per *NBC* 2020, Section 5.9.2. states that products listed in the scope of NAFS need to comply with both NAFS-17 and the CSA A440S1-19 Canadian Supplement to NAFS (refer to Sidebar 1, page 17) NAFS and the Canadian Supplement define the performance level and the process to determine it, the pass/fail criteria and tests protocols for structural considerations, and the air and water management.

When it comes to Other Fenestration Assemblies, *NBC* 2020 Section 5.9.3. provides minimal requirements for air leakage tested at an air pressure difference of 75 Pa (1.57 psf) that is not greater than 0.2L/(s•m²) [0.30 cfm/sf] as per ASTM E283-04 (refer to Sidebar 3, page 19).

Water penetration compliance for *NBC* 2020 is achieved with either ASTM E331-00 or ASTM E547-00. The penetration resistance of the Other Fenestration Assemblies products must be capable of resisting driving rain pressure as determinate using the protocol and the climate design data defined in CSA A440S1-19.

ASTM E330/330M-14 is the acceptable protocol for structural and environment loads by reference in the *NBC* 2020 notes. Regarding loads, consult the *NBC* 2020 "Part 5 – Environmental Separation, Section 5.2 Loads and Procedures," to review all loads affecting the Other Fenestration Assemblies due to a project's specific conditions, location, and design. Even if these are not part of mandatory testing protocols, various loads can affect the fenestration components, and may require either project-specific testing or calculations.

Additional testing methods listed in the *NBC* 2020 notes include AAMA 501-05, AAMA 501.1-05, AAMA 501.4-09, AAMA 501.5-07, and AAMA 501.6-09 (refer to Sidebar 1, page 17). These are not mandatory but offer helpful guidance for the specifications professional.

Sidebar 2

Fenestration product type definitions

- North American Fenestration Standard (NAFS) is for windows, doors, secondary storm products (SSPs), tubular daylight devices (TDDs), roof windows, and unit skylights.
- Out of scope are interior products, garage doors, roof-mounted smoke, and heat-relief vents, sloped glazing, curtain walls, window wall, storefronts, commercial entrance systems, sunrooms, revolving doors, and commercial steel doors.
- As per the *National Building Code of Canada* (*NBC*) 2020, "Other Fenestration Assemblies" includes curtain wall, window wall, storefront, and glazed architectural structures.

One of the largest gym complexes in southern Ontario, the SportsPlex on St. Clair College's Windsor Campus features a combination of aluminum-framed curtain wall with integrated vents, storefront and entrance systems.

Photo courtesy D & M Glass & Aluminum and Alumicor

Photo by Lisa Logan Photography/courtesy Alumicor

Seneca College's Magna Hall is designed with natural light, views, and energy efficiency. Aluminum-framed curtain wall with high thermal performance were specified to enclose the 21,554 m² (232,000 sf) academic and athletic building.

Sidebar 3

Air leakage requirements in codes

- Give special attention to fenestration products' air leakage requirements. The *National Building Code of Canada (NBC)* 2020 and the *National Energy Code of Canada for Buildings* 2020 *(NECB)* do not have the same requirements for operable windows.
- Fixed windows and Other Fenestration Assemblies must meet 0.2L/(s•m²) [0.04 cfm/sf] in both the *NBC* 2020 and *NECB* 2020.
- For operable fenestration products, the requirement is 1.5 L/(s•m²) [0.30 cfm/sf] in the 2020 *NBC*, and 0.5 L/(s•m²) [0.10 cfm/sf] in the 2020 *NECB*. Remember, when a building is within the scope of a *NECB*, performances required in the *NECB* take precedence over those in the *NBC*.

What is in NAFS?

NAFS and other standards have been updated since 2020. These updates may be reflected in proposed changes to the 2020 *National Model Codes* and, if accepted, could be included in the 2025 edition.

NAFS-17 applies to fixed and operable windows, and patio and terrace doors, which also can be integrated into Other Fenestration Assemblies products (refer to Sidebar 2, page 18). The purpose of NAFS is to evaluate windows products for comparable performances and to define performance levels. Aspects evaluated by NAFS include resistance to air leakage, water penetration, and structural environmental loads. In addition, evaluate for quality and durability through auxiliary testing such as operating force, ensuring ease of operation for occupants.

Minimal performance levels, relevant tests, and the test type depends on the product's performance classes (PC). PC definitions describe a project's typical characteristics and suggest differences in the testing protocols and the minimal dimensions required to undergo these tests as per NAFS.

First, NAFS' mandatory testing protocols involve measuring air leakage as per ASTM E283-04 at 75 Pa (1.57 psf). The result will be a measure of the volume of air going through the window at stable pressure differential per second and divided by the window surface area. Fixed products must meet the fixed level air leakage requirement of 0.2L/(s•m²) [0.04 cfm/sf], and operable products must minimally comply with the A2 level requirements of 1.5L/(s•m²) [0.30 cfm/sf]. The expression "air leakage" is used because both infiltration and exfiltration are tested since air can flow in both directions (refer to Sidebar 3).

Next, resistance to water penetration, validated in NAFS, follows ASTM E331-00 uniform static air pressure. Depending on the PC, the window specimen must resist water leakage at a defined minimal pressure of 15 per cent of the design pressure. Criteria to succeed this test differs in the U.S. and Canada. Be cautious when analyzing products to ensure the water penetration test complies with Canadian test requirements, namely that no water remains in an undrained fenestration framing cavity. However, water retained as droplets or surface film are not considered evidence of a failed test.

Finally, structural testing for NAFS references ASTM E330/330M-14, which involves two types of tests, each at a positive and negative static load.

- The first test validates how much a window will deflect under a specified design pressure. This does not validate for dangerous wind loads conditions, but it can demonstrate highly uncomfortable window movement for taller specimens. While all PCs are required to test for structural deflection, passing L/175 is only mandatory for commercial window (CW) and architectural window (AW) classes.
- The second tests the structural-ultimate wind load to 150 per cent of the static design load. All PCs must pass successfully to comply with NAFS. Operable products must remain locked during the test and operate after the test's completion. This test helps ensure occupants egress safely.

In addition to these essential test protocols, NAFS describes minimal requirements to ensure products are easy to use, their screens remain in place on windy days, and they resist forced entry. This forced-entry test does not consider glass breakage type, but the product's resistance to a quieter and less noticeable intrusion with the help of tools.

Products from all PC must also undergo the minimal mandatory tests. Their differences lie in the minimal dimensions of the tested samples, and the minimal water and wind load pressure they must meet. CW and AW classes are required to not exceed L/175 during the structural-deflection test. R and LC classes are tested to this, but the result does not determine a pass or fail.

In addition, AW class has more stringent requirements for air leakage with a maximum of 0.5L/(s•m^2) [0.10 cfm/sf] for operable compression-sealed products and 0.2 L/(s•m^2) [0.04 cfm/sf] for fixed products. Both are tested at 300 Pa (6.27 psf) for infiltration and 75 Pa (1.57 psf) for exfiltration. AW class products also must undergo two water tests: ASTM E331-00 uniform static air pressure and ASTM E547-00 cyclic static air pressure at a minimum of 20 per cent of the design pressure, defined with the structural-deflection wind load test.

The greatest distinction for AW class products is AAMA 910-10 life cycle testing. Life cycle testing involves thermal cycling from -18 C (0 F) to 82 C (180 F); opening, closing, and locking cycles of 4,000 operations each; and a misuse test for operable windows and doors. AW products must pass ASTM E283 air leakage and ASTM E331 water penetrations tests at the completion of cycling. The operating sash are then subjected to a torsion test.

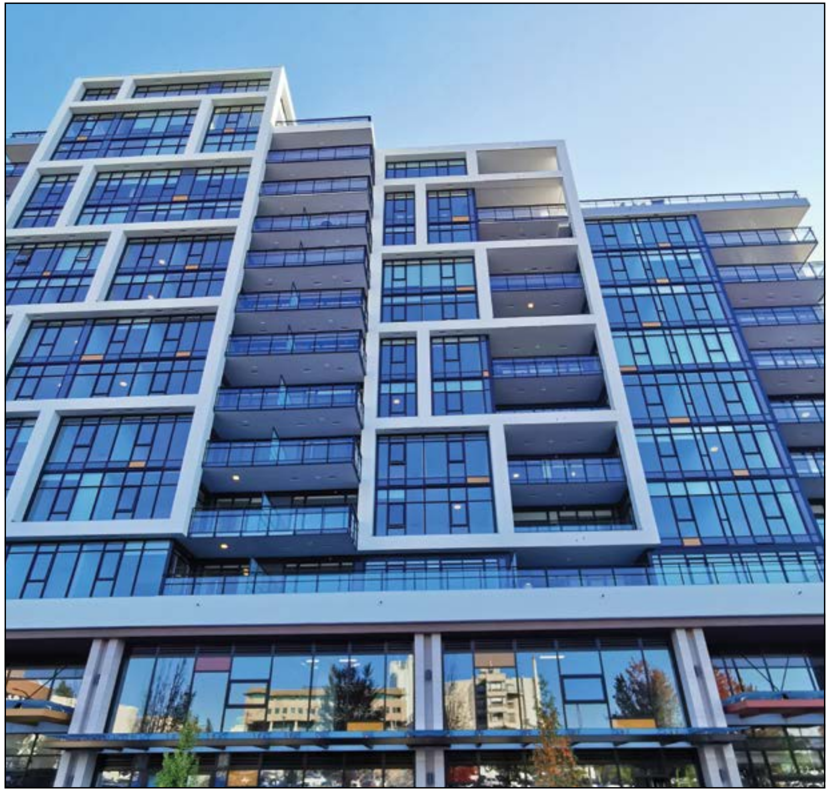

Photo courtesy Transparent Glazing Systems and Alumicor

Aluminum-framed curtain wall, windows, and terrace doors were specified for this 12-storey, 126-unit, mixed-use residential development.

AW class products also require high-performance finishes. Painted finishes must comply with AAMA 2604-13 or AAMA 2605-13, and Class I anodizing must meet AAMA 611-14 standards. This aspect should not be overlooked when preparing specifications (Figure 1, page 21).

Figure 1

NAFS Performance Class Distinctions

	R	LC	CW	AW
Minimum Product Size				
Fixed	1200 x 1200mm (47.24 x 47.24in)	1400 x 1400mm (55.12 x 55.12in)	1500 x 1500mm (59.06 x 59.06in)	1500 x 2500mm (59.06 x 98.43in)
Casement	600 x 1500mm (23.62 x 59.06in)	800 x 1500mm (31.50 x 59.06in)	800 x 1500mm (31.50 x 59.06in)	900 x 1500mm (35.43 x 59.06in)
Hopper	1200 x 400mm (47.24 x 15.75in)	1200 x 800mm (47.24 x 31.50in)	1200 x 800mm (47.24 x 31.50in)	1500 x 900mm (59.06 x 35.43in)
Minimum Performance Grade (PG)	PG 15 720 Pa (15 psf)	PG 25 1200 Pa (25 psf)	PG 30 1440 Pa (30 psf)	PG 40 1920 Pa (40 psf)
Deflection L/175 per ASTM E330/330M	Reported	Reported	Reported	Mandatory
Air Leakage Pressure	75 Pa (1.6 psf) infiltration/exfiltration	75 Pa (1.6 psf) infiltration/exfiltration	75 Pa (1.6 psf) infiltration/exfiltration	300 Pa (6.3 psf) infiltration 75 Pa (1.6 psf) exfiltration
Allowable air leakage for operable	1.5L/(s·m²) (0.3 cfm/ft²)	1.5L/(s·m²) (0.3 cfm/ft²)	1.5L/(s·m²) (0.3 cfm/ft²)	0.5L/(s·m²) (0.1 cfm/ft²)
Minimum Water Penetration Resistance	140 Pa (2.9 psf)	180 Pa (3.8 psf)	220 Pa (4.2 psf)	390 Pa (8.1 psf)
Minimum percent of Performance Grade	15%	15%	15%	20%
Testing	Uniform testing per ASTM E331	Uniform testing per ASTM E331	Uniform testing per ASTM E331	Uniform testing per ASTM E331 + cyclic testing per ASTM E547
Additional Requirements			Sash/leaf torsion	Sash/leaf torsion, Life cycle, AAMA 910
Coatings				
Painted Coatings				AAMA 2604 or AAMA 2605
Anodized Coatings				Class I

Illustration courtesy Alumicor and Tubelite

Photo courtesy Transparent Glazing Systems and Alumicor

The Edgewood Elementary School in Surrey, B.C., was designed with a combination of aluminum-framed curtain wall, projected window vents, sliding doors, and swinging entrance doors.

What is in the specification?

When it comes to specifying fenestration products, the most important consideration is to ensure consistency between requirements for products from Other Fenestration Assemblies, those in the scope of NAFS, and those in related divisions such as glazing and sealants.

First, regarding air leakage, it is important to validate requirements from both the *NBC* and the *National Energy Code of Canada for Buildings* 2020 (*NEBC*) and determine which one is applicable. Will the building be subject to continuous pressure differential because of the chimney effect, HVAC, or winds? These can be indicators for the air leakage rates and the pressure differential to specify.

Secondly, water resistance as per *NBC* 2020, driven rain pressure shall be determined using the climate design data and the protocol found in the CSA A440S1-19 Canadian Supplement to NAFS, as well as for Other Fenestration Assemblies.

The third and critical characteristic is structure. Does the project integrate tall or oversized fenestration products and does a deflection of more than L/175 present a concern to occupants or a risk for the glass?

Sidebar 4

AW – NAFS testing protocol vs AAMA 501 testing protocol

Architectural window (AW) – NAFS testing protocol	AAMA 501 testing protocol
Operating force	ASTM E330 – 50 per cent positive wind load pressure
Force to latch	ASTM E283 – Air leakage
ASTM E1748 – Screen test (Exterior insect screen only)	ASTM E331 – Static water penetration
ASTM E283 – Air leakage	AAMA 501.1 – Dynamic water penetration*
ASTM E331 – Static water penetration	AAMA 501.4 – Interstory lateral displacement*
2000X Opening-closing cycles	ASTM E283 – Air leakage*
2000X Locking hardware cycles	ASTM E331 – Static water penetration*
Misuse testing	AAMA 501.7 – Interstory vertical displacement*
2000X Opening-closing cycles	ASTM E283 – Air leakage*
2000X Locking hardware cycles	ASTM E331 – Static water penetration*
Operating force	AAMA 501.5 – Thermal cycling*
ASTM E283 – Air leakage*	ASTM E283 – Air leakage*
ASTM E331 – Static water penetration*	ASTM E331 – Static water penetration*
ASTM E547 – Cyclic water penetration*	ASTM E330 – Defection wind load
AAMA 501.5 – Thermal cycling	ASTM E283 – Air leakage
ASTM E330 – Defection wind load	ASTM E331 – Static water penetration
ASTM E283 – Air leakage	AAMA 501.1 – Dynamic water penetration*
ASTM E331 – Static water penetration	ASTM E330 – 150 per cent structural wind load
ASTM E547 – Cyclic water penetration	ASTM E283 – Air leakage*
ASTM E330 – 150 per cent structural wind load	ASTM E331 – Static water penetration*
	AAMA 501.4 – 150 per cent lateral displacement*
*Optional testing	

Photo by Olivier Blouin/courtesy Alumicor

Montreal's Complexe Sportif Ville Saint-Laurent features a distinctive, sculptural appearance with a high-performance aluminum-framed curtain wall.

Performance criteria expected of Other Fenestration Assemblies should be similar to those expected from windows integrated into these systems, or to adjoining windows in the same building. In addition to the air-water-structure trio, specification of extensive pre-construction testing may be needed for post-disaster buildings, super-tall buildings, or high-importance facilities. AW class can be an appropriate option for these situations since this PC requires additional, more stringent testing, and aligns with the Other Fenestration Assemblies' AAMA 501 protocol (see Sidebar 3, page 19, and Sidebar 4).

If the project is a post-disaster building, a high-importance facility, or a highly customized design, the project-specific mock-up protocols, such as AAMA 501, may also be applied for fabrication, installation, and design validations. This approach offers the opportunity to identify and remediate potential issues during preconstruction, rather than facing costly changes on the actual building. However, no NAFS procedure specific to windows may be used for a product integrated into a mock-up that is following AAMA 501 protocols. If further job site validation is needed, AAMA suggests several protocols, but they are limited to water and air leakage because structural testing could compromise the integrity of the system or of the surroundings and are practically impossible outside of a test facility (see Sidebar 1, page 17).

Photo courtesy Frontier Glass & Door and Alumicor

The southern glazed wall is lined with an exterior-mounted horizontal brise soleil to create a dappled delicate pattern of light and shadow that changes throughout the day and the seasons.

Many building applications do not require extensive testing. What does a mid-rise, mixed-use complex, or a small commercial office demand of the Other Fenestrations Assemblies and windows forming its envelope? Examine NAFS and AAMA protocols to determine the actual performance needs for the project.

Conclusion

Product performances obtained in the perfect world of a testing facility should only be specified to pre-qualify products. Those performances frequently surpass extreme environmental conditions. Products often do not perform the same as tested when installed on a project. Performance expectations should align with the real world as per climate design data and project-specific wind loads analysis, which already account for safety considerations.

Specifying too many test protocols or requesting job site compliance of air leakage and water penetration above realistic climate design data defined as per *NBC*, *NEBC*, and CSA A440S1-19 Canadian Supplement to NAFS can result in a significant loss of time and money with no real advantage to the project. Specifying few pre-construction test protocols and not verifying the products' capability to fulfil their roles as per climate design data defined by codes, can also result in a significant loss of time and money. The risk of damages, forcing forensic evaluations and actions to correct the situation can be even more costly and time consuming.

These well intended mistakes can be avoided by consulting with experts in the fenestration industry.

- Manufacturers can provide existing reports, offer guidance to align products' performance with project needs, or develop a protocol for project-specific mock-up testing.
- Structural engineers can make calculations to validate the fenestration systems' capacity to withstand loads at project-specific dimensions and can assist in determining the systems' anchoring locations and methods. They also can review dynamic wind effects and assess how this may impact the building's design and its surroundings.
- Consultants and testing teams can determine which protocols to use if mock-up or job site testing is required. They can advise when complex, oversized, or repeated fenestration may benefit from project-specific testing. They also can help define acceptable performance benchmarks for the project.

Finally, the specifier should be aware that fenestration tested to meet the highest standards still cannot guarantee the highest performance building. A project's success goes beyond unquestioningly complying with a list of standards; thoughtful design, proper installation, and collaborative communication are essential.

Steven Gille is the pre-construction manager at Alumicor and Tubelite. He draws from more than 40 years of experience in designing, engineering, testing, and developing curtain wall, storefront, entrances, and daylight control systems. He works closely with specifiers, architects, glazing contractors, and consultants to assist with product information and selections, and new solutions. He can be reached at sgille@apog.com.