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We’ve come to another year end for our print issues. Every Fall, we reflect on what the past year has shown us. This year, we’ve noticed something that goes right along with our current issue theme—Metal Design and Cladding. It seems that designers and architects are specifying more and more of this material for their builds. And time and time again, metal delivers constant performance and aesthetically pleasing attributes.

We’re going to look beyond the functional and aesthetical reasons for specifying metal cladding in the following pages. Metal cladding and how it allows the building to merge with the surrounding environment regardless of its geographical location is a trend we continuously see. This and the use of mixed metal is one of my personal favorite design trends.

Depending on the end use and the necessary budget, architects can now choose from several types of façade claddings. Metal panels, holed and ashlared sheets and metal mesh all make complete, sound and beautiful façades; but those are just some of the options available.

In this issue, our writers address how certain sheet metal products are marketed for their low-life cycle costs, the design challenges that can arise and the many benefits they offer when it comes to the envelope as a whole—including daylighting and energy efficiency aspects.

We hope you enjoy our last issue for 2018, and we look forward to what 2019 has to offer. As always, don’t forget to visit us online at buildingenclosureonline.com to view our current CEU opportunities as well as the latest industry information and technical articles.
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DAMPPROOFING AND WATERPROOFING

CODE INTERPRETATION

The waterproofing applied at the walls shall consist of one of the following membranes:
- Two-ply hot mopped felts
- 6-mil+ polyvinyl chloride (PVC)
- 6-mil polyethylene
- 40-mil polymer modified asphalt

The waterproofing should be applied a minimum of 12 inches above the highest point of the ground water table. The membrane joints shall be lapped in accordance with the membrane manufacturers latest printed requirements.

ROOFING

CODE INTERPRETATION

Existing buildings requirements are sprinkled throughout the I-Codes; for roofing replacements it is necessary to look at the IBC (International Building Code), the IEBC (International Existing Building Code), and the IECC (International Energy Conservation Code). The IBC addresses weather protection, fire resistance and structural performance requirements, while the IEBC includes provisions for retrofit upgrades under certain conditions.

The IECC requirement above is limited to those buildings where the roof assembly contains above-deck insulation and is part of the building’s thermal envelope. Roof replacement is a defined term in the I-Codes; the IBC requires removal of the existing roofing materials down to the deck and installing a new roof covering assembly. Under these conditions, the IECC mandates the installation of enough insulation to comply with either the R-value or U-factor tables. The use of tapered insulation can help meet the requirement if additional assembly thicknesses are required; the U-factor approach can provide even more flexibility.

Note that if the roof assembly includes ceiling insulation or below-deck insulation, this requirement does not apply. Additionally, there are other provisions in the IECC that exempt certain roof recovering and roof replacement projects from energy efficiency requirements, depending on the buildings energy use, roof design and other factors.
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Draining Perimeter Edge

The profile of specific components, their configuration or sequencing, can vary with the roof system, climatic differences, and regional or area practices. Dimensions as shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions. Fasteners to attach edge flashing may be nails or screws, as may be recommended by the single-ply roofing membrane manufacturer. Consult specific membrane manufacturer for additional information.

Four-inch minimum horizontal flanges are recommended. Continuous cleats are recommended when flashing face dimension exceeds 3 inches and in areas deemed high-wind zone as categorized by local building code. Note that ES-1 guidelines have been adopted by the International Building Code. Certain components as depicted in these details may not be provided by the roofing contractor.
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Zinc roofing has been extensively used in Europe for over two centuries, and was introduced into the U.S. market in the 1990s. Zinc is a naturally weathering material that many building designers admire due to its rich coloring and matte finish. However, zinc is prone to premature corrosion when the backside is exposed to repeated contact with water in the absence of air. Manufacturers and architects have used various methods to prevent water from causing accelerated backside corrosion of zinc products. It is relatively frequent practice to provide a ventilation space beneath zinc panels to allow airflow beneath the zinc panels to promote drying. Over the years, we have seen multiple zinc roof failures associated with backside corrosion due to material selection, and improper flashing and ventilation detailing. This article will provide a comprehensive explanation of the zinc corrosion mechanism, and will discuss the nuances of properly designing zinc roofs and cladding to minimize leakage and the risk of backside corrosion.

Zinc roofing has been used extensively in Europe for over two centuries and, more recently, has gained popularity in the U.S. Zinc is a naturally

DESIGNING FOR THE CHALLENGES OF ZINC ROOFING

Minimizing Leakage and the Risk of Backside Corrosion

by Jeffrey J. Ceruti, Daniel P. Clark and Kelsey A. Dunn

ABOVE: All photos courtesy of Simpson Gumpertz & Heger.

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Architectural-grade zinc is malleable, relatively strong and can be field-soldered, lending itself to use in irregular architectural profiles. The material is also versatile, and can be used as both roofing and cladding allowing for smooth transitions between the assemblies, where desired.

Zinc roofing and cladding is marketed for its low-life-cycle costs relative to other sheet metal products. Material costs for sheet metal zinc are similar to copper, aluminum and stainless steel. The service life of zinc roofing is generally estimated at 70 years; however, some buildings in Europe have portions of original zinc roofing performing well up to 120 years after installation. While in service, zinc panels require minimal maintenance due to the natural formation of a protective patina when exposed to the atmosphere. While some metals may require recoating over time, if zinc panels are scratched new patina will form on the freshly exposed zinc. At the end of service, virtually all the zinc material can be recycled and recovered for use in galvanizing. While architectural-grade zinc has many properties that make it a natural choice for use on building enclosures, the material is susceptible to premature corrosion if not designed and installed properly.

**Bring on the Water**

The same process that allows for the formation of the protective patina on the surface of exposed zinc can be detrimental under specific conditions. Near-pure zinc exposed to the atmosphere will react with oxygen to produce a thin layer of zinc oxide. When the zinc oxide layer is exposed to moisture, it forms zinc hydroxide. When the moisture is dried from the surface of the metal, the zinc hydroxide reacts with carbon dioxide in the atmosphere to form zinc hydroxyl carbonate. After repeated wetting and drying cycles, a durable, well-bonded zinc hydroxyl carbonate layer is typically formed on the surface of the metal. Zinc hydroxyl carbonate is a stable material that does not react in the presence of water and functions as a protective patina layer to control the corrosion rate of the exposed zinc.

In the continued presence of water and the absence of air, such as on the backside of zinc roofing or cladding panels where water infiltration occurs, zinc hydroxide can form, but sufficient carbon dioxide is not present to convert the corrosion products into the protective zinc hydroxyl carbonate. Zinc oxide and zinc hydroxide are not stable or well-bonded to the surface of the zinc and are porous; therefore, they offer no protection to the base metal. With continued exposure to moisture, water continues to react with the zinc oxide forming additional zinc hydroxide and consuming additional zinc in the process. The zinc hydroxide layer becomes thicker, forming a build-up of white corrosion product commonly referred to as “white rust.” The reaction can continue unabated until eventually the entire thickness of the metal can be consumed by corrosion.

**The Fight Against Leaks**

Although architectural metal roofs are designed to prevent bulk water leakage, they are considered “water-shedding” roof systems, and it is anticipated that small amounts...
of water may bypass the panels at certain detail conditions. For this reason, metal panel roofs have historically been designed with continuous roofing underlayment to collect and drain incidental leakage water from the system. Most metal roofing materials can tolerate minor water leakage through metal roofing detail conditions without shortening the service life of the roofing material. However, zinc products do not tolerate minor roof leakage or condensation without allowing corrosion that can eventually lead to failure of the roofing material. This process of zinc corrosion on the backside of metal roofing panels has been well documented in the industry for many years. The same corrosion process occurs on galvanized steel (steel coated with nearly pure zinc coating), and occurrences of “wet storage stain,” and its prevention, have been well documented in the industry for decades.

Since the major introduction of zinc roofing, manufacturers have used various methods to control accelerated backside corrosion of zinc products. Common methods to prevent backside corrosion include: providing a “ventilation” space beneath the roofing, using 3D polymer separation mats for venting, and applying organic coatings to the backside of the zinc sheets, resulting in variable degrees of success.

Several variations of separation mats have been used over the years in zinc roofing installations in an attempt to "ventilate" beneath the zinc panel. Typically, these products are either dimpled composite sheets or woven polymer sheets, and range in thickness from 1/8- to 1/2-inch. A critical design consideration when using a separation mat is how the system is detailed at anchor clips and eaves. Typically either the separation sheets are cut out around or extend continuously under the clips. In either condition, when the panels are installed the separation sheets are compressed, commonly resulting in the zinc panel in intimate contact with the substrate thereby defeating the purpose of the separation mat in localized areas. Additionally, it is common for the separation mats to be discontinuous at the roof edge resulting in another condition where the zinc panel is at risk for contact with water.

The Issue of Backside Corrosion

Some zinc manufacturers apply a coating on the backside to protect the zinc from backside corrosion in the event of minor roof leakage or condensation. The coating is typically a factory-applied organic paint that that varies in thickness between manufacturers. The coating is applied in an attempt to prevent moisture from wetting the zinc. However, the authors have observed that this coating is not effective in preventing corrosion, where moisture caused deterioration of the coating and then the zinc in a manner consistent with typical backside corrosion of uncoated zinc. Typical incidental leakage associated with metal roofing detailing flowed down the roof slope, between the roofing panels and the roofing underlayment, and was in contact with the zinc in many areas. Where leakage water contacted the zinc, it caused varying degrees of corrosion on the backside of the zinc roofing panels. The corrosion ranged from initial signs of backside coating deterioration and zinc corrosion (white rust), to complete corrosion through the thickness of the zinc panels.

The only proven method to protect the zinc panels from contact with water infiltration or condensation is to provide an airspace, or capillary break, between the backside of the zinc and underlayment, by using furring.
to lift the panels off of the underlayment. Alternating furring, installed parallel and then perpendicular to the roof slope, provides both an airspace and drainage plane within the roof assembly to prevent any water infiltration from contacting the zinc. Water infiltration that bypasses the roof panels can drop down onto an underlayment, and with proper detailing, drain down the roof slope and out through the eave. Including an airspace within this type of roofing assembly adds cost due to additional labor and materials, potentially making a zinc roofing system more expensive than other metal roofing material choices that are not susceptible to backside corrosion, such as copper or tin-zinc coated copper.

Providing an airspace below zinc roofing is commonly referred to as “ventilation,” which indicates a certain volume of air flow through the space. However, based on the authors’ experience it is more critical to raise the zinc off of the substrate to prevent contact between the zinc and any incidental water leakage, rather than provide a certain amount of ventilation air exchanges within the space. Misconceptions persist regarding the intent of the ventilation system and how it functions. Many sloped roofs use a “cold roof” design, in which a ventilation pathway is provided from the eave to the ridge above the plane of insulation. Stack pressure draws air from the bottom of the roof eave up the roof slope and out of the ridge vent, allowing the airspace below the roof cladding to reach temperatures similar to the outdoor temperature. During winter months in cold climates, this helps prevent ice-dam formation as heat loss from the interior is mitigated by the cold air drawn from the exterior. Typically this type of ventilation space is installed beneath the roof sheathing; however, this location will not protect a zinc roof from potential backside corrosion because the zinc may still be in direct contact with the underlayment and subject to wetting from incidental roof leaks. The authors have observed zinc corrosion on roofs with ventilation below the sheathing.

**Conclusion**

The detailing of zinc roofing systems is critical to limit the risk of incidental leakage behind the roofing, to avoid exposure of the panel to direct contact with water. Special attention should be given to detailing at panel closures, ridges, hips and rising walls. Panel closures at ridges and hips should not be cut to form turned-up pans, as this results in reliance on sealant to protect against leakage. Instead, panel closures should be fabricated using a “bread-pan” technique which folds the panel in a manner to create a pan without cutting the panel. Ridge details should include a continuous cleat at the upturned panels, and a Z-shaped closure between the panels seams. The Z-closure should be soldered continuously between the panel seams.

Even with appropriate detailing, a zinc roof design should always mimic, to some degree, a rainscreen cladding installation. The zinc panels should always have an
Designing for the Challenges of Zinc Roofing

Complete section loss through zinc panel as viewed from the backside of the panel.

Airspace directly below, and should not be in direct contact with the underlayment or other materials to ensure that incidental water infiltration or condensation will not come in contact with the panel, resulting in premature failure of the zinc panels. BE

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Although structural insulated panels (SIPs) often are used as the primary structural elements in light commercial and residential buildings, many project teams also use the panels as skins over metal structural frames to provide a high-performance building envelope.

A Case Study
To set the stage for why project teams combine SIPs with metal structural frames, it is helpful to review a specific example.

The Little Big Horn College Health & Wellness Center (Crow Agency, Montana) includes an NCAA gymnasium seating approximately 1,300 people; spaces for aerobics/community gathering, weight lifting and cardiovascular fitness, locker rooms and support facilities. The college (of the Apsáalooke Nation—Crow Tribe of Montana) built the facility to serve its students, as well as the surrounding community.

The Health & Wellness Center project team faced a daunting schedule. Time was running out to use a government grant for the project, so the team needed to start construction (moving dirt and pouring the foundation slab) even before they finalized the building design. Adding to the timing challenges, they had to construct the building’s shell during one of the coldest Montana winters in 20 years.
On top of requiring rapid completion, the college wanted a very green, energy-efficient building targeted to LEED Platinum standards. This commitment to the environment reinforces the center’s role in supporting healthy living and respects the tribe’s historic, cultural and artistic way of life.

Since the owner, architect and general contractor used an Integrated Project Delivery (IPD) approach, all parties had a strong stake in working together to address the schedule and green building needs. Rather than operating under separate contracts for design and construction, with the IPD the participants all signed one contract focused on successful completion of the project. “This allowed every team member to bring their best ideas to the table and collaborate on solutions,” noted Scott Moore, project manager with BNIM Architects.

One of those ideas was to use SIPs for the exterior walls and roof. “SIPs meet a number of needs with just one system,” said Doug Morley, principal architect with Springer Group Architects. “They install fast, insulate well and are strong. Other than in the large gymnasium, this reduced the need for a secondary support structure in the building and saved a bunch of time and money.”

Echoing Morley’s comments, contractor Glen Kamerman, Partner with Kamerman Construction, said: “The SIPs were really accurately constructed and went together well. Using SIPs probably saved about 15-20 percent or better on the installation time. It also eliminated the need to heat the walls during winter construction.”

“SIPs really helped us meet the accelerated project schedule,” added Matt Anderson, owner of Compass Consulting Engineers. “SIP shop drawings were done concurrently with design, so by the time we released the foundation package, the SIPs were being fabricated in the shop. The erection was extremely fast and in no time at all we were dried in.”

In addition to rapid construction and high strength, the SIPs play a key role in the building’s high energy efficiency design. The large-size panels have fewer gaps requiring sealing than other construction methods and provide continuous insulation (CI) throughout the walls and roof. “Energy savings is a big part of getting to the LEED Platinum goal,” said Ben Mitchell, project manager with the general contractor, Fisher Construction.

**Reasons to Use SIPs**

The 1,300-seat gymnasium portion of the Little Big Horn College Health & Wellness Center illustrates well the types of buildings that are especially suited for using SIPs as skins over metal structural frames. Specifically, buildings needing large, open interior spaces, and for which an energy-efficient envelope is crucial.

Two of the Little Big Horn College Health & Wellness Center project players summarize the role SIPs play in such spaces:

- “They work well in long spans and have high shear and diaphragm values. This was especially crucial to help create the wide-open space in the project’s gymnasium.” – Matt Anderson, owner of Compass Consulting Engineers
- “It’s hard to get a gym to meet any energy code, let alone LEED Platinum, but the SIPs provide a super energy-efficient envelope—much better than we could get from other products for the same labor and material costs.” – Ben Mitchell, project manager, Fisher Construction

In addition to gymnasias, other examples of buildings needing open spaces and an energy-efficient envelope include churches, community centers, cold storage and some factories and barns. 8E

James Hodgson is the general manager for Premier Building Systems, a leader in technical development and code reports for high-performance building panels. Hodgson serves on the Board of Directors of the Structural Insulated Panel Association (SIPA).

For more information, visit www.premiersips.com.
Building teams choose SIPs for commercial/institutional buildings and residences for four key reasons:

- Energy efficiency
- Labor savings
- Lower jobsite waste
- Improved indoor air quality

Energy Efficiency

Sips provide CI over a high percentage of the structure without having to add subsequent layers of insulation. Code required CI dramatically reduces air leakage from the building and has fewer thermal bridges than other building methods. As a result, SIPs can help lower energy costs for space heating and cooling by up to 60 percent above standards set forth in the 2006 International Energy Conservation Code (IECC).

Testing by the U.S. Dept. of Energy’s Oak Ridge National Laboratory (ORNL) showed that SIP structures are up to 15 times more airtight than stick framed walls insulated with fiberglass batts. A SIP structure had an air leakage rate of only 8 cubic-feet per minute (at 50 pascals of pressure) compared to stick framing which leaked air at 121 cubic-feet per minute. This dramatic difference is because SIP-built walls and roofs have far fewer gaps to be sealed. The lab also found for similar wall thicknesses, SIPs were 47 percent better at resisting heat flow than stick framing. A 3.5-inch-thick foam core SIP wall had a 14.09 R-value versus 9.58 R-value for 2-by-4 studs at 16 inches-on-center with fiberglass insulation. The SIP structure’s 14.09 whole-wall R-value even out-performed the 13.69 R-value of “advanced framing” with 2-by-6 studs at 24 inches-on-center.

Labor Savings

Because SIPs are built in a factory, they reduce jobsite labor needed for framing and insulation. The panels eliminate the need to cut and install dozens of studs and other framing members throughout the walls and roof. And, because the panels arrive on the jobsite with pre-cut window and door openings, there is no need to frame-out openings with jack studs and headers. “With the pre-built panels, you just have to piece the building together like a puzzle,” explained Glen Kameron, partner with Kameron Construction. Precut electrical chases also eliminate the time-consuming need to drill through dozens of studs to install wiring.

Lower Jobsite Waste

Traditional building practices—notably stick framing—generate large volumes of scrap from cut-offs for studs, joists and other framing members. SIPs are planned and made in a factory to eliminate such waste. SIPs can also help reduce construction waste by up to two-thirds.

Improved Indoor Air Quality

In addition to helping keep heated or cooled air inside buildings, SIPs’ airtight nature also helps seal out common pollutants for healthier indoor air. Blocking or slowing infiltration of radon, pollen, volatile organic compounds (VOCs), lead dust and the like contributes to a healthier and more comfortable indoor environment.
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Today, the U.S. is facing the largest aging population it has ever seen. According to AARP\(^1\), 10,000 baby boomers are turning 65 every single day. This means that seven baby boomers are turning 65 every minute. Combine this with the fact that the CDC states that one out of every five adults in the U.S. lives with a disability\(^2\) and the trend toward accessibility is a growing one.

**Defining Accessibility**

The growth of the baby boomer generation has many implications for the future of commercial architecture and design. The American Disabilities Act (ADA), is a law first established in 1990 by President George H.W. Bush to “prohibit discrimination against individuals with disabilities in all areas of public life, including jobs, schools, transportation, and all public and private places that are open to the general public.” Title III of the ADA focuses on public accommodations and commercial buildings, laying out guidelines to meet when developing a public space or a commercial facility, like a community library, government building or retail store. These guidelines were further...
defined in 2010 by then Attorney General Eric Holder to better enable people with disabilities to access buildings and facilities.

Generally, ADA regulations are upheld by the Department of Justice. However, local authorities with jurisdiction can also adopt accessibility requirements. For example, the Texas Department of Aging and Disabilities Services, Chicago Public Schools and the Chicago Mayor’s Office for People with Disabilities, as well as the New York City Building Code have adopted specific regulations for products such as operable windows. Additionally, the U.S. Department of Housing and Urban Development issued the Fair Housing Act Accessibility Guidelines in 1991 to ensure the accessibility of housing of more than four units. For more than 25 years, architects, contractors and building owners have diligently built to comply with ADA regulations in Title III and FHA, when specified.

A Growing Movement

In recent years, due to the growing aging population, there has been a movement toward architects specifying accessibility into projects where ADA is not required. For example, private condominiums and places of worship. This evolving trend is often referred to as “universal design,” an architectural concept of bringing accessibility to people of all ages and abilities by simplifying the built environment. While many organizations like the Center for Universal Design at North Carolina State University research and build out guidelines for universal design, there is no one governing body responsible for employing it. The building owner and architect are generally making the final decision as to whether the building meets their goals for accessibility, or universal design. This is a critical shift within the industry, and changes the dynamic around accessibility for architects, designers, contractors, engineers and building owners.

Key Considerations when Designing for Accessibility

Whether designing a building to meet ADA requirements, or a non-ADA building with the intent of providing a universal design, there are many key considerations to take into account to ensure a smooth design process.

Product is only one piece of the puzzle

When constructing a building for accessibility, or universal design, it is critical to understand that a product is only one piece of a much broader building puzzle. An entrance or balcony door can enable accessibility to a building or balcony, however whether it is ADA compliant or not can depend on a multitude of factors. Products that are referred to as “ADA Windows” or “ADA Doors” make the mistake of assuming a window or door can make a building accessible. That is not the case. Hardware, approach area, reach, forces and motion are all critical to enabling a product to provide the right level of accessibility. For example, the selection of inadequate hardware can make a door or window too heavy or tedious to open. The location of the hardware is also key. It must be at the proper height so that anyone is able to reach it, whether that person is standing or sitting down.

Similarly, a standard product like a terrace or balcony door must be part of a holistic design, with all integrated components properly developed and installed for accessibility to meet requirements. For example, as outlined in Title III, Section 404 of the ADA, the maneuvering clearance of a door depends on the size of the opening, as does the type of latch used. So while a specific low-threshold door may enable accessibility or universal design, it can only do so in combination with properly designed building conditions and correct installation. Case in point: if a ramp and platform is not built wide enough so that a wheelchair can climb the ramp, then have enough space to safely maneuver a wheelchair into the correct position to enter the building, then an entrance door is rendered useless, no matter the width.
The takeaway? Products must be verified by the architectural and engineering team for each application in an accessible building. Do your homework and know what each product specified is capable of, then determine what needs to happen to make the product work as intended.

To ensure a project runs smoothly it is important to communicate early in the design process. This is obviously important when designing a building to ADA standards. However, it becomes even more critical when designing a non-ADA building like a condo, where the government is not the ultimate regulator. Because the determination of what defines accessibility in these cases is often up to either the architect or the building owner, everyone should work to be on the same page from the beginning. This allows for any product customization to be designed and manufactured in a timely manner and for the installers to have an understanding of what needs to be done to what extent to ensure accessibility for the particular project.

Some best practices to consider in creating a successful project collaboration:

- The basis for an accessible design starts with thorough, well-articulated specifications. Architects must clearly communicate the critical nature of accessibility to the general contractor and ensure all subcontractors are on board with the design.
- General contractors must articulate accessibility as a key element of the design. Often times, subcontractors will value-engineer their designs in order to achieve a lower cost during the bidding process. In doing so, accessible features can be excluded. It is possible that if this happens, certain aspects of a building will then need to be retrofitted to ensure compliance.
- Close oversight must take place during each phase of the project, from framing to installation, to ensure all measurements are accurate and meet the requirements, whether it is an ADA or non-ADA project.

By collaborating and working together from the beginning, architects, building owners and contractors save time, money and ensure that the project runs on schedule.

**Going Beyond ADA**

As the trend toward accessibility grows, it is critical to go beyond just ADA guidelines to gain an understanding of how to best build out a building that is functional, beautiful and universal. With more knowledge of these key considerations of product, installation and collaboration, each project should be more successful in meeting the needs of every individual—now and in the future. **BE**

**Sources**

1. AARP
2. CDC
3. American Disabilities Act

Heather Evans serves as Certification Program Engineer at YKK AP America Inc. She joined YKK AP in 1999. Heather spent several years managing and implementing collateral and estimating software before joining the Product Development team in 2016. Heather holds a Bachelor of Science in Industrial and Systems Engineering from Auburn University.

**Installation is a critical component**

Installation is core to ensuring a successful accessible design. It starts with the framing, setting up the proper width of doors and height of windows. A low threshold door is only useful if it is framed, then installed at the proper height. As stated in ADA Section 404.2.5, “thresholds if provided at doorways shall be 1/2-inch high maximum.” Similarly, the variability of the slab is critical. An uneven slab from interior to exterior may help to keep water out of a building, but it can make accessibility near impossible. And because the interior and exterior slab is often poured at different times, this is an extremely easy mistake to make.

Another factor to consider is that the fenestration must be installed to the finish floor. Something as simple as a shim will make accessibility difficult. General contractors must work closely with glazing contractors to ensure glass installation is done correctly.

Mapping out the entire design and measurements in detail from the conception of a project helps to ensure a smooth installation. While the ADA outlines the installation guidelines in detail, that doesn’t necessarily mean the subcontractors responsible for installation are following those guidelines. Oversight must be applied throughout all phases of a project to confirm accuracy of all accessible elements. This leads to the next key consideration—communication.

**Collaboration is paramount**

In designing a building for accessibility, a holistic design amongst the many players involved in the project is critical.
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Three new stations in the Toronto Transit Commission (TTC) Line 1 Extension employed inverted roof membrane assemblies to achieve Cool Roof and longevity requirements. Unlike most inverted roof membrane assemblies, these roofs are not flat, nor high atop a building out of public view. At each location the roof is a key design feature utilizing curves in multiple directions to create the architect’s vision. The performance and longevity of each roof system was a top priority to meet Toronto Green Standards at each station.

Architects and roofing contractors agree the longevity of the inverted roof membrane assembly is determined by protecting the membrane from UV exposure and thermal cycles. Increasing membrane life expectancy is achieved by adding layers of material above the membrane. In the most basic assembly, the layers above the membrane may be insulation, filter fabric and ballast. For a vegetated roof, the layers may be insulation, drainage space, root barrier, filter fabric and a planting medium.

When the roof curves, the materials and methods used to protect the membrane of the inverted roof assembly grow increasingly complex and differ from project to project. The structure below the membrane is no longer flat with gentle slopes to facilitate drainage. For each of the TTC roof designs, the steel deck was segmented to approximate the curvature of the roof. This segmented structure opposite the curved finished roof profile created an interstitial space with varying heights.

**York University Station**

At York University Station, the 1,140 square-meter inverted roof with flowing compound curves ended in an undulating perimeter gutter system. Adamson Associates, architect of record, credits the accuracy of the completed station to the early design and budget rounds prior to construction documents (CD) that closely monitored project data. Additionally, “at each CD submission costing was incorporated to help stay the course and prevent surprises,” said Estelito So of Adamson Associates.
Materials used for the inverted roof membrane assembly at York University Station, from the segmented steel deck were: Densdeck Prime, Soprema Elastcol primer, Soprema Sopralene base sheet, Tremco Butyl tape, Radius Track pre-curved hat channel, track and studs connected by varying height angle clips, Roxul Rockboard semi rigid insulation, Kalzip Aluminum Panel standing seam, and ColorGad snow retention system.

The roofing contractor, Bothwell-Accurate, leveraged technology, tech savvy partners and a Kalzip certified in-house installation team to deliver their scope of work under a compressed schedule. As soon as the steel deck was installed, and the roof area was turned over to Bothwell, they executed a 3D scan of the entire roof to identify as-built conditions and precisely locate the roof deck. To bridge the gap from the roof deck to the smooth finished metal roof, Bothwell engaged Radius Track to design, engineer and fabricate a light-gauge sub-system using the 3D scan along with construction documents and supplemental information.

While Bothwell installed the sheathing board and 2-ply modified bituminous membrane, Radius Track designed, engineered and fabricated the sub-system to fit the interstitial space and set the geometry for the custom curved Kalzip standing seam metal roof. The sub-system began with hat-channel fastened to the superstructure through the 2-ply membrane. The installation team unitized pre-curved track and stud profiles onsite and hoisted them into place. Each unitized section was fastened to a specific hat-channel using a clip angle of appropriate height. With the geometry set, standing seam metal roof clips were attached to the track-stud units.

The entire system was closely coordinated with the membrane manufacturer, Soprema, to develop a warranty approved method. Around and below the pre-curved framing, Roxul mineral wool insulation covered the 2-ply membrane system.
In addition to setting the geometry, the light-gauge sub-system provided an airspace between the insulation and standing seam panels. The high albedo standing seam metal panels reduced the overall solar heat gains of the roof by reflecting a large amount of the sun’s rays. This inverted approach, which combined thermal protection via insulation and airspace, also provided protection from the sound of rain or hail hitting the standing seam metal roof—and protected the 2-ply membrane system from thermal and UV degradation.

The high-performance roof system installation was coordinated virtually through 3D model sharing before the sub-system or roof panels were fabricated. Radius Track and Kalzip coordinated and sequenced the sub-framing fabrication, standing seam panel production and delivery to facilitate continuous installation. The curvilinear shape of this inverted roof membrane assembly required the design and construction teams to leverage advanced materials and methods to provide lasting performance and deliver geometric precision.

**Highway 407 Station**

Heading north from York University, the Highway 407 station is a multimodal transportation hub combining subway, regional rail and bus transit services. The roof of this transit hub curves and stretches to provide protection from the elements. Materials used for the inverted roof membrane assembly at the Highway 407 Station starting from the segmented steel deck were: Densdeck Prime, Soprema Elastcol primer, Soprema Sopralene base sheet, Tremco Butyl tape, Radius Track pre-curved studs attached with varying height angle clips, Roxul Rockboard semi rigid insulation, and Kalzip Aluminum Panel standing seam.

“The segmented metal roof deck created variations ranging from 2 to 16 inches in the support heights for the track,” said Brett Moore of Gage Metal Cladding Ltd., the roofing contractor. The team looked to the sub-system to overcome the height differences created by the flat deck sections opposite the doubly curving roof.

**Project Team:**

**Design Engineers:**
- Parsons Brinckerhoff

**Design Architect:**
- Aedas

**Architect of Record:**
- AECOM

**General Contractor:**
- OHL/FCC Limited Partnership

**Roofing Contractor:**
- Gage

**Metal Cladding Ltd.**
**Sub-system Design, Engineering & Fabrication:**
- Radius Track Corporation

Overall view of the Highway 407 Station, Vaughan, Ontario, Canada. Photo courtesy of Jack Landau.
Once contracted by Gage Metal Cladding, Radius Track executed a surface analysis of the finished skin compared to a 3D scan of the segmented roof deck. Using that data, the Radius Track team generated a height differential “heat map” to identify height ranges. The analytical process provided information to color-code stand-off clips based on height. The installation team used color-coordinated layout drawings to match the color-coded clips to achieve the necessary height to connect to the pre-curved studs. This process set the geometry of the roof surface and provided the precise fastening surface for the Kalzip standing seam metal roof.

The collaboration between the sub-system and standing seam providers benefited the roof installation process. The pre-fabricated light-gauge metal sub-system enabled the roofing contractor to focus on other scope of work items while the sub-system was designed, engineered and fabricated. Additionally, coordination of the sub-system and roofing panel 3D models provided geometric fabrication precision and decreased risk. The insulation, airspace and high albedo metal panel roofing combined to deliver the geometry of the design intent and met cool roof requirements of the Toronto Green Standard.

**Vaughan Metropolitan Centre Station**

Traveling further north to the last station of the extension, Vaughan Metropolitan Centre station rises from the ground in a torus shape with 39 skylights penetrating the shell. Here, the roof is topped with a zinc double lock standing seam metal roof system by Rheinzink. The entire assembly is built up from the structural steel deck with Densdeck Prime, Soprema Elastcol primer, Soprema Sopralene base sheet, Tremco Butyl tape, Radius Track pre-curved hat channel, track and stud connected by varying height stand-off clips, Dow Styrofoam rigid insulation, plywood sheathing, Soprema Shield, Enkamat thermal break, Rheinzink Zinc Panel double lock standing seam, and SnoFence snow retention system by S-5.

Like York University station, this roof installation included onsite unitization of pre-curved track and stud sections. Bothwell-Accurate pre-assembled sections of track and stud and lifted them into place while accommodating the skylights. A layer of plywood sheathed covered the pre-curved sub-system and was covered by another membrane. Between this membrane layer and the zinc cladding, a 3D mat (Enkamat) was required to facilitate air movement, mitigate heat buildup
and evacuate moisture. Each layer of the inverted roof membrane assembly was carefully specified to deliver a durable finished product that honored the design intent and met the high-performance cool roof criteria.

“There were many opportunities where things could have gone sideways,” said Alfredo Falcone of Adamson Associates. “We invested significant effort to ensure these projects followed the design intent and were built to the details.” Because the pre-curved sub-system was CNC fabricated using data extracted from the 3D model it removed field cutting operations and decreased site debris. It set the geometry for the standing seam metal roof and provided a transition from the segmented deck to the doubly curved torus shell finished skin. Each layer of the assembly is an integral part of the success of this roof—by contributing as a barrier, protector, geometric determinate, mitigator or second barrier.
Metal Roofs Deliver Vision & Performance

These three transit stations highlight complex roof geometry as a key design feature. Each project leveraged expert collaboration, advanced processes and the capability of metal sub-framing and finished skin panels to successfully honor the design vision with cool roof performance. Trevor McGrath of Bothwell-Accurate commented, “Each of these stations gives back to every person passing through them in a way they may not be aware of, and provides a positive impact through the natural light, beautifully designed spaces and well-planned wayfinding.”

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Sheri Carter, AIA, is project content strategist for the company. She may be reached at sheri@radiustrack.com.
Meeting these needs, translucent cellular polycarbonate glazing (CPG) systems are used widely in new construction and renovation, and are a particular fit with metal building construction. Common building application types for CPG systems are warehouses, aviation hangars, school gymnasiums, college sports practice facilities, wastewater treatment plants, industrial facilities and other commercial applications.

**Optimizing Comfort and Savings**

Access to daylighting provides recognized benefits to health and wellness, accuracy and productivity. Spaces designed for daylight have demonstrated lower absenteeism, shorter hospital stays, higher test scores, improved retail sales and higher job satisfaction. Daylighting in commercial buildings...
also decreases the demand on electric lighting, which reduces the associated energy costs, emissions output and resource consumption.

CPG systems contribute to a sustainable, energy-efficient building envelope and comfortable, daylit interiors. Choosing the optimal amount of diffusion can be critical to the building occupants’ comfort and concentration. Too much light can result in “hot spots” with reflections on computer screens. Too little light can lead to poor comprehension and inaccuracies. Both extremes can cause eyestrain and headaches.

Most often CPG systems are specified with an opal color glazing, which delivers moderate to high diffusion for evenly distributed light, but also may be specified with a clear glazing for low diffusion and high light transmission.

Managing Light and Heat

Daylighting assemblies that utilize older technologies like Fiberglass Reinforced Plastic (FRP) often have a light transmittance range as low as 12-20 percent. With light transmittance this low, substantially more FRP material is required to maintain the same light levels as systems with a higher light transmittance. Also the addition of fiberglass infill insulation to these systems to achieve desired thermal performance could further reduce light transmittance.

In comparison, daylighting assemblies relying on CPG have a light transmittance range of approximately 45-70 percent. Compared to FRP, these materials provide a higher light transmittance per square-foot, improving the amount of daylight entering the structure, while reducing overall system costs and still achieving high thermal and insulation performance.

The high insulating and thermal performance of CPG systems further enhance building envelope performance by keeping the unwanted heat outside in warmer climates and the cold outside in cooler climates. HVAC load reduction can save building owners on both equipment costs and peak usage rates. Some utility providers also may offer credits or rebates to building owners that achieve significant reductions and continued efficiency.

When evaluating thermal performance for a building envelope’s translucent CPG wall systems, U-value is the preferred measurement, but R-value also may be specified by some. Where U-value measures the rate of heat transfer and a lower number indicates better performance, the R-value measures resistance to heat transfer and a higher number indicates better performance. Remember that an R-value does not account for all of the daylighting assembly’s components and facets that are represented in U-value calculations.

On average, a U-factor of 0.26 and an R-value of 3.84 can be expected for a CPG system with a thickness of 1-inch. In contrast, a U-factor of 0.48 and an R-value of 2.08 would be typical of a double-pane, insulated glass unit (IGU) of the same thickness.

Installing with Ease

CPG systems can be field fabricated at the jobsite, or pre-fabricated in factory-controlled conditions to ensure the system performs as intended. CPG products are extremely versatile because the material is easy to fabricate and very workable. It can be cold-formed to a radius in the field.

Integral to proper installation and performance, CPG systems include aluminum framing members with:

• Deep glazing pockets to allow for thermal movement without disengagement of the panels
• Low-friction gaskets to allow the panels to move without pulling the gaskets from the frame
• Thermal movement or pressure plates designed to provide consistent pressure on the gaskets without over-tightening that might restrict the panels
Multiwall CPG systems rely on a tongue-and-groove profile. Joints, which have no battens of any kind, create a visually continuous wall. Some panel configurations allow the insertion of reinforcing bars that extend the length of the panel. These bars increase the panel’s spanning capability.

Compared with IGUs and other heavy glazing systems, the lightweight CPG daylighting assemblies require less material for structural supports, less fuel for transportation and less labor. A 1-inch thick piece of polycarbonate glazing weighs approximately 0.65 pounds per square-foot compared to 6.25 pounds per square-foot for an IGU of the same thickness. Because polycarbonate glazing material is formed through an extrusion process, CPG panels also can be provided at any length, as limited by shipping and handling.

When installation is more efficient, downtime is minimized, allowing building owners and occupants to be more efficient and productive.

Supporting Resiliency and Longevity
In addition to aiding efficiency, comfort and daylighting design goals, CPG systems also are recognized for contributing to projects’ durability, safety and sustainability.

- **Fire resistant** – Polycarbonate will not support its own combustion; meaning, when the source of heat or ignition is removed, polycarbonate will cease to combust.
- **Impact resistant** – Polycarbonate is 250 times more impact-resistant than an equivalent thickness of annealed glass and 30 times more than that of non-modified acrylic. Used in exterior wall and window systems, CPG systems’ high impact resistance helps protect against vandalism and storm damage.
- **UV resistant** – Because CPG systems constantly are exposed to the sun, they are co-extruded with a layer to resist ultraviolet (UV) radiation and eliminate yellowing. The UV protection repels almost 99 percent of harmful UV rays.
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**Guard Every Opening.**

**Protect Every Project.**
**POLYCARBONATE GLAZING SYSTEMS AND COMMERCIAL BUILDINGS**

- **Anti-reflective** – To facilitate a better distribution of light throughout a building’s interior, anti-reflective CPG material may be specified to reduce reflections and glare. Its appearance resembles a matte finish. This option is also ideal for entertainment venues that want to project high-resolution images and lighting effects onto a translucent backdrop.

- **Recycled and recyclable** – CPG material and daylighting assemblies may be specified with up to 40 percent recycled content, depending on the project’s performance needs. At the end of its useful life on a building envelope, the polycarbonate panels and metal framing are 100 percent recyclable. CPG allows for the thermoplastic regrind to be used without diminishing the glazing material’s thermal performance.

- **Durable** – CPG systems involve minimal cleaning and maintenance. If necessary, the CPG tongue-and-groove assembly usually makes simple and quick work of repairs or replacements. For 50 years, European buildings have incorporated CPG systems in vertical wall applications. Some have remained unaltered for more than four decades. Manufacturers say that warranty claims are very rare.

### Ensuring Best Practices

A common misconception is that performance attributes are independent elements. Please remember, changes required in a product to achieve one particular performance number often will cause changes in other numbers.

Working with the CPG system manufacturer early in a project’s design is the best approach to select and specify a system that meets the goals and requirements. Should any compromises be required to achieve better performance, aesthetic or value, it is easier and less costly to accommodate these earlier in the design process and with the expertise of the manufacturer.

When properly specified, engineered and installed, CPG systems offer a sustainable daylighting solution with high thermal performance to achieve the project’s economic and environmental goals. **BE**

Jim Leslie is the general manager for Exterior Technologies Inc.
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Stretch forming was invented during the 1940s with the rise of the aerospace industry for the curving of aluminum aircraft parts to reduce weight, and thereby, fuel consumption. It expanded into car components and eventually, into the architectural industry. Architects and designers pursued new opportunities to create curved facades and building components.

The process of stretch forming is more of an art, than a science. It takes years of experience to become a skilled craftsman that can stretch form consistent, successful, curved aluminum components for architectural projects.

Stretch forming is a metal bending process in which a lineal shape, such as an aluminum extrusion, is stretched and bent simultaneously over a form, called a die. Each form is built to the required radius. These forms may be customized for a special curvature and used only once, or re-used for more popular, repeating arcs.
Opportunities with Stretch Forming

Stretch forming capabilities typically include portions of circles, including half-circles and eyebrows, ellipses and arched shapes. These shapes can be formed with straight leg sections at one or both ends of the curve. This method of curving eliminates several conventional fabrication and welding steps.

The variety of shapes and cross-sections that can be stretch-formed is almost unlimited—from muntin bars and panning for windows, cladding and spirals for handrails, large mullions for building envelopes to serpentine shapes for canopies. Stretch forming allows architects, designers and builders to realize forms as graceful as they are sturdy and functional.

In most cases, the stretch-formed aluminum component’s curvature is so highly precise that even intricate multi-components and snap-together curtainwall components can be formed from metal without loss of section properties or original design function.

To achieve this level of precision, the basic stretch-forming machine has two arms or carriage beams that hold multiple-positioning gripping jaws. Both ends of the extrusion are inserted into the gripper jaws and stretched to their yield point. The jaws are attached to hydraulic tension cylinders that stretch the extrusion. The arms swing by rotating on large, machined pins with bearings that allow the extrusion to wrap around and against the form. This produces perfectly contoured products, while limiting or even eliminating wrinkling inside the arc. When the wrapping is completed, the stretch force is released and the gripper jaws are opened.

Stretch forming maintains close and consistent tolerances with excellent repeatability, and alignments of complex profiles and compound curves. There should be no visible surface marring, distortion or ripples. These benefits inherent in the stretch forming process yield a smooth and even surface. Each component must meet the project’s specifications and warranty conditions.

Structural vs. Non-Structural Application

Aluminum has proven to be a suitable, reliable material for load-bearing structures for more than 100 years. However, the application of the parts being curved dictates the process used.

After being pushed through an extrusion press, extrusions are cut and placed into a tempering oven to harden and give them structural integrity. When they are fully hardened to a T5 or T6 temper, they are too hard to curve. If the parts to be curved have been fully tempered, they will need to be annealed before curving. To do this, the part is placed in a large oven and heated to a peak temperature range of 700 to 800 degrees Fahrenheit for two to three hours.

Annealing makes the extrusion soft again—enabling it to be curved. Metal that is annealed cannot be hardened again. Once it is softened, it will remain soft. In applications...
It takes years of experience to become a skilled craftsperson that can stretch form consistent, successful, curved aluminum components for architectural projects. Photo courtesy of Southern Stretch Forming.

where the parts are expected to carry a structural load or have another structural application, annealing generally is not an acceptable practice.

For structural or load-bearing applications, the best practice is to have extrusions tempered to a soft state of T1, T4 or to a T52 state. Material tempered to a T1 or T4 can be bent without annealing, and can be tempered after the curving process to a T5 or T6 that is typical in structural applications. T52 is a very stable temper and can be curved without annealing, and it maintains its properties after curving without the need for additional tempering.

**Painted or Anodized Finishes**

Similar to the curving process, the end-use application of the part will determine the best practice for how curved parts should be finished. If an extrusion has been painted or anodized, and has been tempered to a T5 or T6 hardness before being curved, the parts will need to be annealed. The high heat associated with the annealing process likely will cause painted finishes to burn and anodized finishes to discolor or craze. For this reason, when parts require annealing, it is best to finish them after the curving process has been completed.

For extrusions tempered to a T1, T4 or T52 hardness, parts can be finished before curving. However, some marring or slight damage to the finished surface should be expected due to the parts being stretched across the form’s hard surface during the curving process. Depending on the tightness of the radius, anodic coatings also may craze or discolor as a result of being curved. If the T1 or T4 tempered extrusions require oven-aged tempering after curving, the high heat will likely damage the coating.

Regardless of the effect the curving process has on the finish, nearly all manufacturer and applicator warranties are voided when extrusions or brake metal are finished prior to curving. To obtain the best finish quality and to keep parts fully warranted, it is best to finish after curving—regardless of the temper of the extrusion. The American Architectural Manufacturers Association (AAMA) publishes industry-accepted specification standards for anodize and paint finishing of architectural aluminum components.

**Thermally Improved Curves**

At least one U.S. finishing and service provider also offers thermal improvement services for curved and radius, finished aluminum extrusions backed with an industry-leading warranty. The thermal improvement processes may be specified as either a full pour-and-debridge of radius material, both structural and non-structural, or a fully cramped thermal strut system. The service provider places no restrictions to the degree of curvature, and finishes may be specified in liquid paint, powder coat or anodize.

Installing the thermal barrier in the metal after it has been curved helps minimize stress on the thermal barrier and ensures performance as specified. Choosing the thermal strut system provides the additional design flexibility of dual finishing, where the interior and exterior surfaces may be finished in different colors and formulations.

Ensure that aluminum products’ thermal improvement options strictly comply with its material suppliers’ standards and AAMA’s quality assurance processing guidelines. For optimal quality and convenience, some finishers provide a single-source solution where stretch forming, thermal improvement and finishing are synchronized and retain the full warranty. When available, utilizing the finisher’s trucks also can reduce material handling and packaging to minimize the opportunity for damage, while saving costs and time.

Tammy Schroeder, LEED Green Associate, is a senior marketing specialist at Linetec. She has more than a decade of experience working with architectural aluminum products and finishes. She also develops the company’s American Institute of Architects/Continuing Education System (AIA/CES) programs, and serves on the AAMA’s Tactical Marketing Plan Group and Value Proposition Work Group committees. Schroeder can be reached at tammy@linetec.com.
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The Ancient Greeks believed five basic elements made-up the Universe: earth, water, air, fire and aether (the so-called “classical elements”). And, coincidentally, the Ancient Greeks were among the first cultures to build masonry cavity walls.

It turns out that masonry cavity walls help defend buildings against several of the classical elements: water, air and fire. As the Masonry Advisory Council (MAC) explains:

“Today, masonry cavity walls are used extensively throughout the United States in all types of buildings. The primary reasons for their popularity are superior resistance to rain penetration, excellent thermal properties, excellent resistance to sound transmission and high resistance to fire.”

**A Closer Look at Masonry Cavity Walls**

In case you’re not familiar with masonry cavity walls, they consist of two separate masonry layers (“wythes”) with an air space between them. Corrosion-resistant wall ties connect the two wythes, which can be built of brick, structural clay tile, concrete, concrete blocks or stone. For best performance, insulation is installed on the inner wythe’s outside face. An un-obstructed air space must be maintained in the cavity to allow any moisture that penetrates the outer wythe to drain down its inside face to flashings that channel it back out of the wall via weep holes.

This system provides exceptional moisture defense for the overall wall assembly by keeping moisture away from the inner wythe. Because the air space is crucial for managing moisture, the TMS 402-11 *Building Code Requirements for Masonry Structures* (section 6.2.2.8.2) calls for:
Numerous wall assemblies. In addition to exceptionally moisture management, the multi-layer wall configuration aids in thermal performance. “Both wythes act as a heat reservoir, positively affecting heating and cooling modes,” notes the MAC. The two wythes with air space also dampens sound, for a quieter indoor environment. MAC also notes masonry cavity walls have “excellent fire resistance,” as shown in testing, and that “all cavity walls have a fire rating of 4 hours or greater.”

Specifying Insulation in Masonry Cavity Walls

Various types of insulation have been used in masonry cavity walls: rigid foam boards, spray polyurethane foam (SPF) and mineral wool. Among these, two rigid foams predominate: extruded polystyrene (XPS) and polyisocyanurate (polyiso).

Let’s look more closely at polyiso’s thermal and moisture performance, along with other advantages, including fire performance and resistance to solvents.

Thermal and Moisture Performance

One of the main benefits polyiso can provide in a masonry cavity wall is meeting today’s higher code mandated R-values without increasing insulation thickness to a point where it minimizes the airspace or forces expansion of the cavity to accommodate the insulation. Polyiso offers increased R-value per inch vs. mineral fiber, XPS or EPS insulation options, so is particularly well-suited for masonry cavity walls, giving the 1-inch minimum air space requirement. This enables a thinner overall wall assembly than is possible with other insulations, thereby lowering material and labor costs for wall construction.

Additionally, as a closed-cell insulation, polyiso resists moisture intrusion. Products with foil facers also enhance water resistance. “The foil face on the polyiso insulation is an impermeable material, which enhances long-term thermal performance,” notes the Polyiso Insulation Manufacturers Association (PIMA) in its Technical Bulletin 401. This dual moisture protection of the facers and closed cells is important, as an insulation’s R-value decreases when it is moistened.

Fire Performance

The chemical bonds within polyiso provide a high level of fire resistance. Unlike other rigid foam insulations, polyiso does not melt when exposed to fire, but instead develops a protective char. In light of this fire performance, polyiso manufacturers have developed products that pass NFPA 285, Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-Load-Bearing Wall Assemblies Containing Combustible Components, in numerous wall assemblies.

Additionally, due to polyiso’s fire performance characteristics, special header details in windows and openings are not required to pass this test. Further, if a building has combustible claddings in some areas and brick in others, XPS doesn’t have approved NFPA 285 assemblies, while polyiso does, so it doesn’t require changing materials in different parts of the building.

Resistance to Solvents

As PIMA notes, cavity wall designs often include materials with petroleum-based solvents—such as adhesives, preservative coatings and waterproofing. Such solvents can degrade other rigid foam insulations, but do not affect polyiso.

Example Project: Manor High School

The fast-growing Austin, Texas, metro area added nearly 300,000 people from 2010 to 2015, and the region remains one of the top 10 for growth in the U.S. The Manor Independent School District in suburban Manor, Texas, experiences the Austin region’s growth impacts first hand as it prepares to double its student count in the next five years from 9,000 to 18,000 students, reports KXAN TV.

To serve the larger student body, the district in 2017 added a new Manor High School on an adjacent campus to supplement the existing high school.

Designed by Perkins + Will, the new school building has cavity walls comprised of rock masonry, metal cladding, and metal stud framing with exterior gypsum. One challenge the architects faced was providing continuous insulation within the cavity, while also meeting fire requirements under NFPA 285.

“The project was originally spec’d with XPS insulation, but swapping that out for Hunter Panels Xci CG polyiso improved the thermal performance, and met NFPA 285,” says Darren Butler, president of NVLP Materials. “The price did not change when switching to Xci CG for the contractor and everyone was happy and code compliant.”

Conclusion

In addition to building with masonry cavity walls and organizing the physical world into their five “classical elements,” the Ancient Greeks produced many of history’s best-known philosophers. One of them, Socrates, said “The only true wisdom is knowing you know nothing.” That might not always be true for highly educated and experienced architects and engineers, but is useful to keep in mind when designing buildings. For example, many building professionals know polyiso as a roof insulation, but considering it for use in walls—including masonry cavity walls—can provide many benefits as noted in this article. BE
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peculation shrouds the future: traditional sources of energy are rec-
ognized to have environmental drawbacks, while alternative sources
have a long way to go before they can be considered viable replace-
ments. In this uncertain time, energy efficiency of the building enve-
lope ought to be a top priority in new construction to reduce heating and
cooling demands.

For stud frame walls, there are two keys to energy efficiency: insulation and
moisture control. The need for insulation is obvious; slowing the transfer of
heat lessens the need for a building’s HVAC systems to run. However, mois-
ture control is just as important. If water is allowed to accumulate or condense,
the structure will begin to degrade, and no amount of insulation will save a
rotting wall.

Clearly, an efficient wall must also be a resilient wall. Nevertheless, specify-
ing a code-compliant wall for both optimal thermal and moisture performance
can be a challenge. Two online tools (one new, one previously existing) are
ready to help the designer simplify this process. The Steel Wall Calculator
and the Wood Wall Calculator developed by the Applied Building Technology Group (ABTG) check a given wall for thermal and moisture code compliance, and allow the user to fine-tune a design for cost and industry best practice. At first glance, the calculators can seem a little overwhelming, so this article will walk the reader through their use to clear up any confusion. Additionally, we will examine how the use of polyisocyanurate (polyiso) insulation can ease the complications of wall design.

Once used primarily on roofs, polyiso also works well throughout the building envelope. In this article, we’ll focus on its use in walls.

One of the greatest threats to the integrity of an insulation system is the effect of thermal bridging. Thermal bridging occurs when there are paths that heat can take through a wall that avoid whatever insulation has been installed. For example, in a stud wall with insulated cavities, heat can travel through the studs themselves rather than the insulation—the studs act as thermal bridges.

When lumber studs are used, they can degrade wall thermal performance by 19 percent when compared to the rated R-value of the cavity insulation. Steel studs are much worse, causing a drop in performance of as much as 47 percent. This is where polyiso comes in. Polyiso is installed as continuous insulation (CI) outside of the studs in an unbroken layer to block the thermal bridges provided by the studs. There are several products marketed for use as CI, but polyiso stands out for having a high R-value.

Getting to Know the Calculators

First, consider the calculators. The user interfaces for both calculators are on display in Figures 1 and Figure 2.

They are organized in a similar fashion, with the top section containing explanatory information, and the input/output section below (input is on the left and output appears on the right). The main visual difference is that the wood calculator includes an optional input section for a net permeance calculation.

Input

Under Wall Assembly Inputs, the user is asked to supply the applicable building and energy code, the climate zone where the wall will be built, and specific details about the makeup of the wall including cladding type, interior and exterior sheathing layers (if included), stud size and spacing, and of course, continuous and cavity insulation R-values. These inputs are used to check thermal and moisture properties of the wall against the code requirements and building science best practices.

Output

On the right, the first section of output compares the calculated assembly U-factor with the energy code requirement. It also compares the prescriptive insulation requirements to the user-proposed insulation levels. If either of these comparisons pass, the wall is considered code compliant for thermal purposes. If both checks fail, the user can increase the insulation amounts in either the CI input or the cavity insulation input until one of the checks passes. By altering the amounts of cavity and CI, the user can compare the relative performance of several configurations, and possibly save on material costs. Note that obtaining higher R-values is more efficiently achieved by adding more continuous insulation due to the reduced thermal bridging.

Below the thermal check is the moisture check. This section computes the ratio of CI to cavity insulation, and, based on the result, makes a recommendation regarding the use of class I, II or III vapor retarders on the interior side of the wall. These recommendations are based on both the U.S. and Canadian codes, as well as independent research (a full treatment of the relevant building science can be found in a research report from ABTG). Following these recommendations will help to ensure that the wall cavity stays dry, and any moisture that does make it inside is able to dry to the interior or exterior, rather than being trapped between two low permeance material layers.

When properly taped, sealed and integrated with flashing, foil-faced polyiso can serve as a water resistive barrier (WRB) and air barrier. The example below highlights the advantages of these traits.

Most polyiso wall insulation is sold in sheets with foil facers. Photo courtesy of PIMA.
Example

Now armed with some basic knowledge, the best way to understand the calculators is to use them. We will design a steel stud wall for a commercial nonresidential building in Chicago.

- Chicago is located in climate zone 5 according to the International Energy Conservation Code (IECC). In the input section of the steel calculator, select “IBC 2015 + IECC-C (Excluding group R)” under Building Code and Year, and select “5” under climate zone.

- To the right, in the Energy Code Thermal Check under “Output,” the U-factor and R-value requirements for the wall have updated to reflect the climate zone 5 requirements (at this point, the calculator allows the user to use the heating degree days at the specific location of the project to interpolate the moisture requirements, but we will leave this field blank and use the default value).

- Inputs three through eight each describe some aspect of the wall’s construction. We will use the default values for cladding, exterior sheathing, stud and framing factor, and interior sheathing, which leaves us with the insulation.

- There are several options. We could follow the prescriptive requirement: R13 + 5CI, or we could choose our own CI and cavity insulation levels, testing different values to find a combination that works. One option would be to rely entirely on polyiso CI, and leave out cavity insulation entirely.

Through trial and error, we find that CI rated R-12.7 satisfies the energy code (Figure 3). The water vapor control check indicates that any class vapor retarder can be installed on the interior due to the high insulation ratio.

The thickness of polyiso CI insulation required to meet the R-12.7 requirement will vary based on the exact product selected. Remember, the high R-value of polyiso CI will require less insulation to meet the same R-value requirement compared to other options. Equally important, most manufacturers supply polyiso in various thicknesses that can be selected to fit the needs of your job. No insulation is needed in the cavities, which simplifies construction labor.

Additionally, relying entirely on polyiso CI results in a wall cavity that stays at the same temperature as the conditioned space year-round. This ensures that condensation within the cavity will be kept to a minimum, so the builder has the flexibility to use any class vapor retarder on the interior of the wall without the risk of trapping moisture. As noted earlier, polyiso CI can serve as WRB and air barrier, eliminating the need for multiple other layers to the wall assembly.

Behind the Scenes

You may be asking yourself, “how do the calculators generate their results?” Due to the large difference between the thermal conductivities of wood and steel, the two calculators use different methods to arrive at a wall assembly U-factor.
• The wood calculator uses the parallel path method described in the ASHRAE Handbook of Fundamentals, chapter 27.4
• The steel calculator utilizes the correction-factor approach from the International Energy Conservation Code (IECC)3 commercial provisions.

The parallel path method assumes that heat flows in straight paths parallel to one another and perpendicular to the surface of the wall, without moving “sideways,” say, from cavity insulation to stud. If this assumption is true, then, the R-value of each path can be computed, and combined to get an assembly U-factor. For current purposes, heat can take two paths through the wall: through the cavity, or through the stud. The R-value of each path is found by totaling the R-value of each layer in the path. Then, the two paths are area-weighted to yield an assembly R-value and U-factor. For studs at 16 inches-on-center spacing, the calculator assumes the wall is 25 percent framing and 75 percent cavity. As the spacing increases to 19.2 or 24 inches, the framing percentage drops to 23.8 and 22 percent, respectively.

The parallel path method cannot be used for a steel framed wall, however. The central assumption—that heat only flows in parallel paths normal to the surface of the wall—does not hold true for steel studs due to the complexity of the stud shape and its thermal conductance. Instead, heat in the vicinity of the stud will flow towards the stud and the less-restrictive pathway it provides. For steel-framed walls, other methods must be used. The correction factor method is one such alternative, which downgrades cavity insulation in steel stud walls by a correction factor determined through testing. The wall assembly R-value is simply the sum of the R-values of each continuous wall layer (cladding, sheathing, finish and CI) and the corrected cavity insulation value. The correction factors for a variety of wall configurations are given in Table C402.1.4.1 of the IECC.

Conclusion
In the complex process of specifying robust walls to meet code requirements, the wall calculators from ABTG can speed up decision making via making iterations easier and with less guesswork. This opens up opportunities to be more creative with respect to making assemblies easy to install while maximizing energy efficiency and economy. Polyiso CI simplifies design and construction, providing an all-in-one control layer for stud walls. More information about polyiso is available at polyiso.org, the website of the Polyisocyanurate Insulation Manufacturers Association (PIMA). Many other resources regarding the use of CI can also be found at continuousinsulation.org. BE

References
1. Results from parallel path R-value calculation for SPF 2x4 studs at 16 inches-on-center with R-13 cavity batt insulation.
2. Results from correction factor R-value calculation for 3.5-inch steel studs at 16-inches-on-center with R-13 cavity batt insulation.
3. Note: the wood calculator includes a second moisture check. If the user prefers, he or she can choose an interior vapor retarder based on the permeance of the exterior layers. Once the permeance of each individual exterior layer is entered in the optional input area on the left, the calculator will display usage recommendations for each class of interior vapor retarder. This alternate check is absent from the steel calculator due to the fact that most steel wall assemblies include class I equivalent vapor retarders on the exterior side of the wall due to CI requirements, and this precludes the permeance based approach.
The U.S. may have withdrawn from the Paris Climate Accord, but that hasn’t stopped cities and counties from adopting their own regulations aimed at mitigating the effects of climate change. The construction and building industry has taken steps to reduce carbon dioxide emissions and mitigate the effects of climate change, but industry leaders should be ready to take these efforts further through stretch and reach codes.

According to the Building Codes Assistance Project (BCAP), stretch codes are a voluntary appendix to a mandatory statewide minimum energy code that allows municipalities to adopt a uniform beyond-code option to achieve greater levels of energy efficiency.

To date, stretch energy code requirements (in municipalities that have adopted them) have applied to the design and construction of:

- New residential buildings of three stories or less
- Portions of existing residential buildings undergoing renovation or addition
- Larger commercial buildings (above 5,000 square-feet for most projects)

Reach codes are a set of statewide optional construction standards for energy efficiency that exceed the requirements of the state’s mandatory codes. Currently, reach energy code requirements apply to the design and construction of new and existing commercial and residential projects where the builder has chosen to comply with the reach code.

According to the BCAP, the goal of both stretch and reach codes is to pull the construction market upward, priming the industry for changes that could be part of the next update for the state baseline energy code.

Benefits of adopting a stretch code include: a winning solution for cities, the building industry and utilities; putting cities and states on the path to achieving zero carbon emissions from the building sector; reducing building energy use and costs; exercising flexibility and creativity in the way one adopts the codes.

**Examples of Stretch and Reach Code Adoption**

Massachusetts adopted a stretch code that provides a route to achieving a 20 to 35 percent increase in energy efficiency in new residential buildings, and 20 percent in commercial buildings. For residential construction, it uses a performance-based code, giving developers flexibility in how they choose to meet that target, as long as they achieve a HERS rating of 55. Commercial developers must follow a prescriptive route that requires a specific set of energy improvements. More than 180 municipalities are participating in the state’s Green Community Designation and Grant Program, which...
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provides funding and technical guidance to municipalities that pledge to reduce their energy use by 20 percent over five years, as well as other criteria that encourage renewable energy development.

In 2015, Governor Andrew Cuomo helped the State of New York establish a roadmap toward a clean, resilient and affordable energy system for the state. To help achieve these ambitious goals, the New York State Energy Research and Development Authority (NYSERDA) led an effort to develop NY Stretch-Energy, a voluntary, locally-adopted stretch energy code which offers municipalities a more energy-efficient alternative to the minimum state energy code. The plan includes three quantifiable targets to achieve by 2030:

1. A 40 percent reduction in greenhouse gas emissions from 1990 levels
2. Fifty percent energy from renewable sources
3. A 23 percent decrease in building energy consumption from 2012 levels

Vermont adopted stretch codes as part of its Comprehensive Energy Plan, with the goal of reducing its greenhouse gas emissions; the state is aiming for a 40 percent reduction below 1990 levels by 2030, and an 80 percent to 95 percent reduction below 1990 levels by 2050. The state says, “environmentally sound energy policy rises in prominence in the context of our urgent need to mitigate the global climate change that is resulting from greenhouse gas emissions, while also advancing local environmental sustainability.”

In 2011 the Oregon Reach Code (ORC) was first made available. It contains both residential and commercial provisions based on the 2012 International Green Construction Code public version 2.0 with Oregon amendments. Its developers intended the code to be economically and technically feasible while maintaining effective energy use and employment of renewable energy technology through regulating design.

Finally, Rhode Island adopted a stretch code in 2017 with the desired outcomes of promoting energy efficient homes, assisting with construction of net-zero energy homes, expanding the installation of renewable energy systems and constructing healthy homes. The development was part of Governor Gina Raimondo’s Executive Order 15-17, which set robust energy reduction targets and clean energy goals for state agencies consistent with her “Lead By Example” initiative and broader policy goals that include clean energy industry and job growth.

**Moving Beyond ASHRAE 90.1**

ASHRAE 90.1 is the international standard that provides minimum requirements for energy-efficient designs for buildings (with the exception of low-rise residential buildings). The New Buildings Institute (NBI) has released a set of stretch codes designed to deliver a 20 percent performance improvement for commercial buildings over the ASHRAE 90.1 baseline. A summary of the new Model Stretch Code can be accessed here. Any city or state can adopt the measures in full or adopt portions into their existing codes.

NBI’s stretch codes target five areas:

1. **Improved building envelope performance:** This includes increasing window assembly performance, reducing solar gain, increasing insulation levels in opaque buildings, reducing heat transmission losses resulting from uninsulated building elements, and improving air barrier performance to reduce energy loss and moisture transmission.
2. **Lighting system performance:** Increased use of LED’s, increased daylighting and more efficient technologies for exterior spaces.
3. **HVAC improvements:** Reducing fan energy use and incorporating heat recovery into ventilation systems.
4. **Domestic hot water:** Reduce supply run length and volume to reduce standby heat loss, as well as incorporating waste heat recovery or solar thermal systems.
5. **Plug and equipment loads:** Deploy the most energy-efficient appliances and incorporate strategies to ensure that equipment is turned off when not in use.

The nonprofit group Architecture 2030 recently released its own guidelines for a similar measure called ZERO Code, which offers new prescriptive or performance standards that can be used to exceed the ASHRAE 90.1 standard. ZERO Code applies to commercial, institutional and mid-to-high rise buildings, and should be particularly relevant in cities with a concentration of construction, where solar panels would be difficult or impossible to utilize.

Mayors from more than 350 U.S. cities have pledged their commitment to the Paris Climate Accord—including those from America’s 10 largest cities. Changes are happening rapidly; California recently adopted a new code requiring most new home construction to include solar panels starting in 2020—the first state to do so.

Stretch and reach codes are an effective way to exact real change in reducing energy demand and greenhouse gas emissions. The construction and building industry—which is responsible for nearly half the CO₂ emissions in the U.S.—should be prepared to embrace and adapt to the code changes. **BE**

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