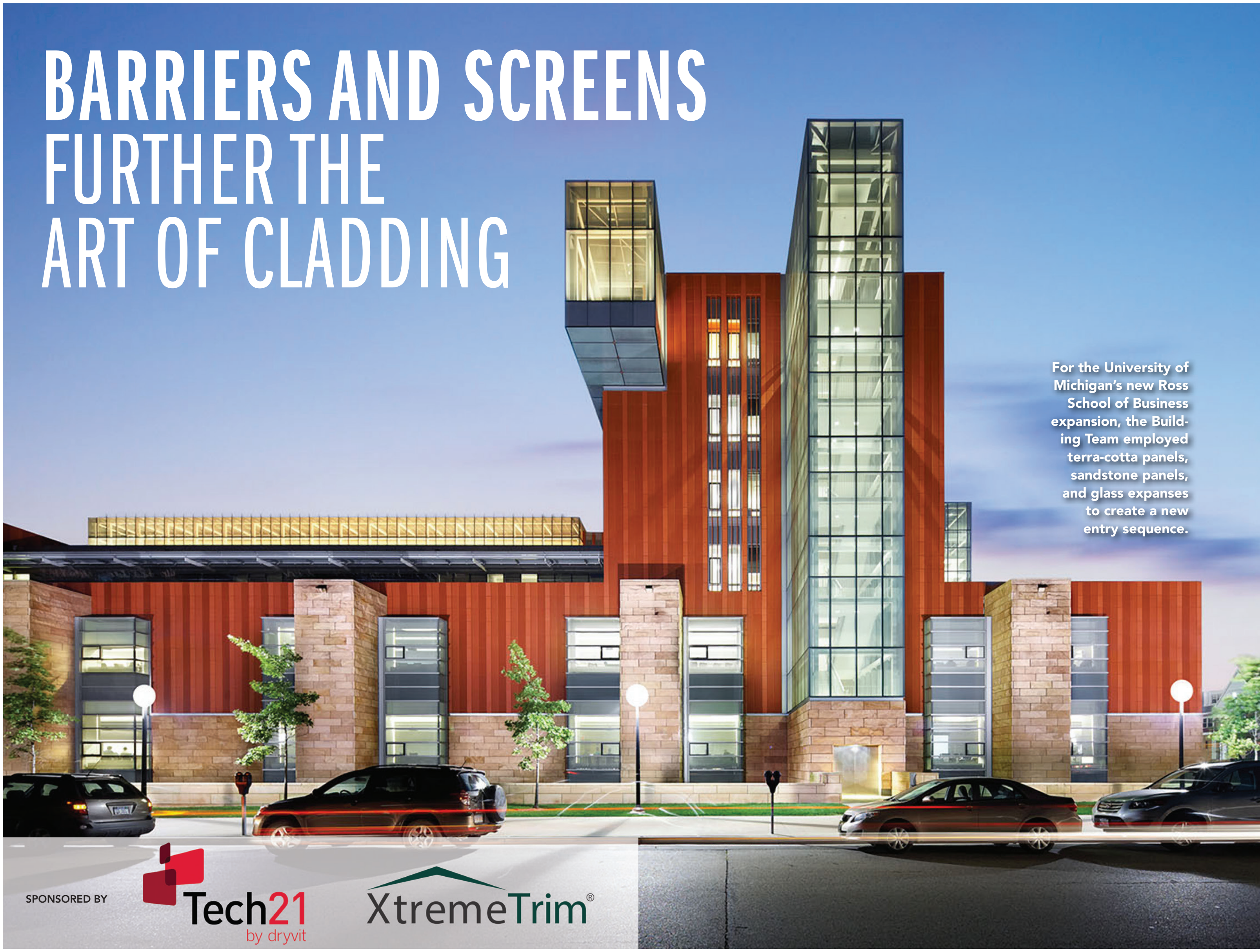
BARRIERS AND SCREENS FURTHER THE ART OF CLADDING



For the University of Michigan's new Ross School of Business expansion, the Building Team employed terra-cotta panels, sandstone panels, and glass expanses to create a new entry sequence.

RAIMUND KOCH, COURTESY COSENTINI

LEARNING OBJECTIVES

After reading this article, you should be able to:

- **+ DISCUSS the differences in design and performance between mass walls, barrier enclosures, rainscreens, and cavity walls.**
- **+ DESCRIBE the basic function of Trombe walls and dynamic buffer zones (DBZs) or mechanically ventilated enclosures, and how they impact building performance.**
- **+ EXPLAIN how BIPV systems can contribute to both opaque and translucent façade systems.**
- **+ LIST two or more cladding approaches that can improve the performance of a building by enhancing its enclosure's effectiveness.**

Is moisture control the absolute for building design decisions? Ask users, owners, occupants, and investors—and expect a chorus of agreement. They'll list moisture vapor, wind-driven rain, rooftop ponding, and material corrosion as just a few of the water-related concerns that add to maintenance, repair, and operations budgets and ultimately stand to devalue their properties.

"Roughly 90% of all wall failures are the result of moisture-related issues," says Keith Lolley, CSI, a Director of the Building Enclosure Moisture Management Institute (BEMMI) and Vice President, Advanced Building Products. Product improvements in cladding for barrier wall and rainscreen systems are critical elements of early-phase decision making. As long as they work well, that is.

In determining methods for achieving attractive, efficient, green, and economical envelopes, the first tradeoff project teams must confront is simplicity versus complexity. Some designs increase the number of components and unique details needed for controlling the ingress and egress of water, vapor, and air. The second factor is a fast-evolving array of cladding materials—metals and insulated metal sandwiches, composite panels, fiber cement, ceramic, and timber.

Advances in installation and cladding material for rainscreen or barrier wall systems are providing new opportunities for builders and architects. They must look at the basics of enclosure systems: What system type is best for the building use, the climate zone, and the project goals?

ADDING THESE MORE EFFECTIVE CERAMIC PANELS TO RAINSCREEN, CAVITY AND BARRIER WALL ASSEMBLIES SEEMS TO BE ANOTHER VALUABLE WAY TO PROTECT BUILDINGS FOR THE LONG TERM.


COURTESY CORELL TIMBER

↑ **Modified timber is increasingly used as cladding material, providing a more stable and decay-resistant material that is natural-looking and nontoxic. The manufacturing process employs steam and heat to thermally modify the material, lending it the more resilient properties.**

ASSESSING MASS AND BARRIER WALLS

Mass walls stand as the oldest form of envelope, and in modern times they are rarely found to be a more economical approach over barrier walls or cavity walls, according to Daniel J. Lemieux, AIA, and Paul E. Totten, PE, of Wiss, Janney, Elstner Associates in WBDG.org (http://tinyurl.com/WBDGwje). Wall thickness and "bond intimacy" between masonry units determine resistance to bulk water ingress for mass walls, whereas barriers are sealed tight and cavity walls employ "effective through-wall flashing to collect and redirect bulk rainwater to the building exterior."

While they may control temperature well through shear thermal mass, certain kinds of stone slabs or unit masonry and mortars can be "transparent to moisture" due to their porous and wicking nature, says building envelope consultant John Edgar. Due to their size and moisture aspects, mass walls often yield to the more modern cavity enclosures; in some cases mass walls may use a barrier wall, typically a seal-tight cladding with single-skin metal wall panels, solid-metal wall cladding, precast concrete or ceramic panels, exterior insulation and finish systems (EIFS), or insulated composites.

To ensure proper installation of barrier-type walls, project teams must take great care with joinery—including the application of gaskets and caulking—because air and water vapor leaking into the assemblies will carry enough moisture to cause damage. The cladding material itself also has to resist water, air, and vapor; most are highly effective in this regard. The joints are the problem, and the more environmental and weather-related moisture there is, the more the cladding system must resist intrusion.

There are positives and negatives to barrier-wall systems. Barriers generally have lower initial costs, as the envelope is thinner than a mass wall and also many cavity wall deigns. Moreover, because the system is often installed in a nonsequential manner, the cladding panels can be removed externally to address any necessary repairs without disrupting operations inside the facilities. Barrier assemblies effectively protect against ultraviolet (UV) radiation, thermal movement, and heavy precipitation. However, one difficulty is that after severe weather facility managers may not be able to determine how much moisture has entered the enclosure, something that can be easier to determine with cavity walls and rainscreen systems.

Weather and aging eventually degrade the gaskets and sealants used in barriers. Replacing and resealing should be planned, as well as routine cleaning for some system types. Sealants and caulks degrade, causing leaching, which may also streak and stain, sullying the façade.

RAINSCREENS: A DESIGN PERENNIAL

Cavity walls are sometimes called screened or drained enclosures, and some may also be rainscreens, typically implying that the cavity has openings at the bottom and the top of the wall. For many years project teams have used screened-wall cavity enclosure systems to handle moisture through the cavity wall.

There are three types: vented; vented/drained; and ventilated. Vented systems are rarely used in high-rise buildings due to wind loading. They provide a warm cavity that maintains a dewpoint similar to that of the external environment, reducing moisture buildup. It is only open at the bottom. Drained and vented systems (also discouraged for high-rises), promote convective ventilation with cavity openings at the top and bottom. The top opening requires an eave to protect the cavity from wind and rain.

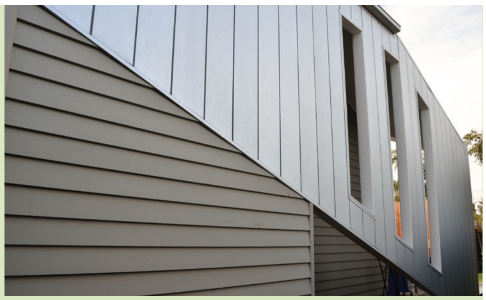
The rainscreen principle has been used in places like Norway for centuries, according to *Rainscreen Cladding: A Guide to Design Principles and Practice,* by J.M. Anderson and J. Gill. Norwegian builders used a top- and bottom-ventilated chamber behind the timber claddings on barns. The drained and back-ventilated cladding, with both open and closed joints, worked well. Water drainage and evaporation helped control the effects of rain, improving the longevity and sturdiness of the structures.

More recently, multiple-defense ventilated rainscreen assemblies have made inroads into construction markets. Though their upfront costs tend to be higher than with other options, some professionals expect more security from ventilated rainscreens and a longer lifespan in windier, wetter climates. More robust than some traditional screened-wall systems, rainscreens control and direct moisture inside and then outside of the building through venting and pressure equalization. Moisture will dry and evacuate, making rainscreens a strong choice for mid-rise and high-rise projects.

The rainscreen's exterior cladding is still the first

Varied Materials Optimize Cladding Performance

A number of cladding materials are finding broader use in today's effective building enclosures. Among the noteworthy materials are:



COURTESY CLADDING CO., SOUTH AFRICA

FIBER CEMENT PANELS

Fiber cement panels offer various performance advantages in wet climates. They resist fungi, mold, and bacteria growth, which has led to an increase in their use in certain climate zones. According Market Research Future, "Fiber-cement panels require special installation tools and can be installed over any form of substrate, which is expected to drive their growth." Like ceramic tile, fiber-cement systems come in various aesthetic sizes, shapes, and colors.

COMPOSITE

Phenolic cladding looks like wood, but it is far more durable. Various layers of paper are treated with thermosetting phenolic and melamine resins. They are bonded together with heat (325°F) and high pressure (1200 psi), with about 50 sheets of paper used to make a standard 10mm panel, according to one supplier.

CONCRETE

Traditional precast panels are known as heavy, costly-to-install cladding materials, but with appealing and enduring qualities. Recent innovations in high-performance concrete with prestressed stainless-steel cables help project teams retain the look of earlier concrete cladding options, but also maintains its design performance. Several concrete manufacturing companies now make panels ranging up to two inches in thickness and with final installed weights of 10 to 25 pounds per sf—much lighter than conventional precast. The concrete mix designs can offer strengths in excess of 5,000 psi, and the panels have been used in rainscreen assemblies attached by J-channels and metal clips bolted to the panels. Another benefit: The lighter-weight panels can be installed via tower crane, and in some cases are delivered and installed through window apertures.

METAL

One benefit of metal is that the finishes—aluminum, stainless, copper, and zinc—are popular among today's project teams. It is also strong, durable, and flexible. Weather and fire resistant, metal can serve as a sustainable cladding material, for example when used in affordable aluminum composite panel (ACP) systems. The typical panels comprise two flat panels of coil-coated aluminum bonded to a non-aluminum core. Because of their light weight, the insulating core, and the short lead time for manufacturing, they can be an economical choice for cladding. However, the core material, if it is flammable, must be properly enclosed and treated.

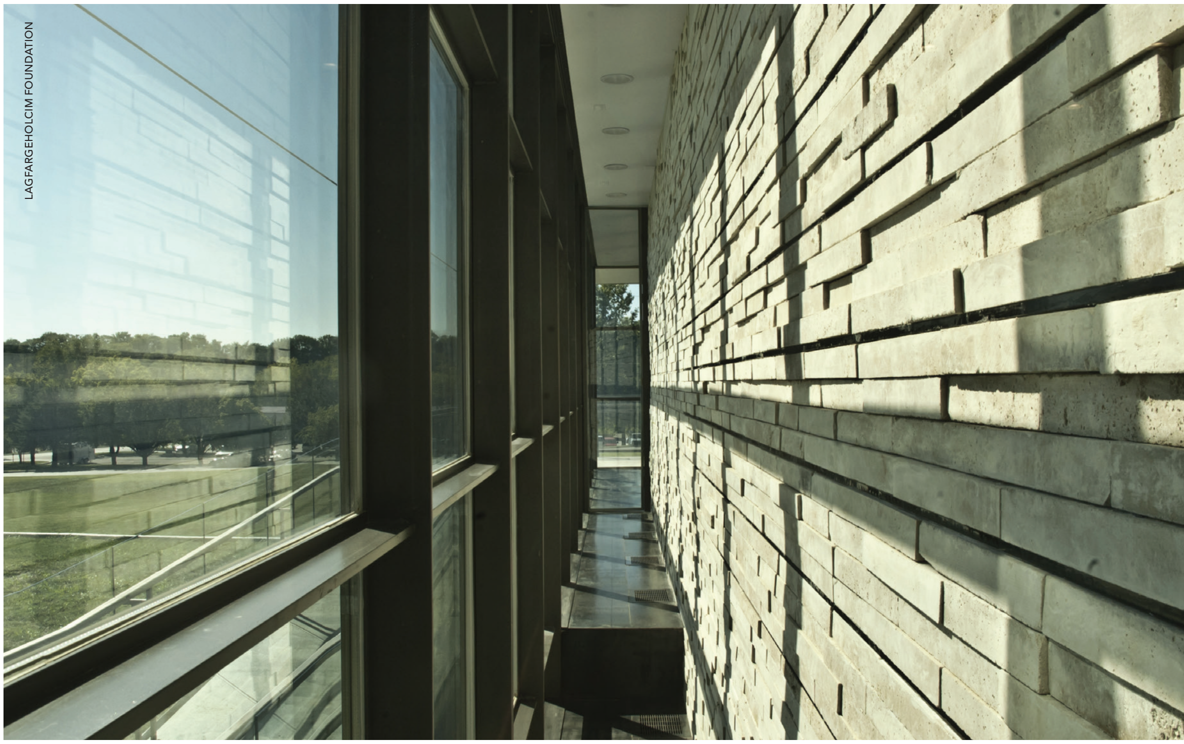
line of defense, says Bob Trainor, President, Ventana Design-Build Systems. It protects the structure from UV exposure and solar heat gain, wind loading, and wind-driven rain. The screen material doesn't have to insulate—that's handled with a third line of defense in the wall system—and typically doesn't need sealants or gaskets. The open or dry joints mean less labor for the construction team, but there is often more work for architects and engineers to ensure the entire enclosure is specified and detailed properly and aligned with all relevant codes.

Pressure equalization is an important aspect of rainscreen system design and operation, says Trainor. Ventilated façades or rainscreen systems are also described as pressure-moderated wall system, says BEMMI's Lolley. The cladding is the first defense. Water contacting the façade becomes a film, which gravity pulls down to the ground. However, unlike a barrier-wall systems that prohibit water entry with interlocking fasteners and sealants, air is allowed to enter the building through the open joints of the screen.

With this action, differential air pressures between the outside and inner wall cavity can draw moisture into the wall system's inner structure. Pressure-moderated rainscreen wall systems significantly reduce those differential pressures because air can enter the wall system and neutralize the pressure differences, according to Lolley. It's a fairly simple effect: As air enters the cavity, it rises within the enclosure and eventually exits at the top. In short, a rainscreen system attempts to create equilibrium. Called the pressure equalization chamber (PEC), the area located just behind the cladding ensures that internal and external pressures are moderated or equalized.

"Those familiar with wall design may ask, if most wall designs strive to eliminate airflow through the wall (because such airflow naturally carries water and moisture) then how can a rainscreen promote such currents and claim to control water penetration?" asks Avenere Cladding, a maker of terra cotta cladding. The answer, according to the company, rests in the "open rainscreen principle," which "limits ventilation to the cladding and the PEC." The systems must always be designed so that "the strength and volume of air flowing past the screen are sufficient enough to equalize the chamber pressure, yet remain relatively weak and therefore cannot carry moisture with them."

It sounds like a sensitive, challenging system type—and it is. In fact, the pressure moderation must be designed so that suction forces occurring within each PEC are reduced as quickly and effectively as possible, helping to cut the wind load on the screen itself. Each PEC must also be airtight, which requires effective, insulated structural walls behind the screen assemblies. Done properly, says Avenere, "Rainscreens are a further improvement on the screened-drained method of wall designs and hold promise for current as well as future wall designs."


LAGFARGEHOLCIM FOUNDATION

At Kansas University, a Trombe wall assembly that vents air in warmer months serves to protect and help heat the Facility for Collaborative Research in Sustainable Energy, a building that boasts other "showcase technologies," including a wind turbine, an electric-vehicle charging station, and an energy-conserving plant-covered roof. It is certified LEED Platinum.

TROMBE WALLS TO DOUBLE SCREENS

A number of new curtain wall approaches have been developed for use in office, institutional, and multifamily residential structures seeking high levels of performance and long-term value.

Among the main questions to address are the sealing of glass panels to framing and the control of thermal migration through the frames and seals supporting the glass, says Karol Kazmierczak, AIA, ASHRAE, CSI, LEED AP, NCARB, a building science architect based in Florida.

Trombe walls. A low-tech enclosure type designed to collect solar heat, the Trombe wall concept has been around for years. By using indirect solar heat gain to passively warm a space, these nonmechanical, effective enclosures are favored today by some green building advocates.

Typically a dark-colored wall with a high thermal mass faces the sun—yes, a mass wall—and a small cavity separates it from the glazing, effectively creating a slim greenhouse trapping solar radiation. In this way, Trombe walls optimize heat gain or loss, depending on the season.

Popularized by French engineer Félix Trombe in the 1960s, the idea caught on in the 1970s among researchers at Los Alamos National Laboratory in New Mexico, who saw the efficacy in sunny, arid climates with large daily temperature swings (delta T). Contemporary examples include projects by Canadian architect Paul Raff, who designed a slate-covered Trombe wall in Toronto. "The integrated design combines a high-performance building envelope with passive solar design systems as an effective, environmentally sustainable strategy for its northern context," according to his firm, Paul Raff Studio. A large internal slate wall behind the building's glass-enclosed southern exposure captures available solar energy to warm the interior in the evening, with smaller openings to admit controlled sunlight.

Dynamic buffer zones. Rainscreen systems use passive ventilation and are wonderful for new construction projects as well as some renovation applications. For reconstruction and retrofit situations, project teams are starting to use dynamic buffer zone (DBZ) and mechanically ventilated enclosures, which require energy for operation and help ensure exterior or interior walls are protected from moisture degradation.

DBZs are defined as "areas that actively separate the interior and exterior air using pressure differences, in order to prevent them from mixing," according to engineer Christian Cianfrone, a Principal in the Building Energy Practice at engineering firm Morrison Hershfield.

There are two ways to mechanically ventilate the cavity. The balloon system, without any intentional exhaust, senses barometric pressure to energize a fan when the pressure drops below a set-point. A second system uses continual fan ventilation with a site-specific exhaust. In typical applications, an interior wall is built for the DBZ. This can be used to remediate some barrier enclosures, as demonstrated in several projects with Morrison Hershfield.

At Ottawa's Canadian Museum of Nature, a DBZ was added to mitigate the degradation of mortar joints. Assessing the project, the engineers determined that the high humidity required for many interior exhibits was essentially degrading the façade.

At a library in Ontario, the project team determined an opposite problem was occurring. Moisture was infiltrating through the enclosure and damaging valuable books. The team solved that problem by using a DBZ retrofit approach.

Double-skin façades. Like DBZs, double façades incorporate two skins or wall systems that allow air flow in the intermediate cavity, whether through mechanical or natural means. The airflow can be used to supplement building ventilation or cooling, or it can simply be used to improve building energy efficiency at the enclosure.

The idea of double-skin façades is not new, but it has seen a renaissance lately. About 87 years after Le Corbusier designed a pioneering double-skin envelope for Villa Schwob in Switzerland—a so-called neutralizing wall with heating and cooling pipes running between large glass panels—project teams have created a wind-catching double wall for 30 St. Mary Axe, the torpedo-shaped tower in London, and a convertible stack enclosing One Angel Square in Manchester, with louvers that are closed in the winter and open in the summer.

Both of these recent commercial projects are highly sustainable, thanks to their passive approaches to heating and cooling, and also provide high levels of protection against moisture migration.

TOWARD NET-ZERO PERFORMANCE

These passive techniques are seen as essential to achieving zero-net-energy operations on a large scale in commercial and institutional buildings. In some recent hybrid construction projects, building teams have also designed enclosures using building-integrated photovoltaic (BIPV) components—not just on the rooftops, a traditionally considered location, but also on areas of the façades.

'A WHOLE NEW VERNACULAR OF SOLAR ELECTRIC ARCHITECTURE IS BEGINNING TO EMERGE.'

—STEVEN J. STRONG, SOLAR DESIGN ASSOCIATES

"Interest in the building integration of photovoltaics, where the PV elements actually become an integral part of the building—and often serving as the exterior weather skin—is growing worldwide," according to Steven J. Strong, President, Solar Design Associates, in the *Whole Building Design Guide*. "A whole new vernacular of solar electric architecture is beginning to emerge."

Challenges for façade BIPV applications include ventilation and cooling of the PV modules, which can lose efficiency when operating under elevated temperatures. Effective BIPV designs have building surfaces that reflect light onto the PV arrays while allowing for shedding of snow and access for periodic washing, especially in areas with heavy dust and other airborne particulates.

When considering these MRO aspects, project teams can employ BIPV materials on facades including opaque, semi-transparent, and fully transparent PV arrays on glass and opaque facades. These can produce savings in building materials and electricity costs, with associated reductions in fossil fuel use and ozone-depleting emissions.

BIPV systems also can add visual interest to the buildings, as at the current headquarters of BP Solar in Fairfield, Calif., which has been operating PV modules in glass laminates for curtain wall spandrel, skylight, and awning fenestration since the mid-1990s. "The heart of the project is a PV glass cube containing the factory's control center," say the project's architects, Kiss + Cathcart. "The PV cladding, in combination with a solar panel entrance canopy and a translucent PV skylight, produces all the power necessary for the control center's lighting and air-conditioning."

The track record is important to many building owners considering BIPV today. Add to that a few recent advances in BIPV that point to a revival in the systems: Tesla CEO Elon Musk has introduced new rooftop solar shingles with the company SolarCity for commercial and residential applications, and Minnesota researchers unveiled a new technique for improving the efficiency of solar windows by embedding silicon nanoparticles into transparent luminescent solar concentrators, or LSCs. Continuing advances in the area suggest less expensive and more reliable BIPV options will continue to find use in large-scale building construction.

OTHER MATERIAL ADVANCES

The BIPV innovation is warranted, if only to serve the growing demand in nonresidential buildings. According to sources such as Market Research Future, the global cladding market will grow to more than $111 billion dollars by 2025, with the lion's share of the investment going to high-efficiency materials that are also sustainable in other ways. "Stringent green building regulations and codes such as the LEED certification and others are encouraging investments in lightweight and energy-efficient exterior panels," says Ronald B. James, an expert with Market Research Future, especially in the Southeast Asia market where rising construction spending and advancing technology are pushing new enclosure approaches.

While the cladding solutions are varied and some are highly creative, a number of enclosure components and materials are worth particular consideration. Among those are:

Drainage and ventilation mats. Some rainscreens may require a very narrow cavity or small air space, due to local codes, energy standards or other project requirements. In the case of an "all-wall" for drainage and ventilation, the depth of the air gap can be as small as one inch, says BEMMI's Lolley—as opposed to the typical 1.5 to 2.0 inches—"without compromising the functionality of the intended airspace." A study of the solution published in 2013 by ASK IMI concluded that 3/8-inch all-wall continuous drainage mats were equally as effective as a two-inch air space for allowing water to drain and providing minimum ventilation for drying of the enclosure. This can improve enclosure performance when increased insulation thicknesses are needed or when there are constraints on wall thickness.

Typical drainage mats include corrugated or dimpled sheets as well as entangled net materials. The specified material should be resistant to mold and mildew as well as chemicals found in other envelope components. Specifiers recommend mats that allow multidirectional drainage and ventilation and have a Class A fire rating per the ASTM E84 standard.

THE 'INHERENT PROPERTIES' OF TERRA COTTA SYSTEMS LED THEM BE USED IN ABOUT A QUARTER OF CLADDING PROJECTS LAST YEAR.
—MARKET RESEARCH FUTURE

When specifying an engineered rainscreen material for masonry applications, the drainage mat should have a filter fabric bonded on one side in order to deflect mortar from the scratch coat, preventing clogging of the drainage medium, says Lolley. Experts in wall design also recommend that drainage mats should be slightly narrower than the air space. This helps masons and installers work on the rainscreen or veneer during construction and is typically adequate to ensure the performance of the air and drainage space.

Ceramic options. As for cladding, project teams tend to favor materials that are easy to clean, weather resistant, and durable. In some project types, a hygienic or fire-resistant material might be required; in others, scratch resistance and graffiti resistance are important. In these cases, ceramic tiles—as well as porcelain and terra cotta panels—have become increasingly desirable. The panels resist soiling and mold and tend to be resilient and durable. This makes them valuable where weather swings are likely and where building owners and operators seek a tradeoff between first cost and lower MRO needs.

Porcelain tile can be applied as a bonded material or as part of a ventilated facade. With the latter, reduced thermal transmission due to the chimney effect adds to the built-in insulation characteristics of the material, which can decrease heat loss and thermal bridging. Porcelain is also recyclable and produces negligible volatile organic compound (VOC) emissions. It also provides good life cycle performance by resisting color loss and providing a self-cleaning surface when exposed to rain and sun. These qualities—and the lightweight cladding systems used with porcelain tiles—make for effective recladding options, as for an existing office building in Carlsbad, Calif., where a team led by Ware Malcomb added a layer of porcelain tile over the original granite façade.

Another ceramic cladding material, terra cotta, can be made with multiple color, glazing, and texture options. Terra cotta siding can be power washed and layered with ship-lapped open joints. Novel terra cotta cladding systems offer ship-lapped open joints that help protect the structural wall from wind-driven rain and snow while still ventilating the airspace behind. According to Market Research Future, terra cotta systems were used in about a quarter of cladding projects in 2016, reflecting “its inherent properties": low water absorption, non-flammability, and frost-proof nature. It fights graffiti, and the aesthetic attractions of its modern look are enhanced by its warm colors and textures.

Recent projects built with terra cotta cladding include the University of Michigan’s Ross School of Business, led by engineering giant Thornton Tomasetti and architecture firm KPF. The modern façade projects a strong vertical presence enhanced with its terra cotta rainscreen cladding, which also contributed to the building’s LEED Silver certification.

A new type of tile that holds promise is *sintered ceramic*. This technology produces tiles and panels with a lower porosity than conventional ceramics by “consolidating” ceramic powder particles during manufacture. Using a sintering process, the pores “diminish or even close up, resulting in densification of the part [and] improvement of its mechanical properties,” according to a summary by Dr. Dmitri Kopeliovich in SubsTech (substech.com).

+EDITOR’S NOTE

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