CONTINUING EDUCATION AIA

New Roofing Concepts and Techniques

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By C.C. Sullivan and Barbara Horwitz-Bennett

Whether it's planting a green roof, installing building-integrated photovoltaic (BIPV) systems, or applying coatings or materials to reduce material heat emittance and surface temperature, Building Teams are paying more attention to the roof plane. Many are focused on the gains in the sustainability of their projects, and others see an opportunity to make a design or social statement on the building's "fifth wall." Others are helping ensure that the building envelope is sealed against moisture and air penetration to improve energy efficiency and occupant health, safety, and welfare.

In light of events like Hurricanes Katrina and Rita and the resulting climb in insurance premiums, roof and roof-wall assemblies need to withstand severe weather better. Other key attributes include offering more insulation, help in mitigating the urban heat-island effect. Newer challenges include structurally supporting vegetated roofs or roof-mounted energy systems, while never forgetting the basic design considerations.

Learning Objectives

After reading this article, you should be able to:

- ✔ Describe new developments affecting the sustainability of roofing assemblies and products.
- ✔ Understand the basic approaches and benefits of vegetated roofs.
- ✔ List and describe factors affecting the selection and performance of "cool roof" materials and rooftop photovoltaics.
- ✔ Discuss approaches to improving the performance of roofs as air-and-moisture barriers.

It's quite a tall order. "Some of the challenges with regard to roofing design and installations are pushing the limits of the structure, increasing the design to keep within the warranties, and creating a successful rooftop—both watertight and aesthetic—for the owner," says Angie Durhman, a green roof specialist at Jessup, Md.-based Tecta America Corp., one of the largest roofing contractors in the U.S.

GREEN ROOF PROLIFERATION

One of the more eye-catching and sustainable choices when it comes to roofing design has been the growing trend of planting atop low-slope roof surfaces. In fact, the idea of heaping earth, sod, and vegetation on rooftops has a long history. King Nebuchadnezzar II gets credit for what is certainly the earliest world-famous example: the Hanging Gardens of Babylon, one of the "Seven Wonders of the Ancient World," which dates back more than 2,600 years. However, only in recent years has the notion been adapted to contemporary roofing, drainage, and barrier technology, perhaps gaining its deepest roots in Germany in the 1970s.

"The trend around green roofs is rapidly growing, partially driven by public awareness of environmental concerns," notes Anton Germishuizen, a principal with design firm Burt Hill, Philadelphia.

Tecta's Durhman categorizes vegetated roofs as possibly having reached "the tipping point" only in the last few years. "Six years ago, I would have to explain what we were actually talking about, but now, green roofs are commonplace and have reached consumer levels of awareness," she says.

Although the U.S. has been taking some time to catch up with its European counterparts, a survey conducted by Green Roofs for Healthy Cities (http://www.greenroofs.org/resources/2007%20Green%20Roof%20Survey%20Results.pdf) revealed a 30% increase between 2006 and 2007 alone in the construction of green roofs in North America. That year, the total roof area of new installations was about 3 million square feet. In addition, the recently released *American Institute of Architects/Autodesk 2008 Green Index* (http://images.autodesk.com/adsk/files/2008_autodesk-aia_green_index_report_final.pdf) reported that 34% of architects are designing green, vegetated roof coverings for more than half of their new projects, as compared to just 7% in 2007.

Green roof benefits. Durhman lists the top four benefits of green roofs as:

1. reduction in the *urban heat-island effect*, defined as the increased collective heat generated by built-up, urban areas)
2. stormwater management
3. increased useful life of the roof—up to twice that of typical commercial roofing systems
4. reduced energy consumption as result of increased insulating value and thermal mass

Air and noise pollution, urban heat-island effect, and lack of green space were concerns faced by the developers of Macallen Building Condominiums, Boston. The sloped green roof, by architect Office dA and AOR Buth Hill, addressed those issues, while incorporating a 20,000-sf outdoor terrace.

"A green roof reduces high temperatures, in turn reducing potentially damaging ozone. Regarding stormwater runoff, green roofs intercept, delay, and absorb stormwater, and return some of it back into the atmosphere through evaporation and transportation," says Rob Ryan, ASLA, LEED AP, principal with the Atlanta-based planning and landscape architecture firm HGOR. "Runoff is also filtered of airborne pollutant particulates before it enters stormwater and stream systems."

As for energy use, a recent Association of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) study of the green roof atop Chicago's City Hall revealed a direct correlation between decreased ambient air temperature and cooling energy use. Specifically, every 1ºF drop in temperature enabled a 1.2% drop in cooling energy use. Because green roofs can maintain a 95ºF surface temperature on a 90ºF day—compared to 160 ºF for conventional dark roofs—the resulting energy and cost savings are significant.

Additional benefits include decreased roof maintenance, fewer roof drains, sound insulation, and, of course, the charm of having flowers growing atop one's warehouse or school. (Some studies have claimed that this increases property values.) In some cases, the green rooftop space can be used for meetings, recreational activities, or community events, provided they are fitted with guardrails and the roof decks can support additional live loads. "Green roofs literally become part of the building's usable floor space, and they are captured as a pure amenity. These spaces are programmed and highly used," says Ryan.

Yet another use of green roofs is for food production. For example, Vancouver's Fairmount Waterfront Hotel

PHOTO: WORCESTER POLYTECHNIC INSTITUTE

Worcester Polytechnic Institute's East Hall residence center is the site of the first vegetated green roof in Worcester, Mass. The 12,985-sf roof mixes reflecting Energy Star roofing with about 5,000 sf of sedum plantings.

grows herbs, flowers, and vegetables on its roof, saving up to $30,000 a year. Decca, a furniture manufacturer in Hong Kong, grows vegetables and fruit for up to 2,000 employee meals per day on its factory roof.

Another point worth noting is growing municipal interest in green roofs. Chicago has already established a reputation with high-profile projects such as City Hall and by co-sponsoring the nation's first green roof conference, Green Roofs for Healthy Cities, in 2003. In fact, according to a survey by Green Roofs for Healthy Cities, Chicago ranked number one as the North American city with the most installations of green roofs in 2007 at more than 500,000 square feet. In New York, the Earth Pledge Green Roofs Initiative has brought together key stakeholders, educators, developers, and government agencies to encourage green roof projects. Similarly, Portland, Ore.'s Ecoroof Program promotes R&D and offers technical assistance.

Germishuizen reports that Philadelphia's water department, faced with an increasing burden on the stormwater management system, is calling on green infrastructure to help reduce the need for building larger capacity and to reduce the number of CSOs in the city, referring to combined stormwater and sewer overflow systems, which can present a hazard during heavy storms. Priority is given to projects with green roofs in the approvals process of this city department, they explain.

Intensive vs. extensive green roofs. The two basic categories of green roofs are *intensive* and *extensive*. These terms refer to the depth of the vegetated roof cover and system used. Ryan explains: "Extensive is a low- or thin-profile system primarily for the ecological roof cover with very limited human use. The intensive is a high- or thicker-profile system that can include a wide variety of plant types." Intensive green roofs are often used for recreation space.

Although recreational use is a great amenity, intensive roofs require more structural support and maintenance, and tend to be limited to very-low-slope roofs, according to researchers at the University of Florida's Institute of Food and Agricultural Sciences. On the other hand, extensive roofs require much less maintenance and can be planted on roofs with higher slopes. And while intensive roofs require regular irrigation, extensive roofs typically initially need to be irrigated for only about half a year while the plants are being established. In general, according to the University of Florida team, extensive green roofs include the following component layers:

- waterproof roofing system
- membrane protection layer
- drainage layer
- filter mat
- lightweight growth media and plants

Choosing plant types. Matt Funk, director of The Aztec Corporation, an architectural firm in Iselin, N.J., explains that many manufacturers offer guidelines and some even have pre-planted, *unitized systems* that come in flats, just like agricultural seedlings.

According to Jay Womack, director of sustainable design in Wight & Company's Chicago office, "Most plants selected for a green roof are adapted to be drought tolerant and are found in rock gardens and other environments where moisture and organic compounds in the soil are very low. *Sedums* make up a good portion of a roof garden, but many native and non-native plants are being used and are surviving quite well."

Durhman adds, "Knowledge of soil depth, moisture retention, hardiness zone, heat zone, and design intent all play into the final plant selection."

Stormwater management. As one of green roof's major benefits, retention of storm rainfall has motivated industry leaders and top Building Teams to tweak their roof designs to maximize the capacity for holding stormwater. A Michigan State University study conducted over a 14-month period found that vegetated roofs retained 60.6% of rainfall, as compared to 50.4% for a media-only roof, and 27.2% for a conventional gravel ballast roof. Another study by researchers at Michigan State analyzed slope and depth and found that platforms with a 2% slope and a media depth of 4 cm had the greatest retention.

A recent University of Texas at Austin study concluded that substrates with large planting-medium retention cups, low drainage-hole area in the drainage layer, and a high proportion of perlite in the planting mix correlated with high water retention.

First cost vs. life cycle cost. Despite all the benefits, one potential barrier to green roof projects is finding the money to build them. "The biggest challenge may be the upfront cost," says Womack, whose firm has been involved in a number of cultural and municipal green-roofing projects in the Chicago metropolitan area. "Depending on the scale and type of roof system being used, the premium on a green roof may be two to five times the cost of a conventional roof. However, if the roof can be developed as an amenity for those in the building, it can be sold as a resource."

Robert Highman, LEED AP and technical architect with NBBJ, Seattle, points out that vegetated roof systems can help projects achieve up to nine LEED credits. "This is a huge benefit for our clients," says Highman. "Not only do they realize the basic financial benefits of extreme longevity and lower maintenance costs, they are recognized as leaders in sustainable practices. This improves marketability and professional visibility." In June 2009, Green Roofs for Healthy Cities will accredit the first group of green roof professionals, including Highman.

Developers can try to cash in on a number benefits, such as increased property values and market exposure, size reductions in stormwater management systems, faster approvals for new projects, and energy efficiency. Green roof grants may be available, as well as greenhouse gas emissions trading credits that may be tied to anticipated energy savings, according to University of Florida researchers.

Experts contend that although it is difficult to quantify benefits such as stormwater retention and improved quality of life, the overall package—including improved roof longevity and thermal insulation—should easily outweigh the increased installation costs for most green roof projects.

ROOF-INTEGRATED SOLAR

With improved aesthetics and technological capabilities, building-integrated photovoltaics, or BIPVs, have become a more serious consideration for roofing projects than five years ago, although high first costs are still an issue. In addition to power-generating solar cells, roof-installed heat collectors, water heaters, and tubular daylighting devices, known as TDDs, have also begun showing up on more projects.

The beauty of tubular daylighting devices, or TDDs, is that they have the ability to collect daylight and effectively pipe it to the interior of a building, where they then illuminate interior space just like lighting fixtures. A standard off-the-shelf system may resemble a transparent roof-mounted dome with self-flashing curb, reflective tubing, and a ceiling-level diffuser assembly. More advanced TDD models utilize sophisticated control systems to track the sun with a mirror from sunrise until sunset, thereby maximizing solar collection, as well as optical fiber bundles for directing daylight into interior spaces. Other TDD advantages include reduction in seasonal heat loss and solar gains, simple reconfiguration, and good control of light patterns and output. In addition, the lumen performance, low operating cost, and long life cycle of TDD systems make them efficient in terms of energy and maintenance resources.

RENDERING: COURTESY EGL ENERGY

Artist's rendering of a sheltered roof with built-in photovoltaics, designed by Jeremy Ho, EGL Energy, Hong Kong. Similar electricity-generating structures could be used to cover outdoor parking lots.

Integrated solar power. As for PV systems, when the technology first gained traction for commercial applications in the late 1970s, the installed cost was about $50 per watt of rated capacity, which translated to around $2.00 per kilowatt hour. By the late 90s, with an increase in demand and the development of thin-film technology, cost had dropped to about $10 per watt. However, almost all installations were done in remote areas as it was cost-prohibitive to connect to the utility grid and thus not possible to sell power back to the grid.

Today, installed costs have continued to decline to around $7 per watt or $0.25 per kWh. Further, state and utility incentive programs can bring the cost down to $3 per watt, and *time-of-use net metering* enables PV owners to sell back electricity at rates as high as $0.36 per kWh during peak summer demand times. "With the cost of production of PV panels dropping, a steady increase in energy costs that will continue to escalate as rates are deregulated, and current grants and financial incentives offered by state governments of up to 30% tax credits, the adoption of this technology is sure to increase," predicts Burt Hill's Germishuizen.

More recently, the industry has turned its attention to aesthetics of BIPVs in an effort to better integrate the panels and enhance the building's architecture. "As photovoltaic modules have become more common, manufacturers, architects, and roofing contractors have struggled to integrate them in a functional, efficient, and aesthetically pleasing manner," says Dan Perkins, owner of Dan Perkins Construction, Ishpeming, Mich.

According to Perkins, photovoltaic modules used to be covered with glass, framed with aluminum, and mounted on rooftops. Moreover, the wiring harnesses and conduit were easily visible. Now, more subtle installations are the trend, with accessible ridge caps for wiring channels and no more bulky racks.

In addition, roof system manufacturers are teaming up with solar system installers to provide warranted roof and PV systems. The resulting turnkey systems include the roof, PV cells, flashing, inverter, and wiring, according to Germishuizen. In addition, the latest PV systems offer increased durability as the new PV panels can be rolled up, making them easier to ship, handle on site, and even heat-weld to the roof membrane. Some *rolled-sheet PV products* are able to withstand high foot traffic, hail, and other hardships. Another recent technological advancement is *integrated panels* seamed into the roof system. These can be used in lieu of the tower or braced systems previously installed, according to Germishuizen.

Even though there is lots of activity in the PV market, however, the reality is that the technology is still not viable in some geographic locations or design situations. "Here in the Northwest, very few clients seem interested in the concept of integrating photovoltaic systems," says NBBJ's Highman. "There is just not enough light available to justify solar power financial expenditures. The concept is a great one, but at the moment it only makes realistic sense in sunny climates."

Nick Bristow, LEED AP, project engineer with Clayco, a St. Louis-based real estate development, design, and construction firm, notes that photovoltaic roofing systems still have a high first cost and, in most areas of the country, a payback period of 20 to 30 years. The size of the system can also be an issue. While only offsetting a small portion of the building's energy use, PV panels can consume a large portion of the building roof space. And with multi-story buildings, even less space is available and achieving a substantial offset of energy use is impractical, says Bristow.

At the same time, with regard to first cost, Bristow has seen some new developments in financing. For example, *power purchase agreements* offer building owners the ability to carry no upfront costs for the PV system. Instead, the utility or other provider of the power purchase agreement funds the BIPV project, maintains it, monitors energy production, and sells the electricity to the building owner at a fixed price, usually set below current market rates, via a 5- to 25-year contract.

Furthermore, Tecta's Durhman predicts that tax incentives and energy savings will continue to boost PVs.

COOL ROOFS, COOL SAVINGS

Cool roofs can be a more economically viable green alternative to green roofs and BIPVs, says Burt Hill's Germishuizen. "The technology is understood, risk free, requires less maintenance, and is often easier to sell to clients and end users," he says. "Installed costs are lower than planted systems, giving building owners options when looking for green or LEED-related products."

Here's how they work, according to Aztec's Funk: "The principle is that if you have a light-colored or reflective roofing surface, the sun's energy is reflected much more dramatically than a darker color. This means that the roof heats up much less, transmitting less heat energy to the building envelope. This has an impact on [lowering] HVAC demand, which reduces energy consumption."

In most cases, cool roofs offer a longer lifespan than their more traditional alternatives. As the cooler systems generally contain the same components as a regular roof, first cost is not significantly different, adds Funk, who has worked with a variety of roofing systems on numerous project types. Cool colors and formulations are available for metal roofs, single-ply membrane, and some built-up roofs using ballast.

One reason cool roofs last longer than traditional roofs is that ultraviolet (UV) rays tend to break down black roof materials faster over time, while cool roof coatings generally slow down this natural process. (Some of the newer single-ply products are made with self-cleaning and mold-resistant polymers to better maintain solar reflectance.) For that reason, cool-roof systems can perform well in preventing leaks, handling greater wind loads, and reducing a building's internal temperatures, according to Scott Shiver, a contractor with Uniqco Restoration & Coating, Clermont, Fla. "We've seen our customers achieve a 15-30% savings on energy almost immediately," says Shiver. "In Florida, many of these reflective roof restoration systems are earning additional rebates."

A few terms and technologies related to cool roofs are frequently used by manufacturers and roofing consultants. Among the most pertinent for Building Teams, according to the U.S. Environmental Protection Agency, are two performance measurements and three roofing products in addition to single-ply:

• *Solar reflectance* – Also called albedo, this is the measure of the ability of a surface material's ability to reflect sunlight—including the visible, infrared, and ultraviolet wavelengths—on a scale of 0 to 1. The higher the rating, the greater the solar reflectance.

• *Solar emittance* – This ranks the ability of a material to release absorbed heat. Emittance is measured between 0 and 1, or 0% and 100%. Again, the higher the rating, the greater the solar emittance.

• *Cool roof coatings* – These typically include white and light-colored paintlike liquids applied with a power sprayer or roller over existing roof structures or claddings. Recent advances include low-odor products and coatings with higher solids content, which can be applied in one coat rather than two.

• *Cool metal roofing* – Unlike untreated metal, which efficiently absorbs and retains heat, cool metal roofing products offer high albedo to better reflect the sun's radiation, keeping the roof cooler.

• *Cool tile roofing* – While traditional clay or concrete tiles usually have a solar reflectance of 10-30%, cool tiles contain pigments that both reflect up to 70% and enable roofing materials to keep their traditional colors, such as brown, green, and terra cotta.

Ballasted roof systems. Another common approach to creating a sustainable, energy-efficient roof is using a ballasted roofing system. This usually consists of a membrane or built-up roof, such as modified bitumen or asphaltic materials, topped with gravel or stone or concrete pavers. Some planted roofs may be ballasted types; in any event, some Building Teams favor the natural finished look and the added thermal mass of the ballast. Although the ballast material has a relatively low thermal resistance, or R-value, the combination of the stone mass and air spaces act as an effective insulator.

A ballasted system with at least 17 pounds of stone per square foot offers about the same surface reflectivity as a cool-roof membrane system. For that reason, it has nearly the same effect in mitigating peak energy demand, according to a recent study conducted by the Oak Ridge National Laboratory, “Evaluating the Energy Performance of Ballasted Roof Systems” (http://www.spri.org/pdf/Thermal%20Performance%20of%20Ballast%20Study%20Final%20Report%2005%2008%20.pdf). Based on three years of experimental data, the study also found that some ballasted systems actually performed better than reflective roof systems in reducing the urban heat-island effect. With such compelling findings, the study’s conclusions prompted ASHRAE and the California Energy Commission to update their cool roofing standards to recognize ballasted applications as an acceptable alternative to cool roofing requirements.

Ballasted roof systems also work well as a hybrid in combination with landscaped roofing, which can reduce first costs while simultaneously maintaining solar reflectance and water retention benefits. Additional sustainability benefits include an average service life of 15 to 20 years and the ability to remove and recycle the underlying roof membrane and insulation, which better maintains integrity in the absence of excessive mechanical fasteners and adhesives required by other roofing systems, according to James L. Hoff, research director at the Center for Environmental Innovation in Roofing, Washington, D.C.

AIR AND MOISTURE PROTECTION

Although green roofing innovations like vegetated roofs, BIPV, and cool roofs offer much in the realm of energy efficiency and building performance, a more elementary but critical issue is protecting the roof membrane against air and moisture penetration. “Figuring out where the water wants to go versus where you *think* it will go is not always a straightforward process,” says Funk. “There are issues that are not so easily managed, like capillary action, condensation, freeze-and-thaw cycles and ice damming.” In general, Funk recommends what he refers to as a “belt-and-suspenders” approach to roofing: Keep things simple, and design so that, if part of the system fails, either due to improper installation or a lack of proper maintenance, the whole system won’t fail.

Whatever design strategy you choose, Funk emphasizes the importance of sealing all openings. “It’s all in the details. Terminations, penetrations, expansion, contraction, and tie-ins are some of the major sources of a roof breach,” he says. “Once the right materials and system are selected, it is essential for the proper details to be followed and the execution performed correctly.” Follow-through by the entire Building Team, from architects and engineers to the general contractor and specialty trades, is essential.

For example, roofing consultants and contractors point out that if water saturates the insulation or gets behind a partially installed roof membrane during installation, there can be major problems: when water evaporates and is trapped behind the roofing layer, the membrane materials can bubble or delaminate.

Barrier materials. With regard to air barriers, the well-known building envelope expert Wagdy Anis, FAIA, a principal with Wiss, Janney, Elstner Associates, Cambridge, Mass., explains that fully adhered or hot/cold-mopped roof membranes can actually serve as air barriers. The *National Roofing Contractor’s Association’s Roofing and Waterproofing Manual* also states that the roof deck itself can work as an air retarder if it is monolithic, such as cast-in-place concrete: “When the deck is used as an air retarder, deck penetrations such as plumbing vents should be sealed, and the deck should be sealed at parapets,” the manual recommends.

On the other hand, with mechanically fastened or ballasted roof systems, an air barrier must be designed into the system. As Anis explains in his article on this subject in the *Whole Building Design Guide*, an online green building design resource with content developed by federal agencies and expert private-sector consultants (http://www.wbdg.org/resources/airbarriers.php), “Either a peel-and-stick air-and-vapor barrier on the inboard side of the roof system (interior conditions and weather dependent), or taped gypsum underlayment board beneath the insulation can be used in a system with adhered underlayers of thermal protection board and insulation.”

Because an air barrier system will not work effectively unless it is carefully coordinated, Anis stresses the importance of close collaboration among the trades. “A preconstruction conference on the air barrier system must include the trades involved in the air barrier system, such as the wall air barrier subcontractor, the window subcontractor, the sealant subcontractor, and also the roofing subcontractor, to discuss the connection between the roof air barrier and the wall air barrier, as well as the sequence of making an airtight and flexible connection.”

Germishuizen recommends regularly scheduled job conferences, field inspections, and required interim inspections and testing by the roof system manufacturer during the installation phase, in addition to regular coordination between the owner, architect, and contractor throughout all project phases.

Polyurethane foam. Among the different product types available to effectively seal roofing systems is *spray polyurethane foam* (SPF). Acting as a vapor, moisture, and air barrier, spray foam can mitigate condensation problems and vapor drive, which can damage roofing materials and other parts of the building envelope, according to Funk. This also reduces the opportunity for mold to develop, as spray foam insulation does not support the growth of mold or mildew, he adds. And because the foam doesn't settle or shrink over time, it maintains a seal against air leakage, which is a major source of heat loss.

According to Germishuizen, SPF works particularly well with flat roof applications over large areas in urban heat-island zones. "Due to the nature of the spray application, the material can be applied over irregular surfaces and shapes to create a seamless, monolithic membrane surface," he notes. "The spray-applied, low-rise foam also allows the installer to increase the amount of foam applied to areas where water tends to pond on roof surfaces due to deviations within the structure."

On the other hand, NBBJ's Highman favors *extruded polyurethane foam* panels. In terms of performance, he says that these panels—sloped and flat—provide technical advantages to sprayed products. "When the mechanical engineer does an energy model for the project, his or her bottom line calculations have a higher degree of accuracy, and from the contractor's point of view, installation of rigid panels is quick, clean and safe, not to mention standard practice," says Highman.

Other products, such as *elastomeric bitumen*, which strongly adheres to most construction surfaces, and rubberized elastomeric membrane, which is durable, UV- and weather-resistant, also offer viable solutions based upon the nature of the project. *Adhesive sheet products* are lightweight, don't require mechanical fasteners, and offer a variety of options, whether it's blocking air and water while allowing vapor through so that the assembly can breathe, or self-adhesive membrane bonds that actually strengthen over time.

Funk says he recently specified such a product for a project located next to a school where fumes and off-gassing were a concern. "We chose a self-adhering, two-ply modified bituminous product as there are no VOCs and minimal odor, and it was relatively easy to install," he says. ("VOCs" refers to volatile organic compounds.)

ROOFING CONSTRUCTION: BEST PRACTICES

New roof installation techniques are helping to achieve the goals of saving costs, improving efficiencies, and even promoting better product performance. "For example, insulation performance is improved when using a double-layer system with staggered joints in lieu of a single-ply system," says Germishuizen.

According to Highman, construction equipment such as tower cranes and other rapid installation systems can play a key role as well. "Tower cranes can be used to stage materials and assist in material distribution, although they must be scheduled well due to their high [rental] costs. For the installation of low-cost systems, low-pressure hydro-seed installation equipment offers a huge advantage as the material to be spread is almost liquid and easy to pump, while the equipment is relatively light and usually only one person is required to operate the entire process."

PHOTOS: COURTESY JOHNS-MANVILLE

A 15,000-sf "cool roof" at the Dover Professional Center, Toms River, N.J., uses a branded modified bituminous two-play system with a light-colored aggregate finish to reflect sunlight. Inset shows flashing around columns.

Some additional installation innovations are delineated by Tom Smith, AIA, TLSmith Consulting Inc., Rockton, Ill., in a section he wrote for the *Whole Building Design Guide* (at http://www.wbdg.org/design/env_roofing.php):

- Wider single-ply sheets for mechanically attached application, requiring few rows of membrane fasteners and fabricated field seams.
- Non-bituminous adhesives in place of mechanical fasteners to attach insulation.
- Self-adhering, single-ply membranes offer faster installation, are more environmentally friendly, and eliminate the need for adhesives and torches for installation.
- Mechanized rooftop application equipment and heavier ballast spreaders.

Yet another trend is sustainable product development. Roof insulation manufacturers are making breakthroughs in the use of recycled material, such as cellulose fiber, denim, and wool, and post-industrial and post-consumer materials, in the development of products, says Germishuizen. According to Funk, greater attention toward VOCs and recycled or recyclable products is impacting how material is managed and installed on site.

LIFE CYCLE BENEFITS IN ROOFING

Sustainable elements are also contributing to the life cycle benefits inherent in roofing systems. "Life cycle may be the greatest attribute of a green roof," suggests Womack. "There are roofs in Germany that are 50 to 60 years old and they have never been replaced, because the roof is protected from UV rays and freeze-thaw cycles—two elements that have the biggest impact on a roof."

In terms of recycled content and recyclability, metal roofing components likely offer the greatest opportunity for building projects. According to Durhman, however, such materials as ballast, rubber, and PVC can be recycled into other roofing products or reused on rooftops as well.

Some systems have much to offer when taking a larger, whole-building system approach, according to Funk. For example, panelized or modular roofing systems that can accommodate not only the functions of a roof, but also provide insulation and some structural spanning ability, accomplish several functions in one. This can speed up construction and offer greater economy by eliminating the need for separate systems and separate trades. "That means less material to manufacture, ship, handle on site, and install," he says.

As for future offerings, an improved, long-lasting, and recyclable PVC-based waterproof membrane is under development, as well as a biodegradable tray system that breaks down over time, putting nutrients into the soil and eventually providing a monolithic growing medium for the plants, according to Womack.

But while sustainability continues to gain momentum, it still must compete with the problem of higher initial cost—real or perceived. "As sustainability and cradle-to-cradle practices become more common and have less of a cost increase associated with them, I think more clients will be receptive," Funk concludes. "Clients like the idea of environmentalism, but in the end it comes down to, 'What will this cost me?'" BD+C