RESOLVING PRACTICAL PROBLEMS IN roofing retrofits and renovations

COURTESY DURO-LAST ROOFING, INC.

Roofers install a prefabricated reroof system on a manufacturing plant in Michigan. Waste from the old roof was shipped to a local plastics manufacturer, which ground it into material for flooring tiles. Prefabrication reduces on-site rooftop membrane seaming by 85%.

LEARNING OBJECTIVES

After reading this article, you should be able to:

+ DESCRIBE the primary benefits of reroofing and roof renovation projects for building performance, with emphasis on the positive impacts on indoor environmental quality, comfort, and health for building occupants.
+ DISCUSS the rationales for existing roofing systems of choosing overlayment or tear-off as strategies for a roofing retrofit, along with their environmental and health considerations.
+ LIST at least four strategies for roofing applications as part of a sustainable design project (including LEED projects) for indoor environmental quality, moisture protection, mold prevention, and building envelope optimization.
+ DESCRIBE the primary requirements for vegetated (green) roofing system design and installation and their benefits in terms of reducing urban heat-island effect, energy consumption, and greenhouse gas emissions.

BY C.C. SULLIVAN AND BARBARA HORWITZ-BENNETT

Over time, the return on investment for a roofing system may seem like a zero-sum game. Consider this rule of thumb given by roofing consultants: Although the initial cost of a building's roofing system runs about 10% of the total construction cost, the roof can end up accounting for as much as 60% of a facility's total maintenance costs throughout the building life cycle.

In practice, the actual percentages vary considerably. But the math reinforces the reality of roofing structures and assemblies: The stakes are high when it comes to properly specifying, installing, and maintaining the so-called fifth façade. As roofing renovation projects—reroofs, tear-offs, and the like—continue to outpace roofs for new construction, Building Teams are finding the best opportunities they can to design and deliver high-quality roofing systems to commercial, industrial, and institutional building owners.

Before reviewing specific options for roofing upgrades, Building Teams should focus on the key to a successful renovation project: *creating a tight, high-performance building enclosure* between the roof and the rest of the structure. To best achieve this for full roof tear-off and replacement projects, experts at the National Roofing Contractors Association (www.nrca.net) recommend removing only as much existing roof as can be replaced in the same day.

"A professional roofing contractor will create a tie-in between the existing and new roof systems, so the roof remains watertight during roof replacement," says James R. Kirby, AIA, AED, an NRCA technical communications specialist. "This requires a strategy for progressing across a rooftop without tracking over the new roof system, and daily coordination of the removal of existing materials and the installation of new materials."

David J. Welte, President of the consulting and

commercial building maintenance contractor GreenPROChicago (www.greenprochicago.com), Lake Forest, Ill., emphasizes that any clear penetrations, major wear areas, and structural components must be repaired as part of a renovation. Otherwise, he says, the entire purpose of renovation will be defeated.

Of course, one of the main goals of any roofing retrofit is to *improve performance*, so in addition to installing new roofing materials, these projects provide a great opportunity to *increase thermal insulation levels* and boost the level of *air sealing*. This involves maintaining *thermal continuity* throughout the roofing plane and at the transition to the perimeter walls, in addition to properly flashing roof transitions, penetrations, and all edge conditions.

To assist with this, Building Teams are increasingly using thermal imaging and other techniques for nondestructive evaluation of existing roof conditions. Mark Yanowitz, LEED AP, Assoc. AIA, UCSL, with design-build firm Verdeco Designs (www.verdecodesigns.com), Andover, Mass., recommends infrared cameras as a thermal scanning device to help pinpoint damaged areas and weak elements in the thermal building envelope. IR cameras offer useful information whether or not the team chooses to pressurize the building.

COURTESY SIKA SARNAFIL

Crews from Black Roofing, Boulder, Colo., work on a 10/12 slope to apply an 80-mil PVC membrane to the roof of the Denver Art Museum, designed by Daniel Libeskind. The original titanium roof started leaking soon after completion in 2006. The job took 31 roofers seven months to complete.

To establish an airtight enclosure, *proper installation of the air barrier is essential.* This can be difficult in many roofing retrofit situations, because access to the proper location for the air barrier may be limited or because of difficulties in creating a continuous and structurally supported substrate for the air barrier. For these reasons—and because the area most vulnerable to air leaks is the transition point between the wall and roof assembly—solutions that allow a layer of protection over a varied roofing assembly, such as spray foam insulation or fluid-applied barriers, are favored in some circumstances, says Shad Traylor, AIA, CDT, LEED AP BD+C, a LEED administrator with the design-build firm BRPH (www.brph.com), Melbourne, Fla.

"The spray-on process for foam insulation does not require clips or structural support; for this reason, it will remain in place after it is installed," says Traylor. "Furthermore, the spray-on application allows the contractor to continue the insulation seamlessly from the wall onto the roof substrate. Most spray-foam products also have an antimicrobial formula for stopping mold growth."

Even when the roofing contractor is working hard to establish an airtight enclosure, it's important not to overlook the potential of leaks occurring during the construction itself, advises the NRCA. The interface between the existing and new barriers must be sealed at the end of each workday, on both the roof deck and existing membrane, says commercial and industrial roofing contractor Anthony Vross, owner of Simon Roofing (www.simonroofing.com), Youngstown, Ohio. "The type of new and existing roof system will determine the proper tie-in method, but the tie-in should always be strong enough to keep ponding water on top of it and also prevent water from entering the roofing system," says Vross.

If water enters into the layers of roofing assembly, an effect called **horizontal water migration** typically occurs. In this situation, water enters into sections of an existing roof and travels between the material layers or on the structural substrate—a fluted metal deck, for example—toward the new sections. To prevent horizontal water migration, contractors typically use tie-in techniques such as false walls, roof curbs, or, in some cases, expansion joints to effectively separate or divorce sections of roof area. Other methods, such as adhering and mechanically attaching a new roof membrane to the old membrane and then sealing with cover tape, may be ineffective at preventing horizontal water movement. If there are multiple layers of roofing material, water may still move horizontally, according to commercial roofing contractors consulted for this course.

For example, to install a new thermoplastic polyolefin (TPO) membrane assembly on an existing low-slope roof, the contractor can cut a channel in the old roof to the substrate and then build a curb, flashing it to the existing roof side as needed and flashing on the new roof side with TPO; a metal coping is typically included.

In addition to the tie-ins, all penetrations should be sealed off at the end of the day. According to Vross, the preferred method is to install flashing on the new roof system completed that day and provide counter-flashings on top of the flashings. At the very least, the contractor should provide temporary flashing and counter-flashing, regardless of the weather forecast.

MAKING THE CHOICE BETWEEN OVERLAYMENT AND TEAR-OFF

When embarking upon a roofing renovation project, one of the first decisions for the Building Team is whether to tear off and replace the existing roof or to overlay the new roof right on top of the old one.

"Typically, you're reroofing because of leaks or damage to a roof," says BRPH's Traylor. "A tear-off allows you to inspect the condition of the roof substrate and is more favorable for roof warranties. If the load-bearing capacity of the roof substrate is in question, a tear-off also reduces the additional weight of a second roof."

However, if the roof has minimal water damage, he adds, *reroofing with an overlayment* strategy can be the quickest, least expensive, and easiest solution because it eliminates tear-off costs and reduces replacement time. "Overlayment also allows owners to maintain a weather barrier if sensitive equipment and products are installed or stored below the roof," adds Traylor.

Analysis and testing may be needed to determine if the existing roof structure is adequate to support the added weight of an overlay. This can involve *core cuts in strategic areas* to analyze material conditions, as well as thermal scans and insulation tests. According to Vross, a rule of thumb is that if more than 30-40% of the existing roof is wet, then a tear-off is in order. The same is true in situations where the existing roof system is ponding water and it is not possible to add drains or taper insulation with the perimeters or penetrations at least eight inches higher than the primary roof surface.

In some cases, the decision on the type of reroof may be dictated by the applicable building codes. For example, where two roofing systems are already in place, most jurisdictions won't allow the addition of a third layer of overlayment. Consequently, a tear-off or full replacement is the only allowable option.

Another instance favoring tear-off is when mechanical equipment upgrades require the roof decking to be rebuilt, in which case tear-off provides the best continuity, says Yanowitz, a 25-year veteran of architectural design and construction management. "Although there have been significant improvements in new insulation adhesives that make quality overlay roofing projects more viable, tearing off an existing older roof almost always assures a better installation and fewer problems in the future," he adds. "This is largely because there are no unknowns with attachment issues as to how the previous roof was installed and the integrity of the overall system."

A number of other factors need to be taken into account, including the building type, location, building usage, roof access, roof traffic, penetrations, decking, and slope.

Other techniques similar to overlayment, such as spray-applied foam products, may be viable alternatives. Another retrofit path for green building projects is the use of a "cool roof" coating, which is fluid-applied directly to the exposed roofing material. Assuming that the roof's surface is relatively smooth, moisture is not a major concern, and decent drainage is in place, these novel, light-colored roof coatings can be a cost-effective option.

"The extra benefit is that the coating type conforms to all shapes and sizes and seamlessly seals all potential water entry points that typically leak, including flashings, termination bars, corners, pipes, and curbs and the like, which don't always conform to the shapes of traditional roofing materials," explains Welte.

Vegetated or planted roof coverings may also lend themselves to part of a reroofing strategy as overlayments. For extensive, unoccupied green roofs, a common strategy is to cover existing roofs with plantings in individual trays. With some products, it's even possible to remove the dividers between the trays, once they've grown, at which point they become a seamless blanket of vegetation, says Blake Jackson, LEED AP, Sustainability Practice Leader with Tsoi/Kobus & Associates (www.tka-architects.com), Cambridge, Mass.

"This type of system is most appropriate when you want to cover a surface quickly," says Jackson. "This will contribute to earning LEED credits and help in terms of building performance and rainwater management."

In virtually every situation, the sequencing, phasing, and coordination of the roofing work is critical to successful, watertight tear-off installations. Contractors should work from the low point to the top of the roof to prevent back-lap areas that buck water, says David Cook, AIA, Principal Architect in structural and architectural evaluation with CTLGroup (www.C-T-L.com), Skokie, Ill. In addition, sections should be worked in a strategic sequence so that workers don't have to walk across finished work surfaces.

Protecting the substrate or deck is another key point, says Jason Hand, Vice President of roofing contractor Property Development Solutions (www.pdscompany.com), Lubbock, Texas. This also goes for the building's contents at times when sections of the roof are fully removed.

"Weather must be tracked and precautions made to dry-in the structure at a moment's notice," says Hand. He, too, emphasizes the importance of staging roof work in portions. "The building assemblies should also be torn off in stages to limit exposed area in the event of unexpected precipitation," says Hand.

COURTESY FIRESTONE BUILDING PRODUCTS

Roofers from All Top Roofing Services, Cartersville, Ga., work on a complete tear-off and retrofit of a 340,000-sf roof in Georgia. They are installing an 80-mil thermoplastic polyolefin (TPO) wide-weld, single-ply membrane with three inches of high-performance insulation.

Craig R. Garey, owner of roofing contractor WeatherSure Systems (www.weathersuresystems.com), Sheridan, Colo., advises going from the inside of the facility outward in identifying liabilities, risks, deck conditions, and design prior to beginning any renovation. Once a sound plan is in place, a disposal chute is the best way to transfer debris from the roof to the ground, unless the building height exceeds 120 feet.

Yanowitz is a proponent of reusing insulation and stone products to the greatest extent possible once the membrane has been removed and replaced. In cases where on-site reuse isn't practical, trash hauling companies with off-site recycling facilities are a good option so that contractors don't have to spend the time segregating products on site.

A roofing retrofit that involves changing a flat roof to a steep slope system can present its own set of difficulties. For starters, the structural engineer must ensure that the weight of the new roof structure meets the proper load bearings and dead-load requirements, says Simon Roofing's Vross. The architect must verify that the building's new look meets aesthetic and building code demands.

"Going to a steep slope from a flat roof will change the drainage design, so an engineer will need to be consulted to make sure the existing drainage system can handle the increased flow of the water entering the drains," he explains. "Due to the amount of air space between the structure and the flat roof, the proper amount of insulation needs to be installed to meet the building code and prevent condensation."

SUSTAINABLE ROOFING: REVIEWING THE OPTIONS

No longer considered a fringe design approach, vegetated roofs are becoming more and more common in North America, having grown by more than 28% in 2010 alone, according to the Green Roofs for Healthy Cities' 2011 Annual Green Roof Industry Survey (http://greenroofs.org/resources/2011_GRHC_Survey_Report.pdf). "Coast to coast, we see commercial, industrial, military, government, and multiple-occupancy structures undergoing envelope facelifts, and many are looking at green efforts to be on top," says C.R. Peterson, Director of Simon ROI Solutions, a division of Simon Roofing, Boardman, Ohio.

Particularly in urban settings, where green square footage is at a premium, increasing numbers of building owners are opting for planted roofs to reduce their cooling loads, positively impact the urban heat-island effect, improve stormwater drainage, and increase the facility's sustainability and aesthetic appeal. The main components of a vegetated roof system are:

- Root barrier over the primary roof layer
- Moisture management layer
- Separation medium
- Growth media
- Wind blanket
- Tie anchors

According to Peterson, growth media depths range from 2.5 inches to 10 inches, with 2-4 inches of drainage media separated by a barrier medium.

IVY & ASSOCIATES / COURTESY MBCI

Roofing contractors from Compass Building Systems, Dallas, work on the retrofit of the roof at the Dallas County Water Treatment Facility. Such retrofits can address problematic water discharge and other roof issues.

The main consideration for retrofit planted systems over existing roofs is structural. The existing steel and concrete substructure as well as the roof deck and any underlayments must be able to support the dead and live loads associated with the green roof system—or any other roof elements, for that matter.

Various roof systems can provide a suitable base for planted roofs. Some experts, such as CTLGroup's Cook, an expert with 30 years' experience in structural evaluation, project management, and design, recommend a hot rubberized asphalt roofing system as the base. In cases where the roof systems are installed under soil, insulation, or gravel ballast, Cook advises including electronic vector mapping capabilities, since it is very difficult and time-consuming to locate any roof leaks that could develop in the future.

For waterproofing and key installation guidelines, Kirby points to *The NRCA Waterproofing Manual* (http://www.nrca.net/rp/pubstore/details.aspx?id=353&c=9) and *The NRCA Vegetative Roof Systems Manual—Second Edition* (http://www.nrca.net/rp/pubstore/details.aspx?id=514&c=9) for details on how to ensure green roofs are installed properly and with good resilience.

To review a building's suitability for the retrofit of green building systems or other roofing products, a list of structural and compatibility issues should be analyzed.

Photovoltaics—Adding juice to the system. A photovoltaic (PV) system can range from three to eight pounds per square foot when installed on top of a typical ballasted system. In this case, a simple structural analysis is in order before moving ahead with such an upgrade. Then the team must determine how to effectively tie the PV supports to the substructure and apply proper weatherproofing.

At the same time, combining vegetated roofs with PVs is considered to be both a mutually beneficial arrangement and a common strategy for buildings seeking net-zero energy (NZE) or zero-energy building (ZEB) status, says Tsoi/Kobus's Jackson, a member of Emerging Green Builders, Boston Society of Architects Committee on the Environment, and the Sustainable Design Leaders Group. "First, the weight of the PV reduces uplift on the rooftops, helping to minimize damage to the vegetation," he explains. "Second, the PV panels are cooled on the underside by the heat-absorbing vegetated rooftop; thus, they tend not to overheat and generally operate at a higher efficiency."

In fact, Jackson points out that studies in Germany have found that PVs function best at temperatures under 77°F, so the heat reduction benefit of vegetation is quite significant.

On the other hand, Verdeco Designs' Yanowitz echoes common industry concerns over the possibility of solar panels increasing *solar ultraviolet transmission* to the roof surface adjacent to the installations. This may have an effect in breaking down the roofing material. In response, he says, some manufacturers have made enhanced UV-modified bitumen sheets and 80-mil thermoplastic membranes for these applications. "Another solution may be to provide a reflective coating over the existing membrane in these areas," he says.

In terms of installation options, PVs can either be installed as panels or laminated directly to the roof. While the panels can be easily removed, their support brackets usually require additional roof penetrations, says Traylor. They can also be attached to the vertical standing seam ribs if the roof pitch and orientation are optimized.

Otherwise, laminated PV panels work well with both membrane and metal roofs, and can be attached without penetrations. Make sure, however, that the roofing system's life expectancy exceeds that of the laminated panel, cautions Traylor, a current steering committee member for U.S. Green Building Council–Brevard and a past AIA Kansas board member.

COURTESY BRPH

One of the largest PV installations in the country, thin-film solar laminate panels on the roof of South Carolina's 1.2-million-sf Boeing 787 Final Assembly Building are providing the site with 2.6 MW of power.

Peterson says he prefers built-up roofing (BUR) over single-ply membrane systems, such as TPO or EPDM, for PV installations. In all cases, he stresses that the array mount system must be installed per the manufacturer's design specifications. (See also "7 Do's and Don'ts for Roof Rack Installation," www.bdcnetwork.com/7-dos-and-donts-pv-roof-rack-installation). He lists the following additional points:

- Membrane roofs lower than 50 feet and not in a wind zone should be ballast mounted.
- All penetrations should be pitch pockets.
- The roofing system should be upgraded to match the solar panel warranty.

WATERPROOFING: It's all in the details

When undertaking any kind of roofing renovation project, proper detailing ranks big. As Craig R. Garey, who owns roofing contractor WeatherSure Systems, Sheridan, Colo., puts it, "It doesn't make sense to construct a 20-year roof with two-year details. If you're relying on roofers' mastic or urethane sealant as the first line of defense, a mistake has been made."

Roofing contractors and other Building Team members strongly recommend carefully following manufacturer's installation instructions and taking advantage of National Roofing Contractors Association technical manuals.

James R. Kirby, AIA, AED, NRCA's technical communications director, also points out that details for new construction are generally applicable for retrofits. Of course, reroofing usually involves some demo and repair work—for example, removing and replacing siding or brickwork in order to install new flashing details.

David Cook, AIA, Principal Architect for structural and architectural evaluation with CTLGroup, Skokie, Ill., says that simply installing a new roof is often not enough to eliminate water leakage, particularly if the real problem is stemming from perimeter elements, which tend to be more vulnerable than the field membrane.

Anthony Vross, Owner of Simon Roofing, Youngstown, Ohio, explains, "Perimeter flashings on a coping wall should be run up the wall and over the top of the coping wall to provide an extra layer of waterproofing." He recommends having a raised seamed joint when connecting the coping together.

In cases where the vertical wall height is very high, or where it's not possible to install a coping cap, then counterflashing is a good solution. "Membrane flashing should be run a minimum of eight inches up the vertical and fastened off to the wall," counsels Vross. "A two-piece, through-the-wall counterflashing is applied by grooving out the existing masonry wall and applying a reglet into the groove to attach it."

In the event that the vertical surface is not masonry, then a termination bar is used to compress the membrane and caulking to the vertical surface. The termination bar should then be fastened according to the wind uplift requirements of the geographical area, says Vross.

As for the seams, Vross recommends laying the seams flat to prevent wrinkles and fish mouths, and to make sure they're free of moisture, dirt, and debris. "Extra attention should be placed on the seams of a roofing system that has only one layer and offers no redundancy in the membrane since it is a direct entry point into the roof system," he says.

- Coatings are widely acceptable.
- No system should be secured to the deck alone, with the exception of a metal roof and the use of specified fasteners.

Cool, reflective roofs—LEED-friendly. Cool, reflective rooftops can be an easy way to score LEED points at a very low cost premium. However, they may not always be effective as green roofs in terms of boosting the efficiency of PV. The effectiveness of a cool roof is dependent on climate: they are best suited to warm, southern regions. In climate zones 4-7 on the U.S. Department of Energy (DOE) climate map, the building may benefit more from a darker roof material to absorb heat and thereby reduce winter heating costs.

To help Building Teams make this call, the DOE offers a free cool-roof calculation tool, developed by the Oak Ridge National Laboratory (www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm). "The software requires a few simple project inputs of your location, proposed roof, energy costs, and equipment efficiencies, and it outputs a detailed comparison between the proposed roof and a black roof to yield the annual energy savings," explains Traylor. "If the project is seeking LEED certification, understanding the solar reflectance index and roof slope parameters is also important."

Cool roofs can be a very effective design strategy in the right settings and situations. "The liquid systems that we apply contribute greatly to the overall net-zero effect of the roofing plan, as they allow for less energy absorption from the sun, lowering energy usage and reducing expansion and contraction of the roof decking and contact points," says GreenPROChicago's Welte.

Wind collectors—Choose the right location. Wind collectors run at a high capital cost, with variable output; for that reason they are often not viable. "They tend to be popular in architectural renderings, due to their symbolism, but their commercial viability at the local scale has not shown good field trials," says Tsoi/Kobus's Jackson.

In order to offer a decent ROI, wind energy systems are most appropriate for high-speed wind zones, where they actually have the potential to exceed the load capabilities, per designated area, compared to photovoltaics. To function properly, they must be installed at a great enough height to enable full access to wind gusts. "The shape of certain roofs and building corners which increase velocities of incident wind could enhance this," says Jackson.

When sited properly with sufficient redundancy, Peterson actually sees wind systems as gaining interest. "Wave energy is another wind-related renewable resource that is gaining popularity in coastal regions," says Peterson. "Movement of the collector body, anchored off shore, by wave motion produces power that is connected to a shoreside substation to convert the power to utility grade."

Daylight harvesting—Skylights and solar tubes. Although conventional skylights and solar tube solutions can be great daylighting solutions for nonresidential spaces, they must be installed in such a way as to avoid disruption to the thermal envelope.

"From the NRCA's perspective, a watertight/weatherproof installation of a roof-mounted daylighting device is primary," says Kirby, a member of ASTM International, Green Roofs for Healthy Cities, and the International Code Council. "Working with roof system manufacturers is important to ensure these devices are installed and flashed appropriately without negatively affecting the roof system warranty."

If the unit is designed with weep channels or holes, Peterson says it is important to keep these spaces clear of debris and regularly inspecting the surface for internal moisture, cracks, or areas of poor clarity.

"For glazing materials, only high-grade silicones should be utilized, never urethanes or acrylics," says WeatherSure's Garey. "For butt-to-butt metal joints, silicone overbanding should be the design."

As for maximizing reflectivity, skylight surfaces need to be periodically cleaned. "Polycarbonate lenses should be rejuvenated with a product specifically developed for that purpose, and glass lenses should be thoroughly cleaned and inspected," says Garey.

Other maintenance items include regular inspection by a roofing professional of the daylight harvesting systems, including the skylight mounting curb or flashing.

COURTESY DURO-LAST ROOFING, INC.

Before-and-after of a retrofit project in Saginaw, Mich., where a single-ply membrane was installed over an old structural metal deck. Such roof retrofits can protect buildings against rain and snow, ice buildup, rust, and corrosion. Such systems can be prebricated in a factory, saving labor costs.

COURTESY SIKA SARNAFIL

A crew from Titan Roofing, Chicopee, Mass., reroof the U.S. Post Office in Brockton, Mass., with 170,000 sf of 60-mil PVC thermoplastic with adhered and mechanically attached sections. The old roof was recycled.

KEEPING IT IN PERSPECTIVE

Roofing and reroofing return on investment is a balance between cost-effective installation and effective long-term building operations. Many building professionals emphasize that Poorly installed roofing systems or accessories can be a maintenance nightmare.

Getting it right the first time is absolutely essential. "The development of a comprehensive roof management plan that documents and monitors all related components is an important measure to protect a property owner's investment and optimize the overall performance of a building," recommends Yanowitz. "When considering options to meet high-performance building design goals, it is always important to recognize the interrelationship of all building components and develop a holistic view of how certain building elements may affect the overall building performance."

Property Development Solutions' Hand points out that there is no such thing as a one-size-fits-all roofing system. Every structure must be carefully evaluated on an individual basis. And with reroofing projects far exceeding roofing for new construction at the moment, this is an area where Building Teams can make a real difference.

> EDITOR'S NOTE

This completes the reading for this course.
*To earn **1.0 AIA/CES HSW/SD learning units**, study the article carefully and take the exam posted at* **www.BDCnetwork.com/RoofingRetrofits.**

roofing retrofits AIA/CES MODULE

*Pass this exam and earn **1.0 AIA/CES Discovery learning units**. Go to* **www.BDCnetwork.com/RoofingRetrofits** *to take the exam.*

1. According to roofing experts consulted for this course, a building's roof system usually costs about 10% of the initial cost of a building's total construction cost; in terms of a building's total maintenance costs throughout the building life cycle, the roof may account for up to what portion of all maintenance outlays?
   A. 0.6%
   B. 6%
   C. 16 – 26%
   D. 60%
2. During roof replacement, a tie-in must be developed between the existing and new roof systems that allows progress across a rooftop without tracking over the new roof system, while also allowing daily coordination of the removal of existing materials and the installation of new materials:
   A. To reduce project material costs
   B. To reduce structural instability
   C. So it remains watertight
   D. So an air barrier can be installed
3. Spray-on foam insulation provides a number of features that are useful for roof performance. Which is NOT among these beneficial features?
   A. Air barrier
   B. Clips and structural supports
   C. Thermal insulation
   D. Antimicrobial content
4. Which of the following are common tie-in techniques for separating or divorcing sections of roof area?
   A. False walls
   B. Roof curbs
   C. Expansion joints
   D. All of the above
5. True or False: A tear-off reroofing project is typically less expensive and time-consuming than a roofing overlayment approach.
   A. True
   B. False
6. As a rule of thumb for a roof with evidence of moisture, a tear-off should be considered when what percentage of the existing roof is wet?
   A. 3% to 5%
   B. 10% to 15%
   C. 30% to 40%
   D. None of the above
7. For a project where the design is changing a flat roof to a steeper-sloped roof system, there are several requirements and benefits. Which of the following is a requirement for the change from a low slope to a high slope?
   A. Drainage may be increased for added water flow.
   B. Structural loads may be reduced.
   C. Code review may typically be waived.
   D. All of the above.
8. Darker roof materials tend to benefit buildings in which DOE climate zones?
   A. 1-3
   B. 4-7
   C. All climate zones
   D. None of the above
9. The main considerations for the effectiveness of wind turbines to generate power are:
   A. Collector height and building siting/geometry
   B. Code restrictions and zoning laws related to building height
   C. Building occupancies and total plug load
   D. Regulations for carbon emissions
10. The NRCA recommends what key steps if skylights and similar daylighting products are employed on the rooftop?
    A. Watertight detailing and construction
    B. Proper installation and weatherproofing
    C. Appropriate flashing
    D. All of the above