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The High-Performance Roof: Synergy in Action

To work effectively, high-performance roofs must be addressed in a holistic manner vs. looking at one component at a time

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"Synergy - the bonus that is achieved when things work together harmoniously." Great American author Mark Twain certainly had it right. And, the effects of Twain's synergistic "bonus" can clearly be seen in the built environment. Buildings constructed from products that fit well together not only meet initial plans and specs, but also pay out an unanticipated bonus by exceeding the expectations of their owners and occupants. Twain's observation also reminds us that, as we strive for higher-performing roofing systems, we should ask ourselves how the pieces fit together to assure harmony and maximize performance.

Like all related segments of the construction industry, roofing has been influenced and affected by the high-performance building movement. This influence, however, may not have generated the expected response. Although the roofing system is filled with high-performance products, the focus tends to be confined to individual performance characteristics (e.g. reflectivity, thermal resistance, or longevity) vs. a larger, multi-factor approach. Given the overall direction of the high-performance building movement toward system integration and synergistic benefit, the roofing community has an opportunity and obligation to explore the value proposition of synergistic roofing systems. Following examples from the high-performance building movement (see *High-Performance Buildings: Synergy through Vision*), the roofing industry should explore roofing systems containing a number of high-performance elements that, together, may exhibit performance capabilities far beyond the sum of the individual parts.

Such a synergistic approach may require new ways of thinking within the roofing industry. In the past, commercial roofing suppliers and specifiers have tended to focus on individual product qualities rather than the combined result of these products. Even some government programs for roofing products fall short of the goal of promoting high-performance roofing systems by focusing on the single performance characteristic of roof reflectivity. Unfortunately, when the synergistic effects of all components of a roofing system are not considered, roof performance can't be maximized.

The first step in achieving economic, energy, and environmental synergy in roofing systems is to identify all possible strategies that can be employed. The list of energy and environmental strategies grows in size and complexity every day, but all of these different approaches tend to fall within three basic high-performance dimensions.

1. Energy Factors

Because buildings account for more than 40 percent of total U.S. energy consumption—and because the building envelope is also involved in more than 40 percent of total building energy consumption—reducing the dependency on limited and mostly nonrenewable energy resources is the most critical factor in designing a high-performance roof. Key roofing strategies to reduce energy dependency include the use of roofing systems that reduce external energy requirements and the actual production of new energy that uses the roofing system as a generation platform. Some considerations:

High-thermal insulation. High-thermal roof insulation includes both material and design dimensions. In terms of materials, high-thermal insulation products provide a high-thermal resistance (R-value) per unit of thickness to reduce energy consumption while minimizing material and installation costs. In terms of system design, high-thermal insulation is typically specified to meet or exceed a minimum R-value for the overall roofing system. As an

High-Performance Buildings: Synergy through Vision

The recent confluence of global economic, energy, and environmental concerns has highlighted the importance of building-system integration and how it can transform conventional buildings into synergistic, high-performance systems. This increased awareness has also stimulated action to understand the critical determinants of high-performance buildings and integrate them into everyday design and construction practices. Although recent high-performance building initiatives have been numerous and varied, all of these undertakings appear to share two important visions:

- Our concerns about economics, energy, and the environment are inexorably linked.
- These concerns must be addressed using integrated, holistic solutions.

Recognizing that many high-performance measures may be incorporated with minimal upfront expense and still yield sizable cost savings over a building's lifetime, many forward-looking building organizations have established ambitious goals to expand the use of high-performance system concepts. Most notably, the American Institute of Architects (AIA) in Washington, D.C., has called for a 50-percent reduction of fossil fuels used to construct and operate buildings by 2010, with additional reductions every 5 years, to achieve carbon-neutral buildings by 2030. Following the AIA's lead, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) in Atlanta is beginning to move beyond its example, the recommended high-performance roof thermal value (as currently proposed in ASHRAE 189P Standard for High-Performance Green Buildings) calls for a significant improvement beyond the prevalent energy-code standards adopted across the United States.

Energy-efficient design practices. High-performance design practices help assure that planned energy savings aren't compromised during roofing-system installation. Important energy-efficient practices include installation of staggered layers of insulation to reduce thermal short circuits, installation of a high-compressive cover board to prevent crushing of the critical thermal insulation layers, infrared moisture surveys to verify that no latent moisture is trapped within the roofing system, and evaluation of the need for a vapor barrier to prevent moisture condensation within the roofing system.

Cool roofs. Cool roofs reduce the impact of the sun's heat on a building's cooling system. In many climates, cool roofs save much more cooling energy in summer than they lose in heat loss in the winter. In addition, cool roofs may make a significant contribution to overall energy costs in communities where peak demand charges are added to electricity bills in the summer. Finally, cool roofs help reduce the environmental impact of the urban heat island effect by reducing the heating of urban air associated with darker roof surfaces. Although white heat-reflective roofs are frequently mentioned in cool-roofing discussions, other roofing systems can also deliver. Recent research by Oak Ridge National Laboratory (ORNL) in Oak Ridge, TN, indicates that many traditional ballasted roofs covered with stones or concrete pavers may provide the same energy savings as reflective roofs. And, green roofs, featuring layers of vegetation, also appear to provide a cooling effect similar to reflective roofs.

Photovoltaic roofs. Using a variety of solar-cell technologies, roof-integrated photovoltaic systems transform the sun's energy directly into electricity that can be used within a building or distributed over the grid. Although it's currently a relatively expensive technology with a somewhat complicated economic model, new advances in production efficiency are expected in the near future; governmental support is also expected to grow.

Roof daylighting. Although similar to traditional skylights, the latest roof daylighting devices maximize the transmission of light into a building while reducing the heating effects of sunlight, but use new technologies to do so. Examples include prismatic lenses that focus sunlight, light tubes that transmit sunlight through attics and ceilings, skylights with external reflectors that track the sun's daily movement, and skylights directly integrated through photosensor-activated switches with a building's conventional light sources.

traditional "code-minimum" approach for building energy standards and is now calling for an "above-the-code" approach in its proposed *Standard for High-Performance Green Buildings (ASHRAE 189P)*.

The vision of synergistic, high performance in buildings has been further expanded by the LEED® Green Building Rating System™, which was developed by the U.S. Green Building Council (USGBC). LEED provides a whole-building rating system designed to transform the built environment. To accomplish this transformation, LEED starts with a simple enumeration of the most-recognized characteristics of high-performance buildings, such as resource conservation, energy efficiency, and environmental sustainability. By combining these key attributes into one standard, LEED helps promote a holistic approach to building design. By developing a comprehensive rating and award system for these key attributes, LEED stimulates competition to achieve high-performance building goals. And, by promoting LEED as an easily recognized concept, the USGBC builds public support of its ultimate goal to transform the way buildings are designed, constructed, and maintained.

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2. Environmental Factors
Because roofing systems directly interface with the atmosphere and climate, factors related to the environment include the use of materials and processes that mitigate the long-term environmental impact of the roofing system. In addition to reducing the urban heat island effect as mentioned in the discussion of cool roofs, environmental impacts that may be mitigated through the proper selection and design of high-performance roofs include stormwater quality, air quality, and solid-waste disposal. Consider:

Vegetated/green roofs. More than 700 U.S. communities, including some of the largest cities, continue to rely on combined sewer systems that annually spill millions of tons of raw sewage into waterways. Unfortunately, estimated upgrade costs reach hundreds of billions of dollars. Although vegetated/green roofs can't provide a complete solution to combination sewer problems, their use in dense urban areas can reduce the amount of stormwater runoff that has to be absorbed by our antiquated sewer systems, reducing the frequency of pollution spills into our lakes and rivers. Not only do vegetated roofs absorb and hold the peak flow of stormwater, but they also improve the quality of water and air by removing airborne pollutants.

Low-VOC roofing materials. Along with combustion emissions from vehicles and factories, VOCs may contribute to ground-level ozone in many areas of the United States, especially during summer months. VOCs can be found in many traditional solvent-based roof coatings, adhesives, and sealants, but low-VOC or VOC-free products are being developed to take their place. Examples include water-based latex roof coatings and adhesives, self-adhering tapes and flashings, and one- and two-part polyurethane adhesives and coatings. Although low-VOC products are readily available for use in warmer climates, or in the summer months in colder climates, solvent-based adhesives and sealants are still generally required in colder climates and seasons—usually whenever temperatures fall below 40 degrees F. Fortunately, ground-level ozone may not be a concern in these colder conditions since ozone formation requires a considerable amount of heat and sunlight, as well as ozone-forming exhausts.

Renewable/recyclable roofing. The U.S. Environmental Protection Agency (EPA) estimates that the construction industry generates approximately 160 million tons of solid waste each year; of that total, roofing waste accounts for 40 million tons. Although recycling is still in its infancy within the roofing industry, several organizations have made some headway in removing aged roofing materials and recycling them. Products that have been involved in national, regional, or local recycling efforts include metal roofing, cedar shakes, asphalt shingles, EPDM, and PVC. With the exception of recycling metal roofing, the results of these recycling efforts have been relatively small and localized. The most significant challenges appear to be the relatively small size of any particular roofing project, difficulties in packaging for transport to a recycler, and the current economic cost benefit of the recycling process. The difficulties experienced by the roofing industry in recycling its products may point to other factors that should be considered during the design phase of a high-performance roofing project. Is there a plan to address the eventual removal of the roofing system after its effective service life? Can some elements of the roofing system, such as the underlying roof insulation, be saved and reused as part of the replacement roof? Can the roofing system be easily removed and packaged to help facilitate recycling?

3. Durability Factors

High-performance energy strategies may reduce the amount of energy that a building needs to operate, and high-performance environmental strategies may reduce the impact of the roofing system—from the raw material acquisition to eventual disposal and/or recycling. But, both of these strategic approaches lack one critical element: time. If a high-performance roof saves twice the energy and reduces half the environmental impact, but only lasts half as long as a conventional roof, little is gained in the long run by these energy and environmental strategies. As a consequence, durability becomes the third key strategic dimension of a high-performance roof. And, in order to assure long-term durability, the following processes should be considered integral parts of any high-performance roofing system:

Durability planning. Durability planning combines the best practices of life-cycle analysis with established quality-management programs, such as ISO 9000. The first step in durability planning is to identify the critical durability determinants, or what can go wrong with the roofing system. Common durability determinants may include regional climate conditions, extreme weather events, and human activity on the roof. After the key durability determinants are identified, durability interventions—or countermeasures—should be identified to prevent or mitigate the negative effects of critical determinants. After the durability determinants and interventions have been identified, a durability action plan and timetable should be prepared to identify when the interventions should be applied to maximize service life. It's important to note that this action plan and timetable may not yield a single "best" path. As an example, a very robust design may require little or no periodic maintenance, but a less robust design may work just as well if periodic maintenance is anticipated and executed.

Project commissioning. The commissioning of a high-performance roofing system allows an opportunity to verify that performance objectives have been achieved (and, hopefully, exceeded, due to synergistic effects). At its core, commissioning is a quality-assurance process that provides a formal review and integration of all project expectations. In addition, commissioning leaves the building owner with preventive- and predictive-maintenance plans, tailored operating manuals, and training procedures.

Ongoing roof management. Sometimes referred to as "continuous commissioning," ongoing management of a high-performance roofing asset is critical to assure that long-term energy and environmental synergies are achieved. As a consequence, any effective roof-management program should be designed to address these critical questions on an ongoing basis:

- Is the building continuing to meet energy-efficiency objectives?
- Are building impacts to the environment measured and in control?
- Have planned durability interventions been implemented on schedule, and have they accomplished the planned effect?

High-Performance Roofs: The Synergy Bonus

After identifying the potential energy, environmental, and durability factors that may be incorporated into a high-performance roof design, the costs and combined benefits of the factors should be analyzed to determine the optimal roof-design strategy. For example, if the building requires air-conditioning, and electricity costs are based on peak demand usage, a cool-roofing strategy—combined with high-thermal insulation—would appear to be an obvious combination. Likewise, if the roof installation was scheduled during the summer "ozone season" in an area of the country with ozone non-attainment concerns, the use of low-VOC materials would need to be integrated into the overall roofing strategy. Finally, if the building owner expressed concerns about his/her ability to manage extensive repairs or refurbishments to the roofing system after initial installation, initial durability of the roofing system may need to be increased to minimize demands for ongoing maintenance.

When the benefits of these high-performance factors are added up, the synergy bonus may be very impressive. According to a recent economic study conducted by TEGNOS Research (*The Commercial Roof Energy Savings Opportunity in North America: A 10-Year View*), the energy-savings potential alone of high-performance roofing systems could prove to be very significant. The study sought to measure the economic effects of adopting high-performance roofing strategies, such as increasing thermal insulation up to proposed *ASHRAE 189P* values, installing cool roofs in climates offering energy savings as a result, and adopting the best roof-design practices for the approximately 4 billion square feet of low-slope commercial roofs installed in North America annually. According to the study analysis, the first-year energy savings was estimated at $55 million.

In addition, if this strategy was maintained for 10 years on 4 billion square feet of roofs each year, the annual energy savings would grow to $550 million, and the cumulative savings for the 10-year period would exceed $3 billion. Talk about Mark Twain's synergy bonus!

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