White-membrane cool roofs are viewed to be significant energy-saving building components. But some research is suggesting that, throughout their life cycle, the overall energy benefits may not be so positive.

Questioning Cool Roofs

Now that we have some experience with white cool roofs, research is indicating that they're not the silver bullet we seek for energy savings and the urban-heat-island effect.

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The "cool roofing" movement is now more than 15 years old and the early installations are entering the mature stages of their life cycles. As with all roofing products, the truth about performance is revealed later in a roofing system's life cycle, after the roof system has been exposed to the elements. It's also later in the life cycle that we see the results of contractor installation variances, product weathering, and unexpected consequences associated with unique applications.

Today's cool-roofing materials have stabilized formulations and improved weathering packages and, for the most part, sufficiently address the physics of reduced thermal downward moisture drive and condensation. To some extent, however, the effects of high reflectance have not been addressed as well as they could have been, especially in cold-weather climates.

An underlying concern with the cool-roofing theory in the professional roofing community has been the fact that institutions and researchers that have promoted the concept have conducted their studies without a holistic view that accounts for the complex interactions of roof-system components. Unfortunately, roofing professionals, with years of knowledge regarding the performance of roofing products, and manufacturers, who warrant the roofing systems, were not properly consulted. Instead, institutions and researchers who have far less knowledge of roofing systems and their inherent performance attributes have assumed a dominant role in the promotion of cool-roofing thinking.

The reports prepared by research facilities, such as Lawrence Berkeley National Laboratories, Berkeley, CA, were based on computer modeling that did not account for atmospheric factors or other unexpected consequences. The research results, in many instances, were promoted as scientific fact even though some factors were left untested. These hypotheses were incorporated into the California Energy Commission and subsequent code and also adopted into systems such as LEED without the due diligence required to validate the underlying theory. Even more damaging was the fact that this thinking promoted a roof-cover-only concept, which lacked understanding of the critical components that lie beneath a roofing membrane and are vital to the performance of any roofing system.

As the cool-roofing concept gained momentum, the industry began to experience unintended consequences that caused roofing systems to perform below satisfactory levels. In recent years, technical research on the validity of cool roofing (for reducing urban-heat-island temperatures and delivering energy savings) and its potential unintended consequences were finally undertaken. The results have challenged much of the initial thinking upon which cool-roofing adoption was based.

In particular, the efficacy of cool roofing as a panacea for energy savings has been called into question by recent technical articles that consider various concerns raised by roofing industry professionals.

Recent research

***Effects of Urban Surfaces and White Roofs on Global and Regional Climate;* Mark Z. Jacobsen and John E. Ten Hoeve; Department of Civil and Environmental Engineering, Stanford University, Stanford, CA.**

No prior study has quantified the global urban-heat-island effect. This Stanford study set out to quantify the net effect of all urban areas on global climate, using a model that measured urban surfaces and their impact on average temperatures both near and far.

The study concludes:

- While population-weighted air temperatures decreased due to white roofs, the global temperature as a result of cool roofs was increased.
- Greater roof surface reflectivity increases the solar absorption of airborne black and brown carbon soot particles, suggesting an increase in atmospheric heating.
- Air, heated by soot, can travel long distances, suggesting that local changes due to white roofs can propagate on a large scale.
- Oleson et al. [2010] found that, on average, white roofs increased winter space-heating demand more than they decreased summer air-conditioning requirements.

***The Effects of Roof Membrane Color on Moisture Accumulation in Low Slope Commercial Roof Systems;* Mike Ennis, SPRI; Manfred Kehrer, ORNL; Proceedings of the NRCA 2011 Roofing Symposium.**

This study focused on the concern that mechanically attached single-ply membrane systems in cool-to-cold climates have the potential to enable the formation of moisture (dew) on the underside of the membrane. Field investigations and hygrothermic studies were undertaken to understand the phenomenon and predict potential moisture accumulation within the roof system.

The study concludes:

- Membrane color can have an impact on dew points within the roof assembly, leading to moisture accumulation.
- Reports mentioned in the study show that moisture accumulation in the roof assembly does occur and, if severe, can have a negative impact on its long-term performance.
- Situations where moisture accumulation occurs are due to improperly designed roofing assemblies.
- Hygrothermal modeling should be used by design professionals to assess the tendency of various roof designs to promote moisture accumulation. Note that the modeling should encompass the construction, commissioning, and building-use phases, as construction activity can lead to long-term detrimental effects on roof-system performance.

Mold growth and moisture led to interior dripping on this 18-month-old mechanically attached white roof system.

In just 15 months, the reflective benefits of this white roof were negated by excessive dirt build up.

***Black versus White: Energy Performance and Cold Climate Concerns;* Samir Ibrahim, Carlisle SynTec, 2012 International Roofing Expo, Orlando, FL.**

Using thermocouples placed on and above the roofing membrane in 6-inch increments, this field study explored the impact of roof color on ambient air temperatures. This effort was inspired by a prior study that was conducted by the Copper Development Association, New York, on the effects of rooftop exposure on ambient temperatures inside conduits.

The study concludes:

- Black EPDM membrane surfaces absorb UV radiation on sunny days and surface temperatures increase. However, this does not contribute appreciably to increased air temperature above the roof.
- White-thermoplastic membrane surfaces reflect a large portion of the UV radiation, resulting in lower membrane surface temperatures. However, due to the membrane's reflectivity, air temperatures above the membrane significantly increase.
- Reflected energy from the white roofing system significantly increases air temperature, potentially leading to higher cooling loads for AC units.

***Effects of White Roofs on Urban Temperature in a Global Climate Model;* K.W. Oleson, G.B. Bonan, and J. Feddema; Geophysical Letters, Col. 37L03701, 2010.**

In this study, the effects of globally installing white roofs are assessed using an urban-canyon model coupled with a global-climate model. The purpose of the study was to highlight issues with using white roofs to mitigate the heat-island effect and to identify what processes must be considered when evaluating the effectiveness of this method. This study uses a canyon model that allows for changes in roof albedo (solar reflectance) only, in contrast to Akbari et. al. [2009], who increased the albedo of roofs and pavements.

The study concludes:

- Heat island temperature decreases depend on the importance of roofs relative to the rest of the urban system (building walls and canyon floor) in generating the heat island.
- Using white roofs to decrease the urban-heat-island temperatures is less effective in winter at higher latitudes.
- At higher latitudes, the benefits gained from reduction in the summertime heat-island temperature need to be weighed against increased heating costs.
- Globally, white roofs cause a net increase in the large-scale space-heating and air-conditioning fluxes, due to a larger increase in space heating than a decrease in air-conditioning flux.

***Long-Term Reflective Performance of Roof Membranes;* David L. Roodvoets, DLR**

Consultants, William A. Miller, Oak Ridge National Laboratory, and Andre O. Desjarlais, Oak Ridge National Laboratory.

This study addresses how the reflectance of cool-roofing single-ply membranes changes over time and how building energy use is affected by reflective roofs.

A key comment within the paper rings true: "Saving energy when the sun shines is what cool roofs are all about. They do not save energy at night when there is no sun or when it is cold outside."

This statement confirms what roofing experts already know: Proper levels of insulation are the most important part of an energy-efficient roof design.

A three-year field study was undertaken in eastern Tennessee, where the climate soiled all-white thermoplastic membranes and resulted in a 30% to 50% loss of surface reflectivity that, for the most part, occurred in the first two years. Findings show that airborne particles are responsible for the loss of roof reflectivity. Additionally, these particles are vehicles for delivering microorganisms to the roof, which form a biological film-like structure on the roof surface and enhance the deposit of dirt on the roof, further reducing reflectivity. As a result, particularly in cool climates, periodic washing of cool-roof membranes may be justified.

The concept of roof-system design using a single-component solution (roof cover) with promised or perceived benefits was ill-conceived and short-sighted. There was no consideration for thermal performance, air penetration, or vapor drive, only for surface temperature at the membrane level. This approach led to a fundamental shift (cheapened assemblies with reflective membranes) in the roofing industry unlike any other we've seen. Current studies are beginning to question the performance of reflective membranes as a panacea for energy savings and challenge the hypothesis on which standards and codes have been based.

Cool-roof single-ply membranes have shown to be good roof covers for many roof-system designs. Architects, engineers, building owners, and roof-system designers are encouraged to design roof systems appropriate for the building use, climate, and contractor base. By focusing on the provision of a high-performance system that can provide overall energy efficiency and withstand extreme weather conditions, the specifier will ensure that the life cycle is maximized to provide the best overall option, cool roof or not. cbp

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