Feature

A New Approach to Codes for Low-Slope Commercial Roof Systems:

Sharpened Focus And Increased Flexibility In Codes Are Needed To Better Serve Building Owners And The Wider Community

By Jason Wilen

AFTER HURRICANE IAN devastated parts of Florida in 2022, almost before the winds had subsided and the floodwaters receded, the predictable discussion of building codes began. Most of the conversation centered on why the devastation was so widespread, especially after Florida had adopted strict building codes in the wake of Hurricane Andrew almost three decades earlier. Notably, while Hurricanes Andrew and Ian received nationwide media coverage, Florida has hardly been unique in experiencing the wrath of increasingly cataclysmic weather events in recent years.

According to the United Nations,[1] the incidence of major floods more than doubled during the past two decades, and there have also been substantial increases in the incidence of droughts, wildfires, and heatwaves. In response to these trends, codes related to low-slope roof systems have become more stringent. While organizations that promote and adopt building codes are to be commended for this effort, this increased stringency has not always translated into better-performing new roofs. Furthermore, existing roofs often do not meet the technical minimum performance standard prescribed in the current code.

THE CHALLENGE OF OVERLAPPING REQUIREMENTS

So why have scientifically informed building codes frequently failed to elicit the predicted building performance during hurricanes and comparably destructive events? The answer to this question may lie, at least partially, in the complexity of current building codes, particularly when we consider the numerous requirements that are being concurrently imposed on roofing design and construction. For instance, in some cases, primarily with regard to low-slope roofs, new requirements meant to increase wind uplift pressure resistance are too complex for many to understand. Standards referenced in many local codes to establish minimum attachment requirements for membrane roofs require a demanding, multistep process to convert predicted wind speeds to pressures, as well as an understanding of roof assembly testing protocols to determine minimum standards. Often the expertise to determine even a minimum approach is not present.

At the same time that building codes aiming to mitigate storm damage have become more stringent, other requirements such as those related to energy efficiency have also become more detailed and demanding. In our societal urgency to incorporate sustainability and resilience into the built environment, some "common sense" energy-saving solutions have not stood the test of time. For instance, recently published research looking at the effectiveness of reflective roofs suggests that "cool" roofs don't reliably translate into promised energy savings for building owners or deliver a reduction of urban heat islands (UHIs) as once thought.[2-4]

It is important to note that these complex efforts to strengthen building codes also apply to reroofing. Replacement roof systems are usually required to comply with the most current code for new construction, although there are some exceptions: preexisting design elements of the existing roof can sometimes make it impossible or impractical to incorporate the new code requirements in the replacement roofing system.

TYPICAL REQUIREMENTS FOR LOW-SLOPE ROOF DESIGN

When low-slope roof systems are designed as part of new buildings, there is an opportunity to design a high-performing roof that is both technically sound and responsive to sustainability goals. The following are the principal issues addressed by building codes in most jurisdictions for low-slope commercial roofs:

- Primary and overflow roof drainage capacity
- Wind uplift pressure resistance of the roof system
- Edge metal wind pressure resistance
- Ballasted roof requirements
- Aggregate surfacing requirements
- Roof assembly fire classification
- Roof system material standards
- Re-cover provisions (adding a second layer of roofing onto an existing roof)

- Roof system replacement provisions
- Specific provisions for vegetative roof overburden
- Specific provisions for rooftop photovoltaic systems (solar)
- Roof system insulation (material standards)

In addition to these issues addressed by building codes, there are also requirements in most energy conservation codes applicable to low-slope commercial roofs. They typically address the following:

- Minimum required roof system thermal resistance (*R*-value)
- Air leakage requirements
- Minimum roof reflectance and emittance in certain climate zones

Beyond these basic energy code requirements, some jurisdictions require builders to follow "stretch codes" (energy codes with above-minimum requirements). Some projects also include roof system–related requirements in an effort to meet sustainability goals for a project or organization. Common above-minimum code provisions or voluntary energy and sustainability goals that affect low-slope commercial roof design and installation might involve the following:

- Rainwater runoff mitigation—roof system design so that rainwater is retained and released over time to reduce runoff intensity
- UHI reduction efforts, such as areas of reflective roof surface, rooftop vegetation, shading strategies, and reflective walking surfaces
- Vegetative roof surfaces that do not require permanent irrigation systems
- Required use of roof system components that have published environmental product declarations and verified improved environmental life-cycle impacts
- Required use of products that have a published corporate sustainability report and whose raw materials were extracted using environmentally, economically, and socially preferable methods
- Required use of products for which chemical ingredients are inventoried using an accepted methodology and are verified to minimize the use and generation of harmful substances
- Required use of products with limited amounts of volatile organic compounds
- Required inclusion of solar-ready roof zones where a section or sections of roof area are designated, structurally enhanced, and reserved for the future installation of solar photovoltaic or solar thermal systems
- Mandatory installation of on-site renewable energy system, which could include rooftop areas

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ROOF SYSTEM DESIGN PROCESS

Given this extensive list of requirements, as well as the modifications that can be added by local jurisdictions, unintended consequences may occur as technical and energy-saving requirements collide. What follows is an example of how this "collision" might play out.

Roof assemblies are generally required by building codes to be designed for wind uplift pressure resistance and per a required fire classification. To demonstrate code compliance, roof system designers research previously tested roof system components (the roof system) on specific types of structural roof decks (roof system + roof deck = roof assembly). The goal is to find a collection of products that, when used together, will result in an assembly that has been shown to perform to at least a minimum level mandated by relevant building codes. Roof assembly testing is typically performed by roof system manufacturers. Therefore, diligent designers collaborate with technical representatives from manufacturers to confirm preferred roof systems and roof decks have been shown through testing to produce the mandated minimum performance.

However, at the same time, roof system designers are increasingly required by code or by project requirements to use only those products that have purported energy conservation or sustainable attributes. Such requirements are an understandable response to the growing demand to create sustainable structures.

Unfortunately, code provisions often do not have enough flexibility or provide adequate guidance for code officials and designers to address the realities of construction when they require mutually exclusive choices.

For example, suppose that a roof system designer has calculated the required fire classification and wind uplift pressure resistance of the proposed roof. Based on those findings, they have designed a roof system and attachment method that has been shown to perform adequately per code when attached to the specified roof deck, also taking into account the testing reports of the roof system manufacturer. However, to comply with a low–volatile organic compounds requirement for adhesives, the designer is required to substitute a water-based adhesive for the traditional adhesive used by the roof system manufacturer during assembly testing.

To continue our example, as often happens, the roof assembly manufacturer did not include the desired adhesive as part of their tested assembly, and a code official may not accept the test for compliance unless all components match the system that was tested. Therefore, the desired roof system could be considered non-compliant. In a comparable example, let us suppose that there is an assembly that uses mechanical fasteners instead of adhesive that has been tested and shown to have equivalent performance. However, the use of this type of assembly could also pose challenges. Perhaps the number of fasteners needed to achieve the required wind uplift pressure resistance would puncture the desired air barrier membrane so often that it would fail to comply with minimum air-leakage requirements. Equally problematic, the increase in thermal bridging due to the fasteners penetrating the insulation could reduce energy performance below desired levels.

These examples demonstrate how trying to comply with both technical and environmental requirements can present challenges that limit final design choices. Design processes become more complex and time consuming to achieve a minimum result, and the final outcome may not be desirable from either a technical or environmental perspective. Code compliance is all too often an "all or nothing" proposition.

As an alternative approach, building codes could include provisions outlining specific situations where code officials may accept documentation demonstrating that a legitimate effort was made to provide as much environmental/sustainable/energy-efficiency benefit as is feasible with available materials without compromising recommended technical parameters as determined by the designer of record. Building code officials, while they typically have the authority to grant relief from code requirements on a case-by-case basis, often don't have a background or experience with the challenges related to the replacement of building enclosure systems such as a low-slope roof. As a result, in my experience, they often default to allowing a replacement of the system in kind, and possible improvements, though short of full code compliance, are not realized.

Also, code requirements generally become more stringent over time; this has certainly been true with those that govern low-slope commercial roof assemblies. For example, when research revealed a need for increased thermal resistance and greater wind uplift pressure resistance in roofing systems, the new information was presented as part of code change proposals during the normal three-year update cycle of building and energy codes. Benefits for both building owners and society in general were cited and demonstrated by scientific research, and ultimately the codes were changed to reflect the additional stringency needed to achieve the desired results. These were necessary changes that required new and more stringent approaches to the design of low-slope roofs. This may have been a benefit in the long term but has created a short-term challenge.

In some cases, research has even demonstrated that code requirements once thought to be desirable are not achieving the expected benefits, or the requirements have unintended consequences. An example of this type of reassessment process is recent research on "cool roof" requirements. The EPDM Roofing Association (ERA) provides science-based technical and research support for the use of EPDM roofing materials. One of ERA's research interests is to determine the value of their members' white and black membrane products in energy-saving strategies. Recent ERA-sponsored research suggests that reliance primarily on reflectivity to deal with UHIs, one of the most expensive and dangerous impacts of climate change, may not be as effective a strategy as once thought. (See the sidebar for additional information about UHIs.) This conclusion is based on the findings of two studies funded by ERA that attempted to measure the efficacy of reflective or "cool" roofing as a mitigation strategy against UHIs.[2,4]

The goal of the research was to determine whether mandating reflective roofing produced a large enough benefit to justify the reduction of available roofing products in the jurisdictions where the restrictions are in place. Data were examined from both southern and northern climate zones to assess the benefits of cool roofing in a variety of climate conditions.

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ERA selected ICF, a Virginia-based independent consulting firm with experience in climate change research, data analysis, and building science, to analyze existing data and previous studies on UHIs, with a specific focus on the measurable impacts of the albedo of low-slope commercial roofing. ICF's analysis of temperature data for cities with cool-roof mandates found no discernable correlation between the imposition of cool-roof mandates and a reduction in UHI. ICF also found that complex and inconsistent temperature assessment protocols are being used in virtually

According to the US Environmental Protection Agency, Urban Heat Islands (UHI) "are urbanized areas that experience higher temperatures than outlying areas. Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes such as forests and water bodies. Urban areas, where these structures are highly concentrated and greenery is limited, become "islands" of higher temperatures relative to outlying areas. Daytime temperatures in urban areas are about 1 to 7°F higher than temperatures in outlying areas and nighttime temperatures are about 2 to 5°F higher."[7]

"Humid regions (primarily in the eastern US) and cities with larger and denser populations experience the greatest temperature differences."[8]

In Phase I of the ICF urban heat island (UHI) research, EPDM Roofing Association (ERA) compared ambient temperatures in three urban areas that have implemented cool roof mandates (New York, New York; Chicago, Illinois; and Washington, DC) to ambient temperatures in three similar localities that did not impose such mandates (Newark, New Jersey; Indianapolis Indiana; and Baltimore, Maryland). In this phase, ERA used publicly available data from location specific weather stations and methodology from Climate Central[6] to understand the incremental effect of commercial roof solar reflectance on UHI effects.

In Phase II, ERA continued to assess the relative role of commercial cool roofs on local UHIs. However, compared with Phase I, ERA used higher-resolution imagery to enable more rigorous analysis of the commercial zoning areas of interest and reframed the analysis to evaluate changes in UHIs within a particular city which then allowed a direct assessment of correlation between UHIs and an increase in cool roofs.

In Phase III, the ERA performed a temperature-based analysis to evaluate daytime and nighttime changes in UHI for 13 US cities on an annual basis over a period of more than a decade. The research compared the strength and significance of daytime and nighttime UHIs with existing published research and the probability of UHI being as prominent as indicated in existing research using alternate weather stations and summertime periods, following the methods used in existing published research.

In this three-phase research study,[2] an increased presence of cool roofs, whether by mandates or market occurrence, was not proven nor shown to mitigate the UHI effect. Because there is no standardized method for determining or analyzing UHIs, research examining UHIs is contextual and influenced by the researchers' biases.[2]

all UHI evaluations, making comparisons of product efficacy problematic. (See the sidebar for additional details about the ICF research.)

Given that the two-year effort of ICF determined that the presumed association between urban temperatures and reflective roofs could not be verified in the real world, ERA then contracted with the Clemson University Department of Construction Science and Management to further explore the presumed relationship between cool roof mandates and the reduction of UHIs. Two Clemson experts designed and led a thorough investigation of published studies and models to understand the impact of membrane color on energy efficiency and UHI effect. The Clemson literature review investigated more than 2,856 published articles and selected 280 references for more-intense review.[4]

The Clemson researchers identified several reasons why there is no clear answer about the relationship between roof color, UHIs, and energy efficiency. These reasons include the following:

- The reviewed studies lack meaningful comparisons of a range of factors that affect UHIs such as roof type, climate and location, insulation thickness, tree canopy, hardscape, and asphalt.
- Investigators have used varied methods of data capture and analysis, rely mostly on simulation-based studies, and tend to capture data for only short durations.
- Conclusions from widely distributed early studies continue to circulate, even though the information from those studies should be considered dated or incomplete information given more current and updated research.

The following example shows how new information could change how certain code provisions are viewed. In this case, new research suggests reflective membranes offer a lesser energy-saving benefit than currently assumed, especially in more northern climate zones. Unfortunately, other than the normal code update cycle that takes years to play out, there is not currently a way in most places for information to be presented to policy makers. The process might be more effective if there were a mechanism within jurisdictions where science-based information could be submitted and evaluated, and adjustments made where appropriate, in a timelier fashion.

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The Polyisocyanurate Insulation Manufacturers Association (PIMA) has produced a technical guide, offering solutions to insulation-thickness and existing-height challenges on low-slope roof system replacement projects. According to this guide:[5]

"The replacement of low-slope roofs offers a unique and significant opportunity for improving the energy efficiency of building enclosures. Under the building code, a roof replacement includes removal of existing roofing materials down to the roof deck, inspection and repair of any damaged roof deck, and installation of new roof materials. In this scenario, the roof insulation installed as part of the new roof system must comply with the energy code requirements for thermal insulation. Modern energy codes typically require the installation of *R*-25 to *R*-35 roof insulation depending on the climate zone of the building.

"On certain roof replacement projects, due to challenging conditions such as low curb heights or door thresholds, installing the energy code required levels of insulation may pose practical challenges. Recognizing these challenges, the Polyisocyanurate Insulation Manufacturers Association (PIMA) is releasing a guidance document to highlight practical solutions to these challenges, which can then be implemented in the design of roof replacement projects.

"While the majority of roofs do not exhibit conditions that inhibit compliance with the insulation requirements of the energy code, PIMA's guidance document is intended to help project teams take the reasonable steps necessary to comply with the energy code when challenges arise. The guidance document can also be a resource for project teams in conversations with local code officials to help answer compliance questions."

The PIMA guidance document—Solutions to Insulation Thickness and Existing Height Challenges on Low-Slope Roof Replacements—will be available to the industry for free at:

www.polyiso.org https://www.polyiso.org/page/reroofingsolutions.

CODE COMPLIANCE IN REROOFING PROJECTS

The roof system design process for the replacement of existing low-slope roof systems is often more challenging than for new construction. With a few exceptions, replacement roof system designs are expected to satisfy the current code requirements for new construction. The challenge is obvious, as roof system designers generally have little ability to modify adjacent surfaces or available dimensions, and they need to accommodate existing rooftop equipment.

The various layers of 21st century roofing systems were, for the most part, designed to meet codes that were less stringent than those that builders face today. Language addressing technical infeasibility is often added as part of the local code adoption process, but such information is needed in model codes to assist local jurisdictions in solving this problem. Such flexibility incorporating into existing model codes would be a step in the right direction.

Another common challenge with reroofing projects is that sometimes there is not space to add additional insulation above roof decks to meet the thermal resistance (insulation) requirements in current energy codes. In the past, requirements were less stringent and adjacent wall elements such as through-wall flashings, walkout door thresholds, and roof anchor length were based on thinner roof systems. When these issues are present, it is often the case that code officials accept insulation with less thermal resistance than the current code would otherwise require for that jurisdiction.

A lesser-known ramification of the common less-insulation situation, in cases for projects in more northerly climate zones, is that, in addition to wintertime conditions where less insulation may cause a condensation concern, the summertime surface temperature of roofs are also important (depending on the overall configuration of the roof system) in limiting condensation within the roof system as higher roof surface temperatures improve the roof system's ability to drive moisture out of the roof system that may have accumulated during the winter when vapor drive tends to be upward and into the roof system insulation.

When dark-colored roofs are replaced with cool (highly reflective) roofs and, for reasons noted above, the thermal resistance of the overall roof system cannot be improved, moisture within the roof can build up seasonally, potentially leading to failure of the roof system and moisture damage within the roof and to adjacent building components. This problem typically occurs when the temperature of the roof during the summer is not high enough to drive out moisture that accumulated in the roof system during the wintertime (that is, the vapor drive cycle).

In these instances, there are better outcomes when the codes allow roof system designers enough flexibility to balance condensation control with other aspects of their designs. In some reroofing instances, when it is not feasible to increase insulation thickness, the best overall outcome that balances energy efficiency and building code–related requirements may include installing a dark roof membrane. This approach can both reduce the likelihood of wintertime condensation due to roof surface temperature and also increase the likelihood of driving moisture out of the roof system in the summer due to higher temperature differential between the roof surface temperature and the indoor temperature.

The insulation industry has begun to address this issue. The Polyisocyanurate Insulation Manufacturers Association (PIMA) will soon release a guidance document[5] for use by designers, contractors, and code officials with the goal of maximizing *R*-value while, at the same time, acknowledging the challenges of increasing insulation thickness on existing buildings. See the sidebar for information about PIMA's guidance document.

CONCLUSION

This article demonstrates the need for greater flexibility in building and energy codes to address modern realities of low-slope commercial roof system design and installation. Additionally, it is important that codes change when new and more complete information becomes available.

Given the complexity of the current code landscape, industry stakeholders need continuing education to stay well informed about requirements, the underlying calculations, and how to demonstrate compliance. Staying informed is a challenge for roof system designers, architects, engineers, and the contractors who install such systems. It is also a challenge for building code officials, who ultimately are required to judge whether specific designs are compliant or, if they are noncompliant, where they fall short.

Finally, the industry needs continuing research and development of new, more environmentally sensitive products. The aim should be to ensure that when new roof systems are installed, they provide the promised benefits for not only building owners and users, but for society in general.

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