

Properly Designed Tapered Insulation Systems Create a Strong Foundation

By Harry Comfort

In any kind of construction, a strong foundation is key. Whether that foundation is the basement of a building or the insulation under a roof system, the foundation sets the groundwork for success. When designing a low-slope roof system over a substrate that is less than ¼:12, a properly designed tapered insulation system becomes the foundation for a sound roofing system that will provide long-term protection.

Considering that the majority of commercial buildings have low-slope roofs, it's no surprise that 40 percent of all building-related problems are due to water intrusion. Even worse is that water intrusion accounts for more than 70 percent of construction litigation.¹

Improper drainage on a low-slope roof system often leads to ponding water, accelerating deterioration of the roof system and then leading to damaging and potentially costly water intrusion. It's a dangerous ripple effect and one that can be avoided with the proper design and installation of tapered insulation systems.



The goal of tapered roof insulation systems is to eliminate ponding/standing water on a membrane when the roof deck does not provide adequate slope. A properly designed tapered roof insulation system not only provides the necessary R-value and the support for the roof system, but it helps extend the life of the roof system because it provides the required drainage.²

Ponding water has the potential to add enormous stress to a building's roof with most warranties voided in areas where ponding water exists for more than 48 hours. In an effort to help building owners and design professionals understand the benefits and components of tapered insulation systems, this article will explore:

- Building code requirements regarding positive drainage and roof slope
- Design elements that need to be considered in tapered insulation systems
- Two most common types of tapered insulation systems
- The role crickets play
- Achieving R-values
- Dangers of value engineering

¹ Architect Magazine, *When It Leaks It Pours*, June 2011 (<http://www.architectmagazine.com/roofing/when-it-leaks-it-pours.aspx>)

² PIMA, *Tapered Insulation Systems Technical Bulletin #108*, July 2011 (http://c.yimcdn.com/sites/www.polyiso.org/resource/resmgr/technical_bulletins/tb108_jun30.pdf)

Building Codes

One of the first things to consider when exploring the use of tapered insulation systems is building code requirements. International Building Code requirements for low-slope roof coverings in new construction states all membrane roof covering systems except coal-tar built-up roofs must have a design slope minimum ¼:12.

When it involves a roof replacement, deviations from that requirement can be acceptable as long as positive drainage is present. The key to this exception is positive drainage. Because positive drainage is difficult to achieve on roof slopes less than ¼:12, it is highly recommended to adhere to building code requirements to avoid potential ponding water issues.

Generally, tapered insulation is the most cost effective method to achieving positive drainage on low-slope commercial roof replacements. However, tapered lightweight insulating concrete should be evaluated as an alternate to tapered insulation as it may be more efficient due to the roof configuration, details and location. In new construction, it may be less expensive to slope the structure to achieve the required drainage.

Design Considerations

As with any product or system, the proper design and installation of tapered insulation systems is directly tied to its performance. Without it, the overall effectiveness of the system can be compromised.

When designing a tapered insulation system, polyisocyanurate insulation is likely to be the type of insulation used. It's a rigid foam insulation used in the majority of low slope commercial roof construction. Polyisocyanurate insulation is compatible with virtually every roof membrane as well as a variety of composite products and provides superior R-values among other advantages.²

Tapered polyiso panels are manufactured in standard 4-foot by 4-foot sizes with a minimum thickness of ½-inch at its low edge and maximum thickness of four inches for a single board. A flat polyiso underlayment board, often referred to as flat fill, is used beneath continuing, repeating tapered panels.

As stated previously, a ¼-inch per foot slope is required by International Building Code. However, a variety of standard (⅛-inch and ½-inch per foot) and special order slopes (1/16-inch and ⅜-inch per foot) are available and acceptable based on field conditions and building parameters. Various degrees of slope may be needed to address or overcome deflected areas in the existing roof deck or reverse slopes in the existing roof deck.

² PIMA, *Tapered Insulation Systems Technical Bulletin #108*, July 2011
(http://c.ymcdn.com/sites/www.polyiso.org/resource/resmgr/technical_bulletins/tb108_jun30.pdf)

In addition to the panel sizes and required slope, existing components on the roof such as curbs, edges, through-wall flashings, as well as internal and external drain locations, expansion joints and heights of parapet walls need to be taken into consideration during the initial design phase. For example, a roof area having a 50-foot distance from the roof edge to the roof drain with a tapered insulation system sloped at ¼-inch per foot and 2-inch minimum at the roof drain will be 14½ inches thick at the roof edge. That thickness has to be accounted for in the wood nailers when developing the roof edge detail as well as in wall flashing heights and curbs.

Two Way and Four Way Systems

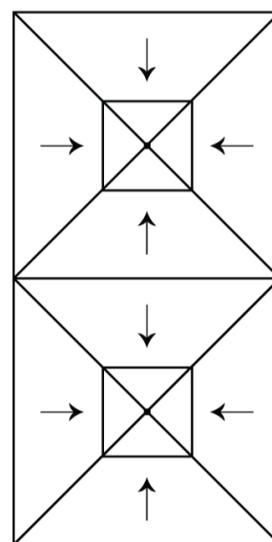
There are numerous ways to design a tapered insulation system, but the most commonly used designs are the two-way and four-way tapered systems. Industry professionals recommend the use of a four-way system (Figure 1) as the most effective way of moving water off the roof.

Assuming you have a square and the drain is in the center of that square, a four-way system is designed to drain down from the perimeter edge on all four sides at a 45-degree angle.

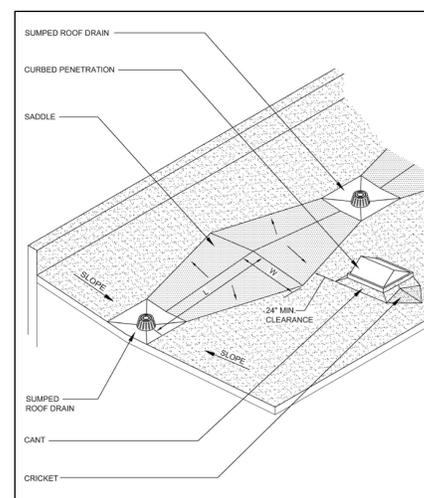
A two-way tapered system (Figure 2) is more rectangular, with the two longest sides sloping to the drain. In theory, the surface is flat to begin with. Therefore, the tapered insulation starts on a dead level surface with a low point that is in a drain line. The slope goes from that point to a high point either at the roof perimeter or at a point between two drain lines. Once the primary slope is created, crickets are installed both between drains and between the end of the building and the drain to direct water to the outlets.

Ideally, the tapered system, either two-way or four-way, in combination with the drains would eliminate any ponding water issues. In order to keep water from ponding at the drains, it is important to ensure the drains are properly sumped so that there is enough momentum for the water to get down the drain. According to NRCA, drains should be located in square-shaped, gradually tapered sumps formed in the insulation to facilitate localized drainage at drains. A typical interior roof drain assembly occupies about a 4-foot by 4-foot square area with a ½-inch per foot-tapered slope. As a general rule, if the insulation is two inches thick or less, a 4-foot by 4-foot sump is sufficient. If the insulation reaches three inches or thicker, an 8-foot by 8-foot creates a more gradual slope while still providing the necessary momentum.

Although it is highly recommended to use a four-way tapered system, there are valid reasons to consider installing a two-way tapered system when certain conditions exist. According to the Polyisocyanurate Insulation Manufacturers Association (PIMA), some of those exceptions include:



Source: PIMA Figure 1
Four-way system



Source: Professional Roof Figure 2
Two-way system

- **Complexity of existing drain locations** – Extended sumps or valleys can be used to simplify design while eliminating complex cutbacks.
- **Multiple drains at a low point** – With the absence of an overflow drain, valleys between drains provide a helpful water path to drain, should one of the drains fail.
- **Cost** – Tapered insulation is an expensive material element of the roofing system and; therefore, is often the primary target for value engineering. Although value engineering can reduce the cost, it also compromises the drainage effectiveness of the tapered system.
- **High point restrictions** – When a perimeter condition limits the thickness of a material.
- **Rooftop penetration locations** – Extended low points, crickets and/or sumps may be needed to move valleys past or around rooftop units or skylight penetrations. In order to provide the most efficient tapered insulation drainage system, one should prioritize design intent and field parameters for each project.

Crickets

Crickets are a secondary application of tapered insulation used to divert water from rooftop curbs, valleys and low points to drains and scuppers. Crickets (Figure 2) are most often used in conjunction with two-way tapered systems in the low points of the tapered system. They are typically diamond or triangle in shape, and slope upwards from the drainage location, scupper or drain to keep water from remaining in the low points and also help direct water around rooftop mechanical units.

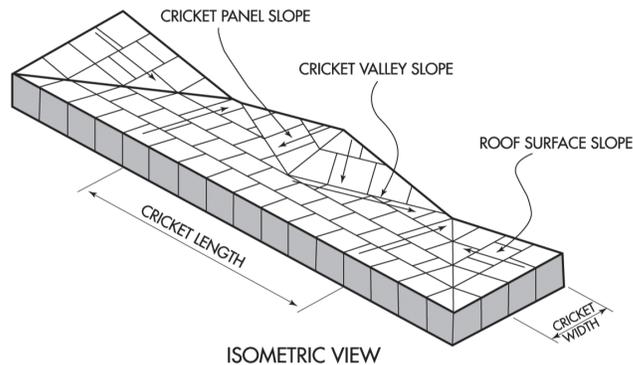


Figure 2 Source: PIMA

When designing a cricket, two items need to be designed – slope and configuration of the cricket. A general rule for designing sufficient slope in crickets is that its slope shall be twice the slope of the adjacent roof field. Typically, that will keep water from remaining on the cricket surface. Some residual water could be expected but it should dissipate within 48 hours.³

When designing the configuration of the cricket, the NRCA recommends designers recognize the importance of cricket geometry and valley slope and provide the following guidelines:

Recommended Maximum L:W Ratios for Crickets		
Roof Slope	Material Slope	L:W Ratio
1/8	1/4	3:1
1/4	1/2	3:1
1/2	1/2	4:1

* Courtesy of NRCA

³ Professional Roofing, *Still Water Runs Deep*, July, 2012

R-Value

When it comes to R-value, there are various ways design professionals can specify the required thermal resistance of the roof. For example, one specification may require a minimum R-value while another may require an average R-value across the entire roof. Code appears to require minimum thickness based on the demands of energy efficiency. However, average R-value is usually used due to the physical constraints of slope, fastener length, and flashing height, as well as the general concern for budgets.

One important change worth noting is that PIMA recently updated its QualityMark-certified R-value program to incorporate a new test method for determining long-term thermal resistance (LTTR) of polyisocyanurate insulation. As a result, new LTTR values will decrease about 7 percent from current values.

The minimum R-values are as follows:

Thickness	LTTR Value/Inch	LTTR Value
1.0	5.6	5.6
2.0	5.7	11.4
2.5	5.8	14.4
3.0	5.8	17.4
4.0	5.9	23.6

As recommended by NRCA Associate Executive Director Mark Graham, designers should specify thickness of insulation rather than R-value to ensure clarity in construction documents.

Value Engineering

Insulation is often one of the most expensive components of a roof system, making it a target for value engineering. Any compromise in product or design also compromises the efficiency of the system. Noted author and roofing expert, Wayne Tobiasson, may have summed it up best. “Money spent on roof slope is the best bargain in the construction industry.”



Oftentimes, building owners will agree to have a tapered insulation system installed only to have it value engineered at some point during the process, reducing the roof system’s efficiency and increasing the potential of creating problems down the road.

In addition to potential drainage problems, the decision to value engineer a tapered insulation system could violate building code and void the roofing manufacturer’s warranty, which typically require positive drainage and specifically exclude areas with ponding water.

Pay close attention to the width of a cricket or saddle. A sign of value engineering is when those crickets or saddles are slimmed down.

The specified R-value also needs to be carefully evaluated. Sometimes, a minimum R-value is bid while other times, a specification requires an average R-value be achieved. The design of a system requiring a minimum R-value of 20 versus one that requires an average R-value of 20 will vary greatly, as will the cost.

Summary

When it comes to designing a properly sloped roof system, the proper design and installation of a tapered insulation system could mean the difference between a roof failing prematurely or one meeting and exceeding its expected life. Tapered insulation systems play a critical role in moving water off a low-sloped roof and create the foundation needed for a roof system that will perform for the long-term. It is also important to note that after investing in a well-designed tapered insulation system, it's critical to protect that system with a high-performance roof. A poorly designed and installed roof system will not provide adequate leak protection and; therefore, reduces the effectiveness of the tapered insulation system no matter its quality or performance.

Harry Comfort is a territory manager with The Garland Company, Inc. with nearly 20 years of field experience providing commercial waterproofing solutions for the complete building envelope. As a structural engineer, Comfort's experience includes evaluating existing roof and wall conditions, providing technical support to design professionals, budgeting for roof restoration, maintenance, and replacement as well as recommending the installation of long-term, high-performance modified bitumen, architectural and standing seam metal roof systems, architectural metal wall panels and rainscreen systems, and fluid-applied waterproofing membrane systems. Comfort continues to work with academic institutions, design professionals and industrial facilities throughout his northern New Jersey territory, all who benefit from the level of service and quality installations facilitated by him.