Determining R-values for tapered roof insulation systems

by **Mark S. Graham**

Q: *How do you determine the R-value of a tapered roof insulation system when the insulation does not have a constant thickness throughout the roof?*

A: Two approaches may be used when determining the thermal resistance (R-value) of a tapered roof insulation system: minimum and average R-value.



The minimum R-value approach establishes the minimum thermal resistance for the tapered insulation by determining the R-value at the tapered insulation system's thinnest point (i.e., low point).

It's appropriate to use the minimum R-value approach when determining the tapered insulation's necessary minimum thermal resistance above a vapor retarder to prevent condensation or when a conservative thermal resistance design is desired. However, the tapered insulation system will have excessive R-value where the insulation is thicker than the low point thickness.

The average R-value approach establishes the overall average thermal resistance for the tapered insulation by calculating the tapered insulation's representative average thickness, then determining the average R-value based on the average thickness. Average thickness can be determined by two methods: arithmetic and volumetric average thickness.

Arithmetic average thickness is the thickness of the tapered insulation at the midpoint between the tapered insulation's low and high points. Use of the arithmetic average method is appropriate for simple-slope (e.g., one- or two-way) tapered insulation systems.

Q: *I am compiling a project submittal that requires metric measurements. How do I convert thermal insulation properties to appropriate metric values?*

A: The values in Table 1 may be used to convert English (inch • pound) units to SI (metric) units. Metric conversions for more common measurements, such as board size, thickness, compressive strength and other physical properties, may be found in *The NRCA Roofing and Waterproofing Manual*'s appendix.

Common metric conversions for energy analyses calculations

Measurement	English (inch • pound) units	Conversion factor (multiply by)	Metric (SI) units
Thermal conductance (C-value)	$Btu/h \cdot ft^2 \cdot °F$	5.678	$W/m^2 \cdot K$
Thermal conductivity (k-value)	$Btu \cdot inch/h \cdot ft^2 \cdot °F$	0.1442	$W/m \cdot K$
Thermal resistance (R-value)	$°F \cdot ft^2 \cdot h/Btu$	0.176	$m^2 \cdot K/W$
Thermal transmittance (U-factor)	$Btu/h \cdot ft^2 \cdot °F$	5.678	$W/m^2 \cdot K$
Permeance (perm)	$gr/h \cdot ft^2 \cdot in.\ Hg$	57.45	$ng/s \cdot m^2 \cdot Pa$
Permeability (perm • inch)	$gr/h \cdot ft^2 \cdot (in.\ Hg/in.)$	1.46	$ng/s \cdot m \cdot Pa$

This information was obtained from the *1993 ASHRAE Handbook—Fundamentals*, page 35.1.

Table 1

Arithmetic average thickness is calculated as follows:

Arithmetic average thickness = LP + (½ [HP - LP])

Where: LP = Low point or tapered insulation system's minimum thickness.

HP = High point or tapered insulation system's maximum thickness.

Volumetric average thickness is the thickness of the tapered insulation where one-half of the insulation's total volume occurs downslope of the average thickness; the remaining one-half volume occurs upslope.

For symmetrical four-way slope (e.g., concentric drainage pattern) tapered insulation systems, volumetric average thickness is determined as follows:

Volumetric average thickness = LP + (⅔ [HP - LP])

Where: LP = Low point or tapered insulation system's minimum thickness.

HP = High point or tapered insulation system's maximum thickness.

For nonsymmetrical or irregularly shaped tapered insulation systems or tapered systems where the fill material has a different R-value than the tapered insulation material, volumetric average thickness is determined by calculating the total board footage of tapered and fill material, deducting for any anticipated waste, then dividing by the roof surface area.

Some prefer the average R-value approach for calculating the thermal resistance of tapered roof insulation systems because it reports a higher thermal resistance than the minimum R-value approach. However, it is important for professionals to realize that when using the average R-value method, one-half to two-thirds of the total roof area may have an actual thermal resistance that is less than the average value.

When using the average R-value method, it is suggested that the tapered insulation system's designer report the minimum R-value, average R-value and method of average R-value determination. PR

Each month in this column, one of NRCA's deputy directors of technology and research will answer readers' technical questions. If you have a specific question you would like answered in this column, send it to Professional Roofing, *10255 W. Higgins Road, Suite 600, Rosemont, Ill. 60018-5607; fax (708) 299-1183.*