Roof insulation: Necessary or not?

Proper design and use of rigid board insulation can enhance roof system performance

by Mark S. Graham

With recent energy shortages and rising energy costs, there has been increasing concern and demand for energy-efficient roof assemblies. As a result, the roofing industry has seen an emergence of roof reflectivity measures, such as "cool roofing" and the Environmental Protection Agency's Energy Star® to provide energy-efficient roof assemblies. Interestingly, there has been little discussion regarding the use and importance of insulation as a roof assembly component to achieve energy efficiency.

Following is a review of some fundamental concepts regarding the use of rigid board insulation as a component of low-slope roof assemblies. These concepts have been fully established and credible in the U.S. roofing industry for years.

INSULATION'S ROLE

Roof insulation's primary purpose is to increase a roof assembly's thermal efficiency. For most buildings, particularly low-rise buildings, a roof is one of the largest surface areas of a building envelope (the surfaces separating a building's interior from exterior) through which heated and cooled, conditioned air passes. Increasing a roof assembly's thermal efficiency, such as by adding insulation, generally will reduce the amount of heat transfer through the roof assembly and help maintain the building's inside temperature at a more constant, comfortable temperature. A thermally efficient roof assembly can reduce the amount and cost of energy required to heat and cool a building.

Roof insulation installed with an adequate, properly placed vapor retarder also can reduce the potential of moisture condensation occurring on buildings' interior surfaces. In addition, rigid board insulation provides a relatively smooth, stable substrate to which other roofing materials, including roof membranes, can be applied.

Certain roof insulation products can provide important fire-resistance properties to roof assemblies, which are likely required by applicable insurance underwriting requirements and/or building codes.

THE IDEAL INSULATION

Ideal rigid board insulation, which is described in *The NRCA Roofing and Waterproofing Manual, Fifth Edition*, has a high thermal resistance (R-value), stable R-value, moisture resistance, high compressive strength, impact resistance, dimensional stability, component compatibility, compatibility with bitumen and adhesives, attachment capability and fire resistance. More detailed descriptions of these qualities follow:

- ✓ *High thermal resistance.* Thermal efficiency of an insulation material generally is described by thermal resistance, commonly referred to as R-value. A material's R-value is defined, under steady conditions, as the mean temperature difference between two defined surfaces of a material or construction that induces unit heat flow through a unit area. R-value topically is expressed in English-based (inch•pound) units °F•ft²•hour/Btu. The R-value of a material or construction applies to a specific thickness of that material or construction and is the reciprocal of the thermal conductance (C-value) of that material (R = 1/C). R-values can be mathematically added and subtracted accurately; C-values cannot. The higher the R-value of a material or construction, the higher

its thermal resistance and, generally, its thermal efficiency. An ideal roof insulation would have a high R-value per unit thickness.

- ✓ *Stable R-value.* An ideal roof insulation would have a stable R-value during a roof assembly's useful service life. Insulation's thermal resistance should remain constant and not drift or lose value with age.
- ✓ *Moisture resistance.* Ideally, roof insulation would resist moisture during application and a roof assembly's useful service life. The insulation's physical properties should not degrade significantly from the effects of moisture vapor or water.
- ✓ *High compressive strength.* An ideal roof insulation would have sufficient strength to resist damage from transportation and handling, roof system construction operations and typical rooftop traffic during a roof assembly's useful service life.
- ✓ *Impact resistance.* Ideally, roof insulation would have the strength, rigidity and density to resist impact damage during transportation and handling, installation and a roof assembly's useful service life. Insulation's performance during typical anticipated hail events, for example, should not effect a roof assembly's overall performance.
- ✓ *Dimensional stability.* An ideal roof insulation would be dimensionally stable under varying temperature and moisture conditions typically anticipated during installation and a roof assembly's useful service life. Roof insulation used as a substrate for a roof covering should be more dimensionally stable than the roof covering material.
- ✓ *Compatibility with components.* An ideal roof insulation would be physically and chemically compatible with other roof assembly components.
- ✓ *Compatibility with bitumen and adhesives.* An ideal roof insulation would be able to withstand contact with adhesives, solvents and hot bitumen at application temperatures required for installation of roof assembly components.
- ✓ *Attachment capability.* An ideal roof insulation would accommodate secure attachment to its substrate and of overlaying materials. Also, its resistance to moisture absorption would not impair its physical properties and attachment capabilities.
- ✓ *Fire resistance.* Ideally, insulation would be noncombustible during typical roof assembly application operations. Also, it would improve a roof assembly's overall fire resistance and comply with applicable fire test standards, insurance underwriting requirements and building code requirements.

Although the 10 properties described would be found in an ideal rigid board insulation product, in real-world conditions, no single, commercially available insulation product in the United States has all these properties. Therefore, NRCA recommends roof system designers choose rigid board insulation products that have properties best suited to specific project conditions.

Double-layer usage

When using rigid board insulation as a component of low-slope roof assemblies, NRCA suggests roof system designers specify double-layer applications of differing rigid board insulation types. This will allow for optimizing the desirable properties of two rigid board products to provide insulation assemblies best-suited for specific projects.

For example, though some commonly available foam plastic insulation products have relatively high R-values per unit thicknesses, other products generally provide better dimensional stability, compressive strength, component compatibility, and compatibility with bitumen and adhesive properties. At the same time, though some common rigid board insulation products, such as those used as cover boards, have relatively high compressive-strength and impact-resistance properties, these products generally have relatively low R-values per unit thickness. Using a rigid board insulation assembly consisting of a bottom layer of a suitable plastic foam insulation with a relatively high R-value and suitable cover board product provides for optimal properties of an insulation assembly.

When rigid board insulation is used in a double-layer application, NRCA recommends the joints of the top layer of insulation (for example, the cover board) be staggered and offset from the joints of the insulation board layer below. End joints of adjacent insulation boards also should be staggered.

In addition to optimizing insulation's desirable properties, double-layer applications of rigid board insulation can have other positive effects. Research reported in "Thermal Evaluation of the Effects of Gaps Between Adjacent Roof Insulation Panels," a paper from the *Proceedings of the DOE-ORNL Workshop on Mathematical Modeling of Roofs*, reveals a double-layer application of rigid board insulation can increase a roof assembly's effective thermal performance and reduce roof covering fatigue.

The actual R-value of a roof assembly using only a single-layer thickness of rigid board insulation may be reduced by as much as 10 percent because of heat losses through gaps at the joints between insulation boards. By designing for and installing rigid board insulation in two layers with joints staggered and offset between layers, the actual loss in thermal efficiency through gaps in insulation board joints can be reduced significantly.

Use of a double-layer application of rigid board insulation with board joints staggered and offset between the layers also reduces the amount of mechanical stresses applied to a roof covering at insulation board joints. This results in a notably reduced potential for roof membrane buckling, ridging and splitting.

Mechanical fasteners

The use of mechanical fasteners, such as nails or screws and plates, often is

required with the use of rigid board insulation by project specifications to meet specific wind resistances or building codes. Using metallic mechanical fasteners that penetrate the full thickness of a roof assembly's insulation layers significantly can affect roof assembly performance. Such mechanical fasteners are good conductors for thermal bridging and result in "thermal shorts" through insulation.

In research reported in the paper "A Heat Transfer Analysis of Metal Fasteners in Low-slope Roofs" from The American Society for Testing and Materials' Special Technical Publication 958, Roofing Research and Standards Development, it is indicated that such thermal shorts can result in losses of overall R-value of 3 percent to 8 percent when fasteners penetrate through insulation's full thickness.

By designing and installing rigid board insulation in a double-layer application with the bottom layer mechanically fastened to the substrate and top layer installed in adhesive or a mopping of hot bitumen, thermal losses through fasteners are reduced significantly. This installation method sometimes is referred to as the "screw one, mop one" technique.

Also, installing mechanical fasteners through only the bottom layer of rigid board insulation protects a roof covering from the possible effects of fasteners backing out, compression of the insulation at the fasteners and/or improper fastener installation.

In situations where a double-layer of insulation is to be installed using mechanical fasteners, NRCA suggests roof system designers specify the use of the "screw one, mop one" technique when possible.

How much R-value?

When considering using rigid board insulation as a component of low-slope roof assemblies, a question frequently raised by roof system designers is, "How much insulation, or what R-value of insulation, is necessary?" Although most roofing professionals know the answer likely will vary regionally and by building type, they may not realize industry-accepted standards provide guidelines for minimum R-values and buildings' overall energy efficiencies. In some instances, state codes require compliance with these standards.

ASHRAE Standard 90.1, "Energy Standard for Buildings Except Low-Rise Residential Buildings," provides minimum energy-efficiency guidelines for buildings, including specific requirements for minimum R-values for roof assemblies. ASHRAE 90.1 bases its requirements for minimum R-values for roof assemblies on a building's type and geographic location.

Compliance with ASHRAE 90.1-89 ("-89" designates the standard's 1989 edition) is a specific provision of the Energy Policy Act (EPAct) of 1992. EPAct mandates individual states develop energy-conservation codes that comply with currently recognized energy-efficiency standards. As a

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result, compliance with ASHRAE 90.1 is required by many state energy-efficiency codes. (For more information about ASHRAE 90.1, see "Codes now mandate minimum requirements for thermal insulation," May 1996 issue, page 26.)

In 1999, a revised and updated edition of ASHRAE 90.1 was published. ASHRAE 90.1-99 also includes allowances for reducing the minimum R-value required by roof assembly guidelines in certain geographic locations with prescribed, highly reflective roof surfaces. (For more information, see "Revised thermal insulation requirements," May issue, page 56.)

NRCA suggests designers of roof assemblies use ASHRAE 90.1 as a guideline for determining minimum roof assembly R-values.

Closing thoughts

The use of rigid board insulation as a component of low-slope roof assemblies remains an effective means of providing for buildings' overall energy efficiency. Use of such insulation has been substantiated with fully established, credible research and years of practical experience.

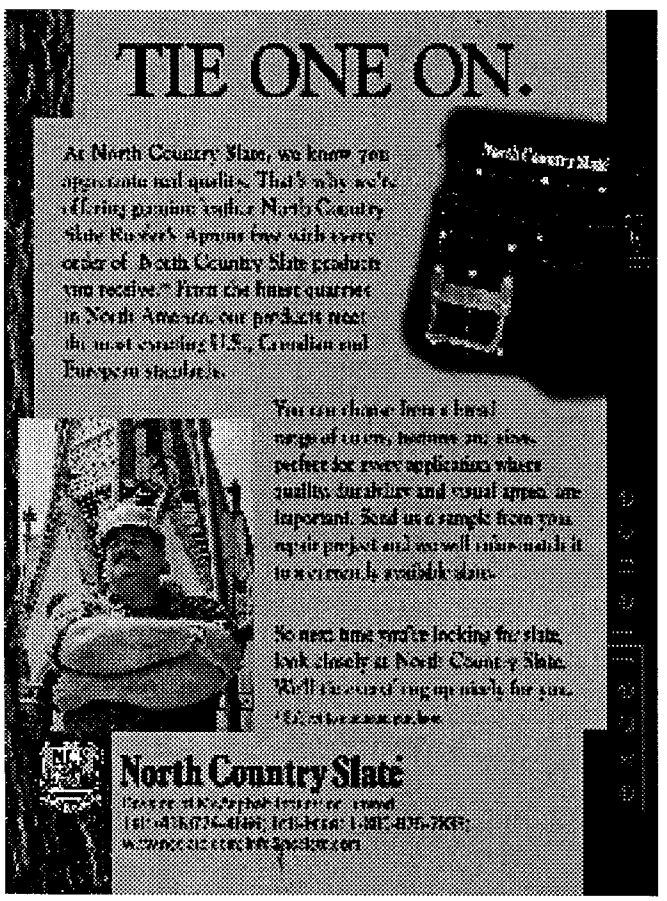
Additional information regarding the use of rigid board insulation in low-slope roof assemblies, including specific information regarding various insulation types, is provided in *The NRCA Roofing and Waterproofing Manual, Fifth Edition.*

Also, assistance in performing various energy-efficiency calculations, including R-value, heating and cooling costs, and ASHRAE 90.1 calculations, is provided in a CD-ROM application, RoofWise: The Digital Energy Workbench, Version 2.0.

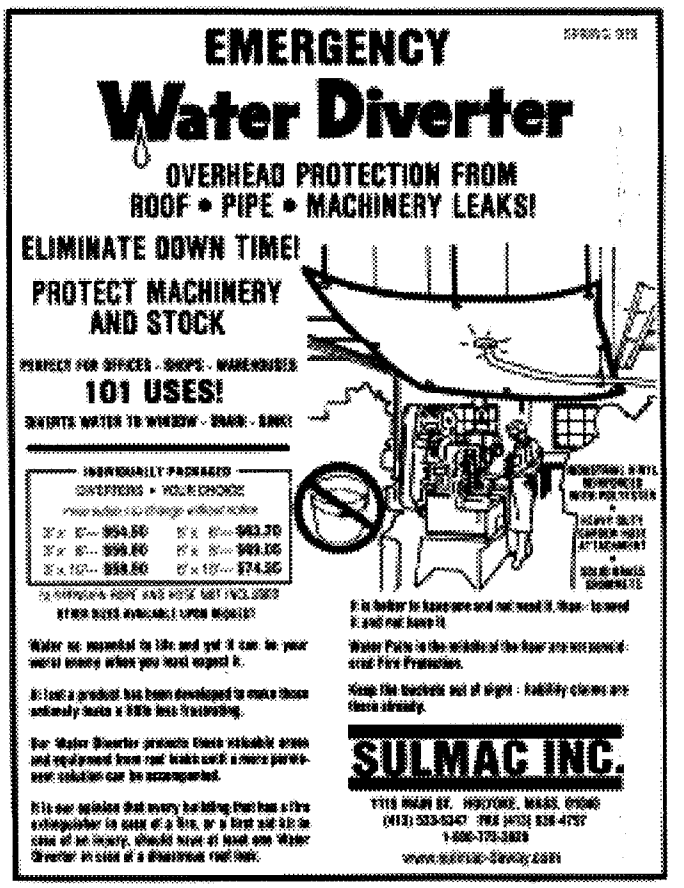
Both products are available from NRCA's InfoExpress by calling (800) 323-9545 or (847) 299-9070; faxing (847) 299-1183; or accessing NRCA's Web site, www.nrca.net.

Mark S. Graham is NRCA's associate executive director of technical services.

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