Oak Ridge National Laboratory: Stone-Coated Metal Roofing Research to Enhance Energy Saving Performance

Summary Results of Two Oak Ridge National Lab Studies (Oak Ridge, TN), Clarifying the Energy Saving Performance of Stone-Coated Metal Roofing:

January 6, 2006: ***The Effects of Infrared-Blocking Pigments and Deck Venting on Stone-Coated Metal Residential Roofs; ORNL/TM-2006/9 – January 2006 by William Miller***

January 12, 2012: ***The Tradeoff Between Solar Reflectance and Above-Sheathing Ventilation for Metal Roofs on Residential and Commercial Buildings; ORNL/TM-2011/X – January 2012 by William Miller, Ethan Herman & Russel Graves***

- Both studies were prepared for the **U.S. Department of Energy Buildings Technology Program** and the **Metal Construction Association**

2006 ORNL Lab Test Summary

In 2005, the Oak Ridge National Laboratory (ORNL), a United States lab dedicated to U.S. Department of Energy research, conducted field studies on energy efficient steep-slope roof installation of stone-coated metal roof systems (shake pattern and 'S' mission tile pattern) on a shed-type roof over an attic space, spanning both winter and summer seasons.

Two primary attributes were tested on the stone-coated metal roof system – the use of infrared-blocking 'cool roof' stone granules and the use of a batten installation method to enhance underside roof system venting – to reduce the heat flow penetrating the conditioned living space of a residence by at least 70% compared with the amount of heat flow penetrating roofs of the same pitch with conventional asphalt shingles.

The fully instrumented attic test assembly provided measurements of the roof, deck, attic, and ceiling temperatures, heat flows, solar reflectance, thermal emittance, and ambient weather recorded for each test roof and attic space. All roof assemblies had ridge and soffit venting (1:300 ratio of vent space to attic floor space); the ridge was open to the underside of the stone-coated metal roofs. The control assembly with conventional asphalt shingle roofing was used for comparing heat transfer rates.

The stone-coated metal roof system installs included both the shake and 'S' mission style tile roof panels applied both direct to the roof deck, and applied using battens and counter-battens to facilitate greater air flow between the roof panel underside and the top of the roof deck. Roof panel colors included both light gray and dark gray stone granules, with and without 'cool roof' infrared-blocking color technology. One roof assembly was also retrofitted over an existing cedar shake roof.

Test Results

Stone-coated metal roofs are energy-efficient, offering excellent energy credits as steep-slope cool roof products because of the improved solar reflectance afforded by the infrared-blocking stone granule cool roof colors combined with the underside roof deck venting. The best performing roofs were the 'S' mission style roofs on battens and the light gray 'cool roof' shake panel roof on battens and counter-battens. The reduction in heat penetrating the ceiling with these prototypes was about 70% of the daily heat penetrating the control asphalt shingle roof. Retrofitting a stone-coated metal shake roof over an existing cedar shake roof proved to be beneficial and resulted in the best thermally performing system, dropping ceiling heat flow by 75% over that of an attic with a conventional asphalt shingle roof.

The improved summer performance, coupled with the reduced heat losses during the winter as compared to an asphalt shingle roof, show that offset-mounting stone-coated metal roofs can provide the metal roof industry the opportunity to market stone-coated metal roofs in climates that are dominated more by heating loads (tests were conducted in Tennessee; having both hot summers and cold winters).

Air flow between the stone-coated metal roof system and the roof deck proved that naturally induced air flow can be expected at lower roof slopes and at small temperature differences. Measures of these air flows under the roof system were conducted using tracer-gas techniques.

Conclusion

This test and resulting data show the combination of improved solar reflectance provided by 'cool roof' heat-reflective stone granule colors and underside roof system venting make stone-coated metal roofs energy efficient. These materials can offer excellent energy credits as steep-slope roof products. The light gray stone-coated metal shake panels offset-mounted with a batten and counter-batten system reduced the heat transfer penetrating the roof deck by about 45% compared to the heat penetrating the deck of an attic covered with an asphalt shingle roof. Approximately 15% of the reduction was due to heat-reflective 'cool roof' granules, while 30% of the reduction was due to sub-roof tile venting. The synergistic effects of solar reflectance and underside venting supported a 70% reduction in the heat flow penetrating the ceiling into the conditioned space. Sub-roof tile venting of the stone-coated metal roofs is just as important as the boost in solar reflectance for reducing the heat gain into the attic.

2012 ORNL Lab Test Summary

Cool roofs continue to receive positive trade press for the benefits delivered in energy savings. In mixed climates with both significant heating and cooling loads, the wintertime effect reduces the energy benefit because the desirable roof heat gain in winter is diminished somewhat by the higher solar reflectance of the roof. Field data shows that metal roofs that are elevated off the roof deck and that exploit the use of cool color pigments provide an excellent design strategy for reducing roof heat gains and losses.

The venting design improves the durability of the roof assembly because the natural convection ventilation helps to dry the roof deck of any incidental moisture, including condensation. It can also protect the roof from wildfires common in wilderness urban interfaces (WUI). The thermally induced buoyant air flow increases as the metal's temperature increases. Therefore, intense heat from fire is not conducted directly through the metal to the wood roof sheathing, and ignition is delayed if not eliminated from the system.

An alternative approach to white and cool color roofs was documented that meets prescriptive requirements for steep-slope residential and non-residential roofing. A roof, fitted with a 1.5” inclined air space (such as provided by the use of 2x2 wood battens) above the roof deck, can be black in color and still have a seasonal cooling load that matches the conventionally constructed cool color (solar reflectance of 0.25) stone-coated metal roof. Computations for a replacement roof application (based on ASHRAE data) shows that above roof sheathing ventilation (ASV) air spaces of 0.75” and 1.5” would permit black colored stone-coated metal roofs to have cooling loads equivalent to the direct-to-roof deck applied cool color roof system.

In the 2012 ORNL lab report (with field research conducted in 2011), steep slope roofs and attics were installed using stone-coated metal roof systems. All roofs were equipped with ridge and soffit vents for ventilating the attic, with vent area to total attic floor area installed at a 1:300 ratio. Roof system installs were either direct to the roof deck or installed on a wood batten and counter-batten configuration. The inclined air space formed by the offset between the roof deck surface and the stone-coated metal roofing provided a ventilation path for the redirection of solar heat away from the attic. Essentially, the 2012 research work was a follow up to the similar research conducted by ORNL in their 2006 research report on this subject.

Test Results

ORNL determined that a stone-coated metal roof installed with a 1.5” air space between the roof panels underside and the surface of the roof deck (as provided by installing on nominal 2 x 2 wood battens), need only have a solar reflectance of about 0.10 to match the cooling load for a 0.40 solar reflective cool roof that is fastened directly to the roof deck. Clearly, the impact of providing an ASV of 1.5” has a significant effect on improving the energy efficiency performance of a roof in a cooling climate (where air conditioner use is significant in hot months).

Again, researchers confirm that of the 45% energy savings gained by the use of cool color granules, along with providing a 1.5” ASV pathway, the energy-saving contribution from the cool color roof surface provided approximately 15% of the total energy savings – 30% of the savings was netted from the 1.5” ASV space between roofing panels and the roof sheathing surface. In fact, even in markets experiencing combined hot and cold seasons, the ASV factor is an excellent strategy to reduce roof heat gains and losses. The ASV factor also improves the durability of the roof assembly because of natural convection ventilation that dries the roof deck of any incidental moisture. Also, this roof assembly provides protection from wildfires common in WUI regions, where the effect of the airspace retards the ignition of the roof deck.

Summary

All test data garnered from both ORNL studies came to the same conclusion:

The combination of improved solar reflectance provided by cool color granules used on stone-coated metal roofing and above sheathing ventilation (ASV) make batten installed stone-coated metal roofs energy efficient. These materials offer excellent energy credits as steep-slope cool roof products.

The light-gray stone-coated metal panels mounted on a batten and counter-batten installation system reduced the heat transfer penetrating the roof deck by about 45% - as compared to the heat penetrating the deck of an attic covered with an asphalt shingle roof. 15% of the reduction was attributable to cool roof granules with reflective color pigments, while 30% of the reduction was due to above sheathing ventilation (ASV).