Managing Moisture and Condensation in Metal Roofing Systems with Vapor-Permeable Underlayments and Drainage Layers

By Marcus Jablonka

Most steep roofs are ventilated on the underside of the deck, and the composition and performance characteristics of an underlayment don't appear to be all that important. In fact, the most important function of a roof underlayment in many cases will be limited to the installation period itself. This is particularly true of assemblies such as asphalt shingles over ventilated attics. Unlike impermeable, synthetic, sheet products or conventional roofing felts, vapor-permeable underlayments allow for faster drying (via vapor diffusion through the underlayment) of moisture-sensitive components that have been exposed to the elements. This performance characteristic is especially important for nonventilated roofs and for assemblies where the insulation layer is installed within the limited space of the roof cavity, between the trusses.

Vapor-permeable roof underlayments are part of the puzzle in dealing with increasingly stringent energy-efficiency requirements in construction that have led to more and more airtight designs and assemblies. The reduction in airflow through the roof or wall assembly has implications for the moisture management of building enclosures and their sensitivity to humidity because, although it helps conserve energy, it diminishes the drying potential of the building envelope.

While some simple synthetic underlayments are virtually vapor-proof, high-end membrane products allow moisture in the form of water vapor to pass through at impressively high rates while remaining completely watertight. In Europe, the need for the entire building enclosure to rid itself of incidental moisture is well understood. Highly vapor-permeable envelope components for both walls and roofs are fully established in the construction market. In North America, this conceptual thinking is widely accepted for sidewall assemblies. Nevertheless, in many cases, the roof assembly appears to be excluded.

The most commonly used underlayments in North America today are still 15- or 30-pound asphalt-saturated felts, and both are only marginally vapor-permeable. Next in use are self-adhering membranes in the "ice and waterproof" category – the latter being almost perfect vapor barriers. In recent years, a variety of synthetic underlayments have entered the North American market, and their manufacturers claim numerous advantages for such products, e.g., less weight, improved tear resistance, or no mold growth.

Most of these underlayments are actually plastic sheets with or without reinforcement – very similar to products found in the tarpaulin industry. Most common in this category are laminated, woven slit-films, which are made by weaving individual flat yarns slit from extruded plastic film into a sheet and subsequently laminating the sheet to make it watertight. Since slit-film-based products have a slippery surface, almost all of them are coated with an anti-slip coating on either one or both surfaces in order to reduce the potential hazard for the installer.

Only a few of the synthetic products offered today are actually vapor-permeable and specifically designed as underlayments for well-performing roofs. It is this product segment of high-end underlayments that can add true value to a roof assembly by improving its moisture and thermal performance and – in the case of metal roofs – reducing the risk of corrosion-related premature failure.

It appears that many designers are, in fact, unaware that they are inadvertently creating a potential moisture problem when sealing off the outer surface of a roof deck with a vapor-impermeable membrane. It is virtually impossible to avoid the occurrence of construction moisture that enters into the roof assembly and may get stored in its components, namely trusses or roof decks. Additional moisture may accumulate due to potential air leaks that can transport moisture from the interior into the roof cavity. Unless the inside of the roof structure is sufficiently ventilated, this moisture will be trapped under an impermeable layer, since it can't dry out. This moisture eventually condenses to cause wetting of structural components and insulation materials, with undesirable consequences. The results are likely to be 1) a reduction in energy efficiency of the roof, 2) moisture-related decay leading to structural defects, and 3) mold development that can have an impact on the health of inhabitants.

Innovative synthetic underlayments have contributed to significant improvements in moisture and energy performance, as well as functional reliability of pitched-roof systems, particularly metal-clad roof assemblies. In nonventilated roofs with claddings that have a vapor permeance of less than 2 perms, elevated construction moisture, occupancy-derived humidity, or moisture that may have entered the assembly due to less-than-watertight conditions – materials will dry out very slowly or not at all. Metal claddings are vapor-retarding layers that can make a roof assembly virtually vapor-impermeable. When the metal cladding is installed over a ventilation layer outboard of an impermeable roof underlayment, the underside of the metal panels faces less exposure to moisture that could induce corrosion damage. Nevertheless, the roof structure and cavity are still exposed to potentially excessive moisture that cannot escape quickly. Moisture-sensitive components, such as wood trusses and boards or thermal insulation, may contain an elevated amount of moisture from the construction period. Through potential leakage

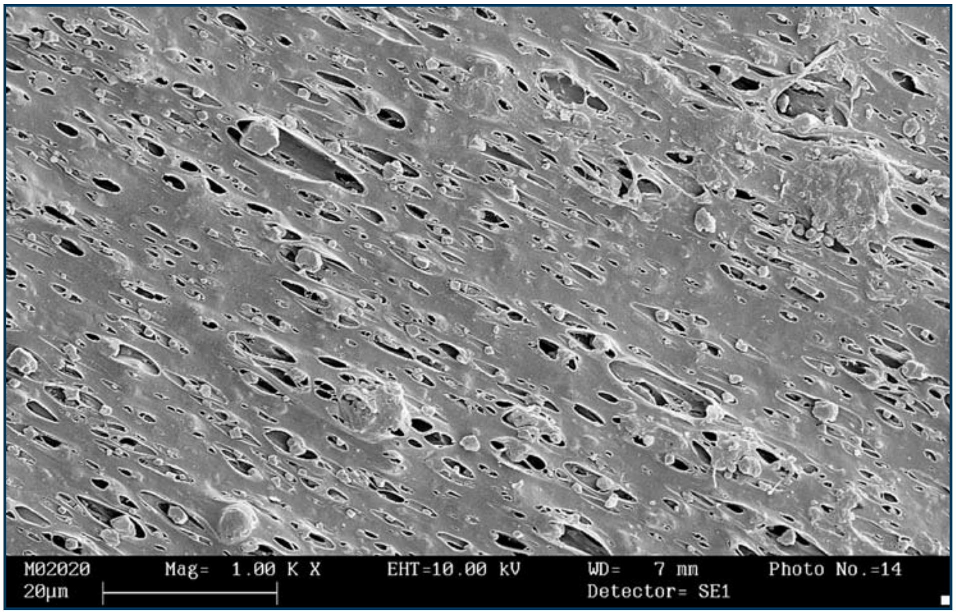


Figure 1 – Minuscule openings in a monolithic film shown under an electron microscope.

points in the air-control layer and seams, additional moisture from the inside of the building may enter this part of the building envelope via convection, and it can accumulate above the critical amount. Potential leakage of water into the roof cavity can significantly increase the amount of moisture accumulation.

In climate zones where a vapor barrier on the inner side of the thermal insulation is not required by building code, a certain amount of moisture may slowly be able to dry to the inside. In all other climates, the drying potential is negligible, since vapor diffusion can neither take place to the outside, due to the vapor-impermeable underlayment and metal cladding; nor take place to the inside of the structure, due to the vapor barrier that is part of the design to protect the assembly from moisture intrusion.

The most pragmatic solution to allow unsolicited moisture within the roof cavity to escape is the use of a watertight underlayment with high water-vapor permeability. Such characteristics can be achieved with several different technologies, i.e., composite membranes incorporating monolithic films or polymeric coatings that have a high resistance to liquid water penetration while providing a high water-vapor transmission rate. *Figure 1* shows the minuscule openings in a monolithic film. The typical opening size in this particular product is less than 2 µm (0.002 mm). A very small water droplet typically would be around 2,000 µm (2 mm) in diameter. Surface tension of water will prevent liquid water droplets from migrating though such small openings.

The question arises: What happens to the moisture once it diffuses through such a vapor-permeable underlayment and ends up on the underside of the impermeable cladding material? Since temperature variations (i.e., day and night temperatures) can cause condensation under the metal roof cladding, it is critical that the moisture can be evacuated to the exterior in order to avoid corrosion problems. Vapor diffusion will initiate redistribution of excess humidity and, through solar warming of the metal cladding and the resulting increase in vapor pressure, some of the humidity will be released through the standing seams of the roof panels. However, this limited drying mechanism may not be sufficient to avoid periodic condensation on the underside of the metal cladding, with its consequential potential for corrosion and premature failure of the system. (See *Figures 2* and *3*.)

Structured separation or drainage layers play a vital role in providing an effective escape route for condensate. Such structured monofilament layers are typically manufactured out of polyamide or polypropylene. In addition to drainage, the

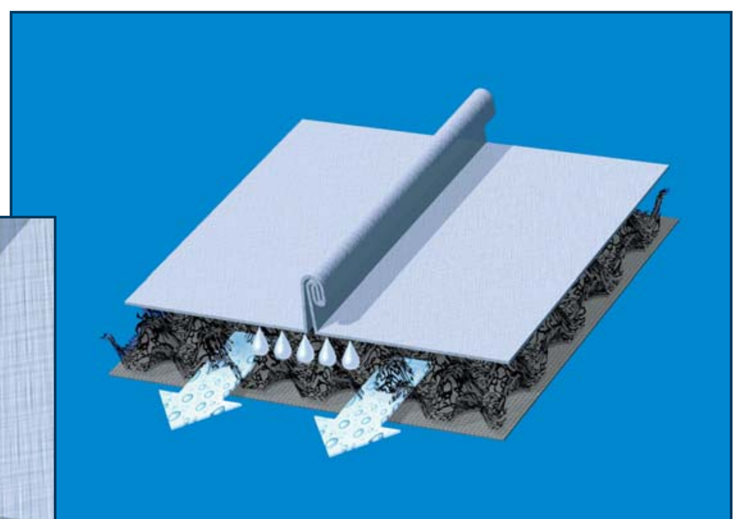


Figure 3 – Drainage.

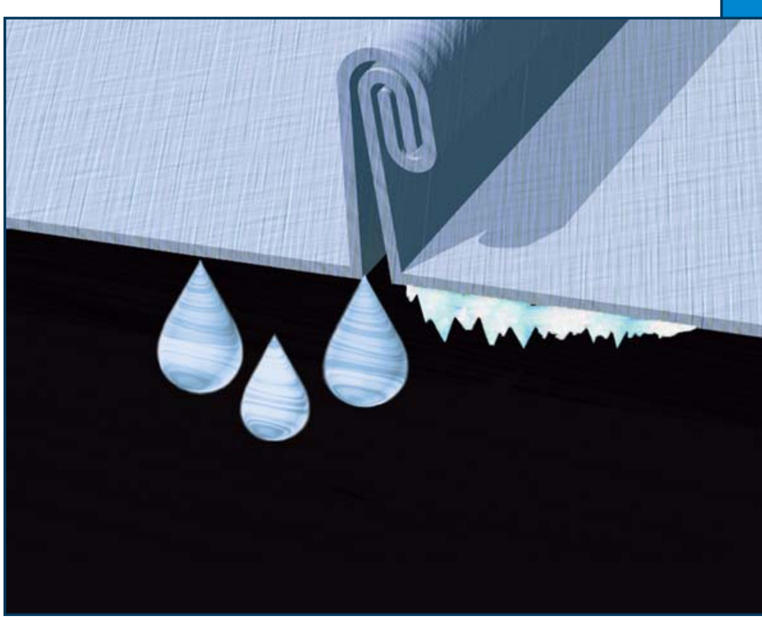


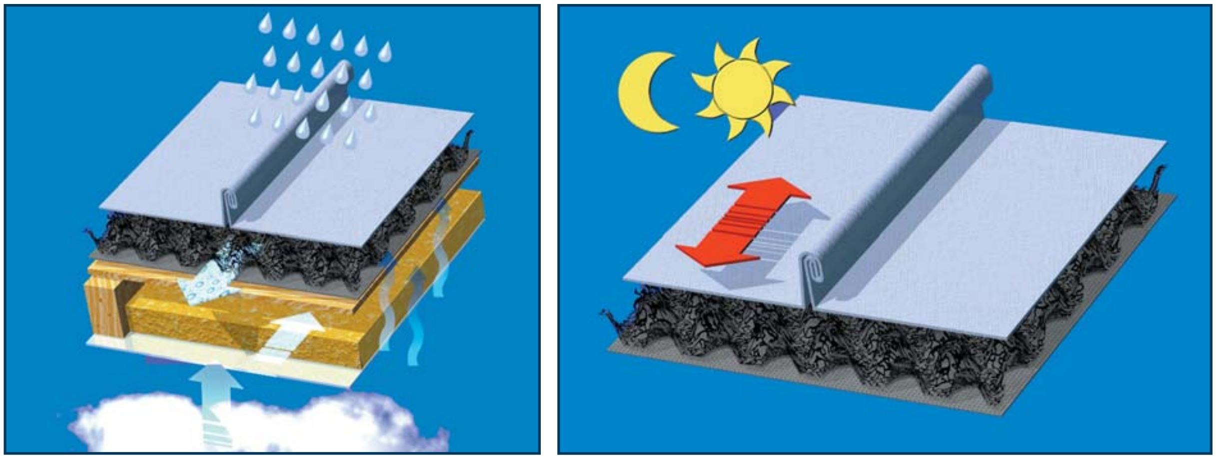
Figure 2 – Moisture condensing on underside of metal cladding due to daily temperature variations.

Figures 4 and 5 – Ventilation ridge detail of permeable underlay with separation layer.

entangled mesh layer also allows for ventilation on the underside of the metal roof panels, provided that suitable air intake and exit sections are designed into the roof assembly. (See *Figures 4* and *5*.)

If the roof system is designed with an appropriate ventilation detail, any excess moisture that may diffuse through the vapor-permeable underlayment will be quickly evacuated to the outside.

The material properties of both these functional layers may vary within a certain range. An underlayment is generally considered vapor permeable if its permeance is



Figures 6 and 7 – A combination of vapor-permeable underlayment and structural-separation layer allows for effective evacuation of moisture and helps to eliminate binding of metal panels due to thermal expansion.

higher than 1 perm. However, to increase the effectiveness of the vapor-diffusion transport, the permeance should be not less than 10 perms. Today's technologies allow for perm ratings between 10 and 100 perms. Some exceptional products achieve extreme vapor permeances of over 200 perms while maintaining their water-penetration resistance.

Structured separation layers are typically manufactured at a height of three-eighths to one-half of an inch. Their compressive strength may vary to some extent, depending on the manufacturer, process, and raw material used. While compressible under point load, these products are generally providing a substantial compressive strength, making them suitable to support the loads relevant for metal roof-cladding systems. When installed conventionally, the clips, as well as the metal roof panels, are typically placed over girds or solid substrate. If a structured separation layer is used in the assembly, the fibrous structure will be compressed in the contact area of the clip only, to achieve a firm installation. Hence, the separation layer has no effect on the wind uplift of the assembly. The metal panels are "floating" on the structured layer, in between the clips, causing a barely noticeable bow in the cladding in between the standing seams. It is generally recommended to use metal cladding at a thickness of 24 gauge or higher in such assemblies to ensure that foot traffic and other external loads don't affect the metal panels when installed over structured separation layers.

A number of beneficial characteristics can be achieved by combining a vapor-permeable underlayment with a structured separation layer. Besides supplying effective moisture evacuation, free drainage of condensate water, and backside ventilation of the metal cladding, such products allow for

Figure 8 – Installation of an underlayment with incorporated structural separation layer under stainless steel panels at the Cleveland Clinic Lou Ruvo Center for Brain Health in Las Vegas, NV.

thermal expansion without compromising the surface of the roof underlayment from friction. Structured separation layers improve the slippage of metal panels during thermal expansion and contraction. Hence, they help to eliminate the occurrence of binding of the metal panels, which can cause unsightly kinks and premature material fatigue. They also reduce the drumming sound made by rain or hail as it hits the metal cladding by up to 15 dB. (See *Figures 6* and *7*.)

As one application example, DELTA-TRELA, a highly vapor-permeable underlayment with an integrated structural separation layer, was recently applied on the Cleveland Clinic Lou Ruvo Center for Brain Health in Las Vegas, NV. Designed by world-renowned architect Frank Gehry, this masterpiece of architectural design has a challenging façade formation featuring approximately 40,000 sq ft of brushed stainless-steel panels as a cladding system. This means good moisture management is imperative. This underlayment has a permeance of 120 perms and is thermally bonded to the separation layer. Available in roll form (4.9 ft x 98 ft or 1.5 m x 30 m), it is lightweight and easy to install.

Gehry has also successfully used this

Figure 9 – The Lou Ruvo Center, opened in July 2009, shown here under construction.

BUILDING ENVELOPE KNOWLEDGE ASSESSMENT

Test your knowledge of building envelope consulting with the following questions developed by Donald E. Bush, Sr., RRC, FRCI, PE, chairman of RCI's RRC Examination Development Subcommittee.

1. **If a roof system has a total thermal resistance of R-11, what is the "U" value of the system?**
2. **If an existing roof system that is being overlaid has a total R-value of 16 and code requires a minimum U-value of 0.05, what is the minimum required R-value of the new overlay roofing system?**
3. **What is the mathematical average insulation thickness for a one-way sloped roof using tapered insulation and sloping from 4 in to 1 in?**
4. **What is the volumetric average insulation thickness for a two-slope roof using tapered insulation and sloping from 4 in to 1 in?**
5. **Roof-deck deflection should be limited to a fraction of the total span of the supporting purlins. What is the maximum deflection fraction?**
6. **When metal fasteners and plates are used to mechanically fasten rigid board insulation to the roof deck, how does it affect the overall thermal resistance of the insulation?**
7. **When plastic plates are used with the metal fasteners to attach the insulation to the deck, how does it affect the overall thermal resistance of the insulation?**

Answers on page 24

BUILDING ENVELOPE KNOWLEDGE ASSESSMENT

Answers to questions from page 23:

1. 0.09

2. R-4.0

3. 2.5 inches

4. 3.0 inches

5. 1/240

6. The R-value can be reduced by 3% to 8%.

7. Losses of 1.7% to 4.5%.

REFERENCES:

NRCA Energy Manual

ASHRAE 90-1

Figure 10 – Frank Gehry also used a highly vapor-permeable underlayment on his famous MARTa museum in Herford, Germany. Photo by Thomas Mayer, copyright, MARTa Herford.

design concept on the prestigious MARTa museum in Herford, Germany, and subsequently specified it for this new project in Las Vegas, which represents one of the first major applications for DELTA-TRELA in the U.S. The product was originally introduced to the construction market in Germany in 2001, and has since proven its performance characteristics in many metal-clad buildings around the world. (See *Figures 8, 9,* and *10*.)

In conclusion, underlayments can play an important role in designing and constructing a well-performing roof. While in assemblies that are ventilated under the deck, an impermeable underlayment would generally not cause problems, it may generate a high-risk potential for moisture-related damage in nonventilated roof construction. It is in this type of roof design that vapor-permeable underlayments can make a significant contribution to ridding the structure of excess moisture. In combination with structured separation layers, such underlayment products are ideally suited in applications under metal claddings, as they not only help to protect the structure from moisture damage but also protect the backside of the cladding itself. Certainly, this concept can be expected to ensure excellent performance of the enclosure design for many decades to come.

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Marcus Jablonka is vice president of research and development and production for Cosella-Dörken Products, Inc. A specialist in plastics technology, Jablonka holds a mechanical engineering degree from the University of Paderborn (Germany), as well as a graduate degree in business administration from the University of Bochum (Germany). He joined Cosella-Dörken in 1999. Prior to that, he held positions with Borealis and BASF in Europe. Marcus has over 15 years of expertise in foundation waterproofing and drainage systems. Jablonka is an active member of the Building Envelope Council of Ontario, the ASTM E06 Committee on the Performance of Buildings, and the ASTM C15 Committee on Manufactured Masonry Units. He is also a member of the National Institute of Building Sciences, the Building Enclosure Technology and Environmental Council (BETEC), and RCI Inc. as well as a member of the technical committee for the Tile Roofing Institute (TRI).