

Controlling Condensation in Steep Slope Metal Roofing Systems

Introduction

Water is the most common cause of rot and corrosion within buildings. Moisture inside a building can also contribute to the formation of mold. A report commissioned in 2004 by the Federal Centers for Disease Control and Prevention was prepared in response to the rising public concern about mold. The report found that damp or moldy buildings are linked to episodes of sniffles, coughing and wheezing in otherwise healthy people.

Any evidence of liquid water within the building commonly is misunderstood by engineers and property owners as leakage or failure of roof covering materials. But condensation is frequently the cause.

The principle thermodynamic properties responsible for condensation in buildings are identical for all building envelope materials. Moisture condensation is not unique to metal roofing systems but frequently is the cause of rotting of timbers or corrosion of metal decking, metal roof panels and metal fasteners.

The control of condensation in steep slope metal roofing systems is important to maintain the effectiveness of the insulation and to protect the roof material from degradation.

Condensation

Condensation in roof systems is based on the flow of water vapor through the various layers of building materials to a point where cooling forces moisture to condense. Each building component has some resistance to heat and to vapor transfer. The choice in composition and assembly techniques of building components is key to successful control of condensation. A building's environmental conditions determine the moisture content of ambient air. Internal temperature, building use and air movement impact the relative humidity of the interior air and dictate the design requirements necessary to prevent condensation.

The current construction practice of making buildings "tighter" to improve energy efficiency traps moisture inside the building envelope. In many cases, the building is completely sealed off so that moisture cannot escape. Moisture is generated inside a building when inhabitants breathe, cook, wash, or shower, and by bathrooms, and damp

basements. Another source of moisture is what is entrapped within the materials of construction.

The thermodynamic principle behind condensation is based on a phase change from a gaseous state to a liquid state when moisture-laden air contacts a cooler surface. Cold air has less capacity to hold water vapor than warm air. The temperature at which this phase change occurs is called the dew point. In a building, air that comes in contact with cooler surfaces at windows or the underside of the roofing plane will condense when it reaches the dew point. The result can be rotting wooden components, corrosion of metal components and mold formation.

Low slope commercial buildings such as warehouses and distribution facilities typically are not vented and rely on different types of construction to control moisture inside the building. Steep slope buildings (ex. > 3:12 slope) such as residential dwellings, institutional facilities, or retail structures usually have a higher human occupancy load which results in the need for more moisture control. Building codes require passive ventilation for steep slope roofing construction. In a typical residential roofing assembly several components are recommended to minimize condensation in the attic space. They are:

1. A vapor retarder located on the attic side of a ceiling board
2. Insulation located above the air barrier on the warm side of the surface
3. Vented air space above the ceiling
4. A moisture barrier or underlayment located between the roof covering material and the roof deck
5. A roof covering on top of the underlayment

Vapor Retarders

Vapor retarders are an important and effective component in a roofing system in areas where the mean daily temperature reaches 40° F or lower, and the indoor relative humidity is 45% or greater. Vapor retarders physically block the flow of moisture-laden air, which prevents it from contacting a cold surface. Vapor retarders are generally thin flexible membranes, with a perm rating of 0.50 or less. The perm rating is a measure of the resistance of a material to the passage of water vapor through it under specified time rate, temperature, and humidity conditions. A rating higher than 0.50 perms is generally considered to have a diffusion too great to adequately serve as a vapor retarder. Perm ratings are established by standard ASTM E96. A 1.00 perm rating indicates the passage of 1 grain of water vapor * through 1 square foot of material in 1 hour for each inch of mercury pressure differential that exists between the two sides of

*(1 pound of water vapor = 7000 grains; 1 inch of mercury = 0.491 pounds per square inch)

material. ASTM C755 includes information on the selection of vapor retarders for thermal insulation.

Vapor retarders are most effective when they are placed on the warm side of the building insulation. The practice is applicable for both wall and roofing applications. For most roofing applications, the proper location would be above the building's drywall ceiling. The building owner is advised to contact a design professional to determine the proper design for and placement of a vapor retarder.

Calculations can become complex for more sophisticated designs such as when placing vapor retarders within layers of insulation.

The vapor retarder can be placed anywhere in the building assembly as long as its temperature always remains above the dew point temperature. This can be accomplished by installing a sufficient amount of insulation on the outer side of the vapor retarder. It is strongly recommended that a design professional be consulted for specific information on the need, type and location of vapor retarder materials within a building envelope.

The permeance rating of a vapor retarder material is an important parameter to consider when designing the building assembly. Condensation can occur even with a properly chosen vapor retarder. Moisture-laden air can leak through the joints of vapor retarder membranes, tears within the material, or around penetrations such as lights, flues or ventilation piping. As a result, joints in vapor retarder membranes need to be sealed, especially in colder northern climates where the moisture drive is the strongest.

Other considerations when selecting vapor retarder materials include:

1. The chemical compatibility with the building's environment and the other construction materials used.
2. The effect of the vapor retarder materials on the fire performance of the total system. Factory Mutual Research Corporation lists acceptable vapor retarder materials, which if used properly, do not affect the fire ratings of roof systems.
3. Tear resistance, tensile strength, and resistance to rot and mildew.
4. The safety of the roofing installers. For example, a 6 mil polyethylene sheet material is economical, easy to work with and has an extremely low perm rating. However, installing this slippery material on a steep slope roof where installers may be placed in a hazardous condition may be unwise.

It is important to remember that vapor retarders can alleviate condensation concerns, but they do not remove heat or prevent the formation of ice dams.

In some cases, moisture that is transported through air leaks is more of a problem than diffusion through non vapor retardant membranes. In these cases a properly installed air barrier can provide more protection against trapped moisture than vapor barriers.

Proper sealing of air barriers' side laps, end laps, window and door penetrations, and foundation sills is critical to their performance.

Insulation

In commercial roofing applications, the insulation material may be loose-laid over the purlin or truss structure, with the panel attachment securing the insulation. A composite insulation board wood panel (wood panel laminated to a rigid insulation) is also a common substrate used under architectural metal panel roof systems.

Care must be taken not to compress and deform the insulation. A metal or wood batten, counter-batten system can also be used to create ventilation space below the metal panels where needed.

For residential construction, insulation in the attic cavity minimizes the heat flow from the attic into the living space during the warm seasons. It also minimizes the escape of warm heat from the living space into the attic during the cold seasons. The heat flow into the attic space below a roof can occur due to a number of sources. Solar heating of the roof surface can raise the surface temperature and allow for heat to be conducted into the space below the deck. Heat from chimneys, waste pipes and heating system ductwork can also raise the temperature of the attic cavity. Finally, warm air from the interior living space can escape through a ceiling into the attic and raise the air temperature.

In some modern homes where cathedral-style or vaulted ceilings are popular, insulation is placed between the roof rafters.

Where metal panel systems are to be installed, the amount and placement of insulation should be properly designed. In construction where the insulation is placed above the substrate, a vapor retarder may be needed between the roof substrate and the insulation. In construction where the insulation is placed below the substrate, a vapor retarder may be needed below the insulation - on the warm side of the roof assembly.

Ventilation

Venting air and water vapor out of a building can be an effective way to minimize condensation but ventilation alone does not cure the problem. Proper ventilation replaces the warm moist air with air that contains less water vapor. Ventilation is relatively easy to accomplish in conventional attic spaces. However it is more complicated when used in cathedral ceilings and with structural insulated panels. Positive ventilation and air flow is necessary to maintain consistent temperature between the vented area and the outside conditions. This condition will cause moisture to escape rather than to condense on cold surfaces.

Ventilation is generally expressed by the number of times per hour the building air is replaced with outside air. This is referred to as air changes per hour. The number of air

changes required per hour varies per application. For commercial building construction, general guidelines for whole building air exchanges, (i.e. in building types that do not have an attic space) are 3-5 air changes per hour for warehouses, 5-10 air changes per hour for light manufacturing facilities and 10-20 air changes per hour for heavy manufacturing.

Air flow requirements can be determined as shown in the following example:

Assume a 100 ft. wide X 500 ft. long X 30 ft. high building being used for light manufacturing, assembly and storage. The first task is to determine the total cubic content of the building.

$$\text{Cubic content} = 100 \text{ ft.} \times 500 \text{ ft.} \times 30 \text{ ft} = 1,500,000 \text{ ft}^3$$

Next, the total airflow can be determined through air changes. Air changes measured in Cubic Feet per Minute (CFM) are calculated as follows.

$$\begin{aligned}\text{CFM} &= \text{Cubic content} \times \text{air changes} / 60 \text{ minutes} \\ \text{CFM} &= 1,500,000 \text{ ft}^3 \times 5 \text{ air changes}^* / 60 \text{ minutes} \\ \text{CFM} &= 125,000 \text{ ft}^3/\text{minute}\end{aligned}$$

(* Rule of thumb air change for this type of building)

Thus, in this example, 125,000 cubic feet per minute of air must be moved through the building to provide proper air ventilation of 5 air changes every hour.

In residential construction, ventilation requirements are dependent on the size of the attic, and the placement and rating of the vents. The two types of vents are intake and exhaust vents. The combination of these two types of venting provides free-flow ventilation, which is the most efficient way to move hot and moist air in enclosed areas.

Most building codes require that a minimum free-flow ventilation area equal to one square foot per 150 square feet of attic floor area must be designed and properly installed to provide proper ventilation. Where a properly designed 50/50 balanced eave and ridge ventilation system is used, or with the use of a vapor retarder (such as in new construction), a free-flow ventilation area equal to at least 1 square foot per 300 square feet of attic floor area is often sufficient. The best ventilation technique is to combine eave and ridge venting. This allows air in the entire attic to be pulled from the soffits in the low areas of the eave to the vents at the ridge in the high areas.

Homes with cathedral-style or vaulted ceilings must be designed with free-flow ventilation under the roof deck through the use of vent baffles or chutes, which create a space between the roof deck and the insulation. Alternatively, a ventilated deck sub-assembly can be installed over or in place of the existing deck. Insulation should never block the eave intake vents or be in contact with the underside of a roof deck.

Where residential construction does not include an attic space, the IBC calls for a minimum 1" vented airspace beneath the roof deck. In Canada, the ventilation space requirement for this type of construction is 1 1/2".

Underlayments or Moisture Barriers

On roof applications over solid decking, an underlayment (with slip sheet as needed) is recommended as a secondary barrier against water penetration through a roof system. The underlayment should “breathe” wherever possible, allowing air to pass through while shedding moisture.

NRCA recommends a minimum of one No. 30 asphalt-saturated felt for use as underlayment with architectural metal roof systems. NRCA also recommends that one layer of rosin-sized sheathing paper or other slip sheet material be used over the asphalt-saturated felt prior to panel installation where adhesion or bonding of the metal panel to the felt underlayment may occur. In cold climates an ice dam protection membrane is recommended, and often required by local building codes, in addition to the felt underlayment, around the perimeter, at valleys and around penetrations. A minimum amount of coverage may also be required in areas on the roof surface where ice could potentially build up.

Moisture Balance

If a balance between wetting and drying is maintained, moisture will not accumulate and condensation related problems in roofing are unlikely. The extent and duration of wetting, storage and drying must be considered when assessing the risk of moisture damage. The concept of using materials with greater drying potential and storage capacity has begun to receive more attention.

A quick reference guide using this Moisture Balance approach is shown below:

STRATEGY	OBJECTIVE	MEASURE
Control of moisture access	Eliminate air leakage	Air barrier system
	Restrict vapor diffusion	Vapor retarder
Control moisture accumulation	Raise temperature of condensing surface	Insulation outside condensing surface
	Allow harmless accumulation	High moisture storage capacity at condensing surface
Removal of moisture	Promote drying	Vapor permeable layers
		Capillary active layers
		Cavity ventilation
Reduce moisture load	Remove condensation	Drainage
	Limit construction moisture	Initially dry materials

Condensation Control Materials

A benefit of metal roofing is that it does not absorb condensed water like some other roofing materials. Certain condensation-control fleece materials are available to absorb liquid condensate into capillary pores and release it back by evaporation or drainage at

a later point when conditions favor evaporation. The water vapor then gets transported out of the system by convection and diffusion. These types of self-adhesive fleece materials are typically laminated to the underside of metal roof panels during manufacturing but before forming. The adhesive layer acts as a barrier to prevent the moisture from contacting the surface of the metal roof underside.

In many cases, these materials can replace anti-condensation blankets and vapor retarders.

Conclusion

Careful design of roof systems can prevent or at least minimize condensation in building assemblies. The proper use of vapor retarders, insulation, ventilation, and moisture barriers can reduce the presence of moisture in a building and control the formation of condensation. Building codes and ASTM offer some guidance in the selection of these building components. However, it is always recommended that a moisture control or roof design professional be consulted for specific information on how to design metal roof systems to minimize condensation problems.

References:

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5. J.F. Straube, Moisture in Buildings, ASHRAE Journal, January 2002.
6. H. Hens and F. Vaes, Laboratory of Building Physics, Katholieke Universiteit, Leuven, Belgium, The Influence of Air Leakage on the Condensation Behavior of Lightweight Roofs, Air Infiltration Review, Volume 6, No. 1, November 1984.

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