Cool Roofing Systems and Condensation ***by Charles McGarvey***
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Concerns in the roofing industry about condensation under single-ply thermoplastic membranes classified as Cool Roofing Systems have become an extensively discussed, sometimes misunderstood topic. For someone who would like to understand the problem, I guess the easiest way is to start at the beginning.

Light-colored thermoplastic roofing membranes have been successfully marketed in the roofing industry for over 40 years, but before the 1990's, their overall market share was small. However, with the emphasis on lowering building energy use by reducing air-conditioning costs in hot climates, it was obvious that a major cause of interior heat buildup was a dark-colored roof surface. This occurs as sunlight is absorbed into a roof assembly and converted into heat, which is then transferred into the building.

Thus, in climates where cooling a building was a major cause of energy use, local, state, and national building codes adopted requirements for light-colored, reflective roofing membranes. The membranes reflect varying amounts of sunlight back into the atmosphere, which lowers the roofing membrane's temperature closer to ambient conditions and reduces heat transfer into a building. These types of solar energy-reflection systems are known as Cool Roofing Systems.

Cool Roofing System

A second benefit of Cool Roofing Systems installed in any type of heating or cooling climate is the potential reduction of the Urban Heat Island effect. This term describes higher summertime air temperatures in large metropolitan areas compared to surrounding suburban or open-space areas. It's caused by the absorption of sunlight by closely spaced dark-colored buildings, parking lots, roofs, etc. These surfaces slowly release the heat absorbed from sunlight into the surrounding atmosphere, raising the air temperature. And while the higher temperatures may not be immediately noticeable during a hot summer day, they can be felt several hours after sunset as stored heat is released, and urban air temperatures are several degrees higher than in surrounding non-urban areas.

Higher air temperatures not only increase cooling energy use but, when combined with sunlight and stagnant air, also convert airborne hydrocarbons into health-endangering ground-level pollutants such as smog and ozone.

In an attempt to reduce the Heat Island effect, several states and large metropolitan cities require Cool Roofing Systems to be installed. While their building code requirements always apply to new construction projects, in some jurisdictions, reroofing alterations are exempt. Also, code adoption may or may not appreciably lower an individual building's cooling energy use. Furthermore, in some colder climates, there could even be an increase in the building's overall energy usage by not absorbing the heat of wintertime sunlight and transferring it into the building. Nevertheless, this code requirement is intended to lower metropolitan summertime air temperatures, which would theoretically reduce cooling energy use and ground-level atmospheric pollution.

But, with the widespread installation of Cool Roofing Systems, excessive roof assembly moisture accumulation, which is caused by condensation cycling, has been reported in various climate zones and in both new construction and reroofing projects

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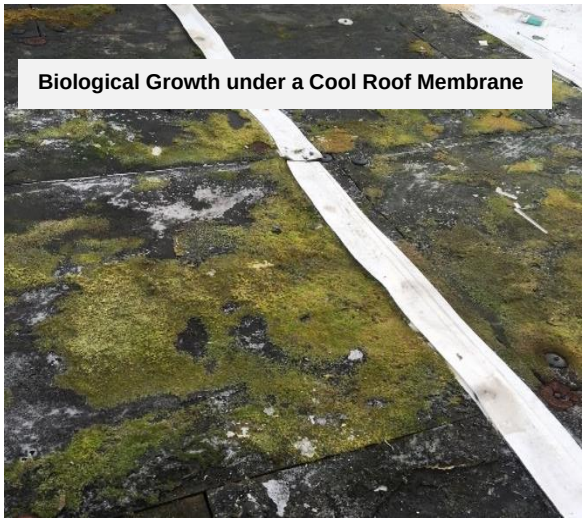
This has led to reports of buckled roof insulation, delamination of the insulation facer, insulation shrinkage, decayed decking, biological growth, or water dripping from under a new Cool Roofing System, even though it hasn't rained in several days. And while the discovery would be understandable in buildings with high interior humidity levels, it has also been reported in buildings with low or average humidity.



Biological Growth under a Cool Roof Membrane

Likewise, however, condensation has been found under much older, dark-colored, non-energy-efficient, loose-laid, ballasted, or mechanically fastened single-ply roofing membranes, but the systems never experienced the same widespread roofing industry anxiety as when it was discovered under an energy-efficient Cool Roofing System membrane.

So, what's the single largest difference that causes excessive "long-term" condensation moisture gains under a single ply Cool Roofing System membrane, as compared to older dark single ply roofing membranes? Without getting into more technical terms, such as Emissivity or the Solar Reflective Index, the simple answer is Color, but the more technically correct term is *Solar Reflectivity*.

Biological Growth under a Cool Roof Membrane

Cool Roofing System membranes are white or light-colored and have high solar reflectivity, which helps keep them closer to ambient air temperature. Older single-ply membranes were mostly dark colored, which would absorb sunlight and raise the membrane's temperature. Higher membrane temperatures would cause the condensation to vaporize more quickly and escape from the insulated roof assembly into the building or into the atmosphere through cracks, crevices, flashings, or permeable wall constructions. This effect is one part of the Self-Drying Roof Concept.

But, without winter or summertime sunlight being absorbed to raise a membrane's temperature high enough to convert condensation moisture into a vapor, it remains trapped under the membrane for longer periods of time. And if more and more moisture from an interior source finds its way under a Cool Roofing System, the cycle of condensation converting to water continues until enough water has accumulated to cause noticeable roof assembly problems.

Generally, manufacturers of Cool Roofing System membranes consider excessive and damaging condensation accumulation within roof assemblies to be an extremely small percentage of their overall installations. And while the manufacturers may think it's only a small percentage problem, try explaining to a customer that condensation within their new Cool Roofing System is not an industry-wide problem and thus it's not your fault that the roof deck is decaying, the insulation is buckling, or the ceiling is wet, and it hasn't rained for several days.

Furthermore, all building owners, roofing system designers, and roofing contractors should be aware that "if the problem does occur, it will be considered a design defect and is not covered under any manufacturer's material warranty".

Why a design defect? Because whoever submitted the roofing system specifications is going to be considered the roofing system designer and, as such, will be blamed for not submitting a design specification that prevents the possibility of damaging condensation and moisture accumulation within the roofing system.

Therefore, a roofing contractor or roofing system designer should research how to install a Cool Roofing System to prevent damaging condensation within the assembly. And once the information is understood, you may wish to submit to a potential customer a good, better, best cost solution to a random but potentially damaging problem.

Start the information investigation by first understanding the four common ways moisture can accumulate under or within any completed low-slope roof assembly:

Air Intrusion - Capillary Movement – Diffusion – Gravity

Air Intrusion

Of the several ways moisture can move into a completed low-slope roof assembly, the one most responsible for excessive moisture accumulation, leading to condensation problems in low- or average-humidity buildings, is *Air Intrusion*.

This occurs as interior building air carries moisture vapor through small cracks, gaps, or spaces into the roofing assembly. And if the air movement somehow finds its way through the roof assembly to the outside atmosphere, then *Air Intrusion* becomes known as Air Leakage.

Air Intrusion is generally not a problem during a recovery project if the existing roofing membrane is left in place and can function as an air barrier under the new roofing system. But unless it's addressed in the specifications or through best installation practices, it can be a problem in new construction and tear-off projects when the building's interior humidity conditions come into direct contact with the underside of a new roof assembly.

Capillary Movement

This is the movement of water horizontally, vertically, or diagonally through very small cracks, holes, openings, or pores. A common example would be a very small seam defect that allows water to be drawn through the seam and under the roofing membrane. But any water that finds its way through a defect caused by Capillary Movement would be expected to be localized, repairable, and unrelated to excessive condensation and moisture accumulation throughout a Cool Roofing System.

Diffusion

The movement of a gas, liquid, or vapor equalizing in concentrations, energy levels, or pressure is known as *Diffusion*. Moisture vapor diffusion occurs across the entire building envelope as pressure differences between the exterior and interior drive vapor to move toward equilibrium. It's a different issue than Air Intrusion or Air Leakage, and the Diffusion movement of moisture can even be in the opposite direction of natural convective air currents.

Gravity

In both low- and steep-slope roofing systems, gravity is the downward force that drives the positive drainage required by building codes and most membrane manufacturers. And if there is a hole in a roofing system, gravity will carry water to the hole, which is the starting point of roofing system leakage.

Therefore, of the several ways water can enter a roofing system, Air Intrusion and Diffusion are related to the damaging effects of condensation and moisture cycling. But either condition is generally not a problem during a simple recovery if the existing assembly can be left intact and function as an Air and Vapor retarder.

However, there is one recovery situation: leaving an intact roofing system in place can allow condensation under a Cool Roofing Membrane. Condensation can become a problem if the existing roofing system is a built-up slag-surfaced roofing system. The problem - even though the loose slag surface can be easily removed by power vacuuming or manual methods - is that the remaining embedded slag may look dry, but contains excessive moisture within its pores. This moisture will eventually escape through evaporation (drying) into the overlaid Cool Roofing System. And if enough moisture is present, condensation will occur on the underside of the membrane, which could damage a moisture-sensitive insulation substrate. For this reason, the slag surface should be hand-scrapped or mechanically scraped clean to remove this potential source of moisture.

Air Intrusion

For new construction or reroofing projects, which include a tear-off of existing materials, Air Intrusion in “low or average” humidity buildings (=< 40% R.H.) can be restricted by sealing seams, openings, or joints in the roof deck or insulation substrate. This limits moisture-laden air from reaching the underside of a Cool Roofing Membrane.

Of course, how effective air sealing a roof assembly depends on many factors, but several simple recommendations include:

1) Seal/tape all joints, edgings, and openings if the roof deck is classified as an air barrier (e.g. plywood, OSB, etc.).This also holds true if a separate barrier board, such as a gypsum board, is installed over an air-permeable roof deck if the board is classified as an air barrier.

2) Do not install a single layer of insulation, but double all layers, which includes staggering and butting joints firmly together.

3) Fill all curb joints, openings, etc., in the top layer of insulation with expanding foam sealant before the membrane is installed.

4) If a loose-laid or partially attached system will be installed, consider the placement of moisture resistant insulations, insulation facers, or overlayments, which will be in direct contact with the underside of the membrane.

5) Consider a fully adhered installation instead of a loose-laid or partially attached one. This limits the lateral movement of air under the roofing membrane which would have the potential to expand a condensation problem within large areas of a roofing system.

But the most efficient way to create an air barrier with any type of roofing system may be to install a flexible sheet membrane classified as an air barrier; however, if these materials function as vapor retarders, they are better discussed as part of moisture-vapor diffusion protection.

Diffusion

But what about high-humidity buildings with outward moisture vapor diffusion, which cannot be stopped by air sealing methods? This is when vapor retarders, which also act as air barriers, are specified.

Several common causes of high humidity within a building's interior include:

1) Buildings with naturally high interior humidity conditions, such as manufacturing processes, swimming pools, commercial kitchens, exercise/shower rooms, etc.

2) The drying (evaporation) of a new building's interior as moisture-laden paints, cementitious floors, plaster, etc., release large amounts of moisture into the building's atmosphere during their curing process. This condition can be a short- or long-term problem.

And with any of these conditions, a vapor retarder installed under the roofing system will be necessary to prevent moisture from eventually condensing within the roofing system.

However, whenever air/vapor retarders are installed, there are drawbacks, such as

- Roofing system leakage may be hidden for years and spread over a large area before leakage through the vapor retarder is discovered. Investigations could become very extensive, trying to find the source of the leakage, and once found, large areas of wet materials may have to be removed.

- The self-drying roof effect is lost as any moisture accumulated within an assembly will remain trapped below the roofing membrane and above the vapor retarder, as it cannot escape.

- In cold weather climates, a *Dew Point calculation should be completed to make sure there will be enough insulation over the vapor retarder's surface. Otherwise, condensation could occur on its underside and cause substrate decay, water dripping from ceilings, etc.

*Note - For more information on the thermal performance and estimated energy costs of a roof assembly. contractors can access the National Roofing Contractors Association (NRCA) Energy Wise computer program. Among other things, this program will analyze the Dew Point location within a roofing assembly and let you know if there is enough insulation above the vapor retarder.

Common examples of dual-purpose high-quality air/vapor retarder materials that can be part of fully adhered systems and not penetrated by fasteners include

a) Self-adhered elastomeric membranes specifically designed as a vapor retarder.

b) Several plies of base/ply sheets adhered in asphalt, cold adhesives, etc.

c) Polyethylene sheets that are adhered or loosely laid under a ballasted system.

But, what about a common low-cost practice of installing a generic flexible sheet air/vapor retarder, such as polyethylene (PE) sheeting, that will be punctured by countless fasteners to either attach the insulation or a mechanically fastened membrane to the roof deck?

Several issues should be understood:

1) Make sure the material is approved by the roofing material manufacturer for fire/wind ratings, warranty approval, etc.

2) There is small-scale testing and empirical evidence (i.e., history) that air/vapor retarders, which are penetrated with fasteners may work, but there are no independent large-scale tests to determine efficiency with varying levels of interior humidity, and empirical evidence is unique to each building construction (i.e., what works for one roofing system on one building may not work on another).

3) Make certain that all penetrations, seams, and terminations are sealed; but most importantly, make sure all penetrating fasteners are installed in such a way as to create a firm gasket effect between the sheeting and a solid roof deck or barrier board surface. With steel roof decks, this will require that fasteners only penetrate through the bearing surfaces (high ribs); otherwise, the gasket effect is lost.

There is also another situation in which a high-efficiency air/vapor retarder must be installed over a roof deck that is not directly related to diffusion but is more correctly related to evaporation or drying (curing). This occurs during the installation of any new cementitious roof deck substrate, such as structural or lightweight concrete, lightweight insulating fill, etc. The problem is the release of excess mixing water not needed for hydration (curing). This moisture must not be allowed into an insulated roofing system, as it will be a major cause of condensation and moisture buildup that can damage the system.

Generally, on a new construction project, the architect will be responsible for determining whether an air/vapor retarder is necessary and, if so, which materials will be installed. But for new or reroofing Cool Roofing System projects without an architect, a roofing contractor submitting a proposal should be knowledgeable enough to understand Air Intrusion and Diffusion.

So, what are the easy answers to stop potential condensation and moisture cycling under a Cool Roofing System?

- Stop air leakage.
- Install moisture-resistant insulation.
- And, if an air/vapor retarder is to be installed, understand the pros and cons.