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# Mold in Vented Wood-Frame Roofs in the Coastal Pacific Northwest

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## Introduction

Sloped roofs over ventilated attics are one of the most common, if not the most common, roof configuration in the United States and Canada. This type of roof assembly is typically associated with single family houses, but they are also commonly used on townhouse complexes and large architecturally complex multi-unit residential buildings. Unfortunately, in coastal areas of the Pacific Northwest, moisture problems including mold growth on roof sheathing are common in vented wood-frame roofs.

Often this type of damage is attributed to rain water ingress through the roof assembly, inadequate ventilation of the attic space, and condensation associated with airborne moisture from air leakage, duct leakage, or re-entrainment of humid exhaust air into the attic space as shown in Figure 1 and Figure 2. However, despite recent improvements in ceiling airtightness, reduced duct leakage, and code compliant attic ventilation rates, issues of fungal growth and mold on roof sheathing are still common throughout coastal areas of the Pacific Northwest.

*Figure 1: Locally stained and wet sheathing due to condensation (frost) of humid air which is leaking from a poorly sealed bathroom exhaust duct*


*Figure 2: Visibly wet roof sheathing caused by rainwater ingress through the shingles and underlay*

## Causes of Vented Wood-Frame Roof Moisture Problems

Detailed investigations and testing of many of these roofs have shown that the traditional wetting mechanisms identified above cannot account for the observed mold growth as moisture related problems have been found to occur when in the absence of rainwater ingress, air leakage, duct leakage, or inadequate ventilation. Consequently, an alternative source of moisture must be contributing to the observed performance problems.

### Study of Attic Sheathing Performance

To identify and confirm this moisture source, a long-term monitoring study was conducted to evaluate wetting and drying of attic roof sheathing, and the impact on observed fungal growth. The study used monitoring of controlled test huts to investigate the field performance of different roof slopes and underlayments. This controlled test hut approach allowed for the evaluation of the field performance of these assemblies under unrestricted ventilation conditions while eliminating many of the conventional wetting mechanisms, such as air-leakage.[1]

While the largest factor affecting the sheathing moisture content was found to be the ambient exterior conditions, in many cases the sheathing moisture content was measured to be significantly above or below the equilibrium moisture content indicating that other wetting and drying mechanisms were at play. Through the study, these mechanisms were determined to be primarily: condensation on the underside of the sheathing due to night sky cooling depressing the sheathing temperature below the dew point temperature of the ambient air, and solar heating of the roof surface increasing the sheathing temperature and facilitating drying.

*Figure 3: Roof hut decoupled from interior conditions by unrestricted ventilation to the underside of the roof sheathing. Monitoring equipment was installed to measure performance characterisitcs including sheathing moisture content at various depths, roof surface temperature, sheathing temperature, and ambient temperature and relative humidity.*

Condensation due to night sky cooling occurs when the roof sheathing temperature falls below the ambient dew point temperature as a result of net radiative heat loss to the much cooler night sky. As the condensing moisture is coming from the ambient air, this moisture cannot be prevented by ventilation alone. For the test roofs, this wetting combined with seasonal fluctuation in the sheathing moisture content created by changes in ambient conditions led to sustained periods in which the sheathing moisture content was sufficient to initiate and sustain mold growth.

[1] Additional more detailed information about this study is available at *Why Wood Frame Attics Get Wet & Mouldy in the Pacific Northwest* – Conference Paper from the 30th RCI International Convention & Tradeshow.

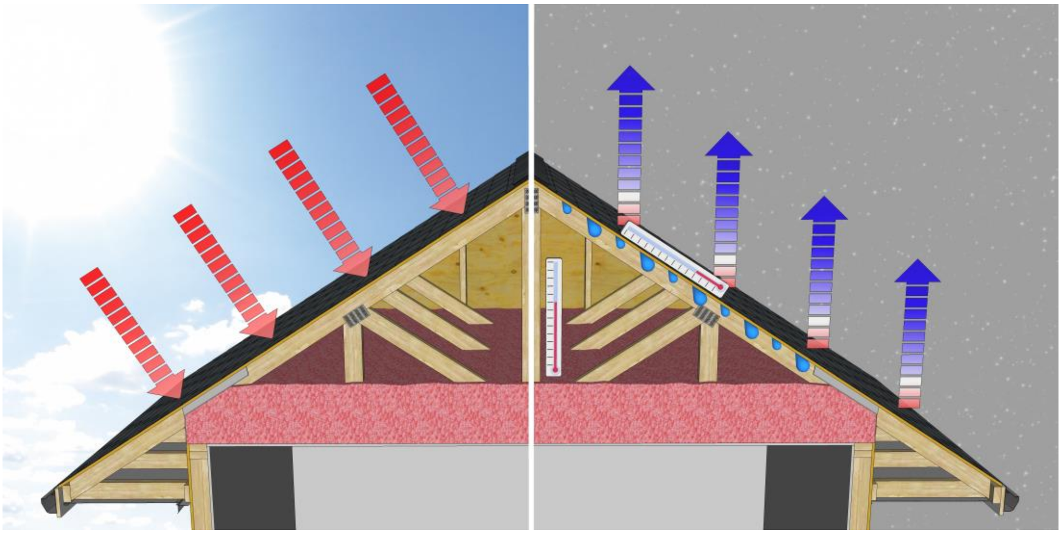


*Figure 4: Graphic representation of solar heat gains on a roof during the day which would cause the roof sheathing temperature to increase (left) and of radiation to the sky at night causing the temperature of the roof sheathing to drop below the ambient air temperature and potentially cause condensation on the underside of the sheathing if it drop below the air dewpoint temperature.*

Absorption of solar radiation on the surface a roof can significantly increase the sheathing temperature above ambient air temperatures and cause the roof sheathing the dry. The amount of solar radiation absorbed is dependent on the exposure of the roof to sun, and consequently, roofs of different slopes will experience difference amount of drying. More importantly, however, roofs with different cardinal orientations will also experience significant different amounts of solar heat gains. The difference in performance resulting from the difference in the amount of solar heat gain absorbed by north and south facing roofs is shown in Figure 5 and Figure 6.

*Figure 5: South facing attic roof sheathing for same attic as shown in Figure 6 showing negligible fungal growth*



*Figure 6: North facing attic roof sheathing for same attic as Figure 5 showing significant fungal growth*

The night sky cooling and solar heat gain wetting and drying mechanisms are apparent in the study monitoring data shown in Figure 7. The moisture content of the sheathing and occurrence of fungal growth depend on the balance of the wetting and drying mechanisms. In coastal areas of the Pacific Northwest, these wetting mechanisms can outweigh the drying mechanisms and lead to conditions conducive to mold growth.

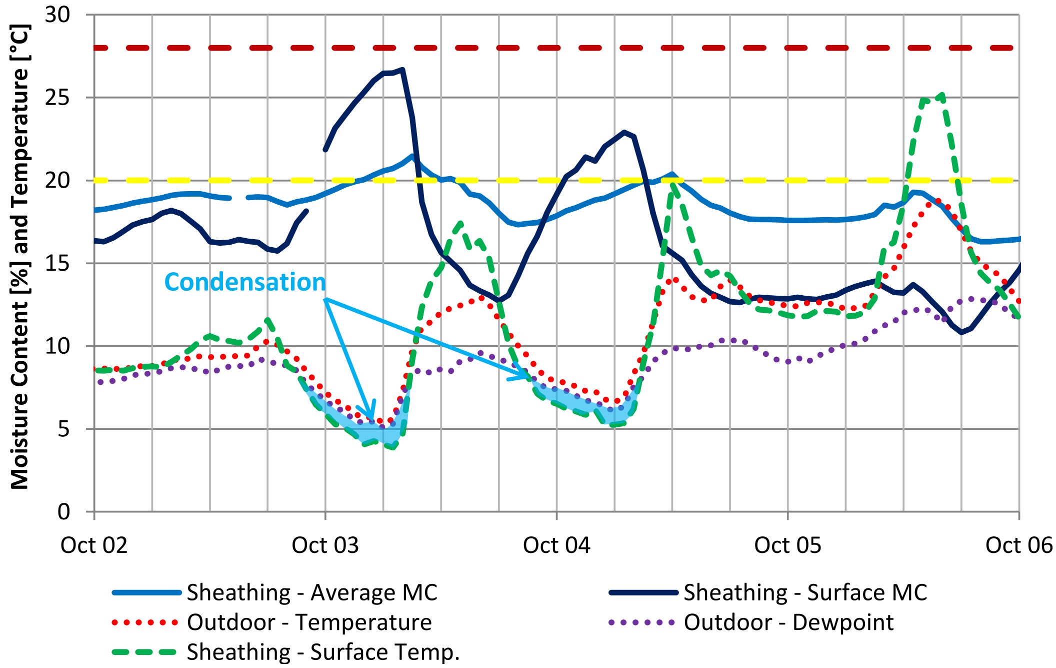



*Figure 7: Chart showing fluctuations in sheathing moisture content over the course of four days in October, 2013. Note during two night the sheathing temperature drops below the ambient dew point temperature of the air creating wetting events which are also reflected in the increased moisture content during these periods. During the day time the sheathing surface temperature is often greater than the ambient outdoor temperature due to solar heat gains, and associated drying occurs.*

While the study focused on vented wood-frame attics, low-slope vented wood-frame roofs share many of the same characteristics and have been observed to experience similar moisture problems.

## Why Coastal Areas of the Pacific Northwest?

Interestingly, the observed mold growth problems in vented wood-frame roofs is a relatively geographically localized phenomenon due to a unique combination of environmental conditions that exist in coastal areas of the Pacific Northwest, and other similar areas. In particular, for significant wetting due to night sky cooling to occur, relatively high ambient exterior dew point temperatures must exist during periods when the sheathing temperature can be cooled below that dew point temperature by night sky cooling, and then there must also be relatively little solar heat gain to facilitate drying during the day.

In many climates, this will not occur because the winters are relatively cold and dry[2]. In these types of climates, the amount of moisture present in the cold outdoor air is insufficient to cause significant wetting, and solar radiation is sufficient to heat roofs and facilitate drying. On the other extreme, this phenomenon will not likely occur in locations with overly warm winters because condensation is both unlikely to occur at such high temperatures, and when it does occur, there is ample ability for this moisture to dry during warm daytime hours. In the coastal Pacific Northwest climate, however, extended periods of mild temperatures, high relative humidity, and little solar radiation (i.e. overcast or

[2] Note that relative humidity during the winter is actually often near 100% due to the presence of snow on the ground, but that when the air is heated to indoor temperatures the relative humidity is reduced creating the perception of “cold and dry” winters.

raining) are frequent and create conditions conducive to significant wetting without opportunities for drying. The coastal Pacific Northwest area where there is likely an increased risk of these vented wood-frame roof moisture problems is shown in Figure 8. These types of problems may also occur in other locations with similar climatic conditions.

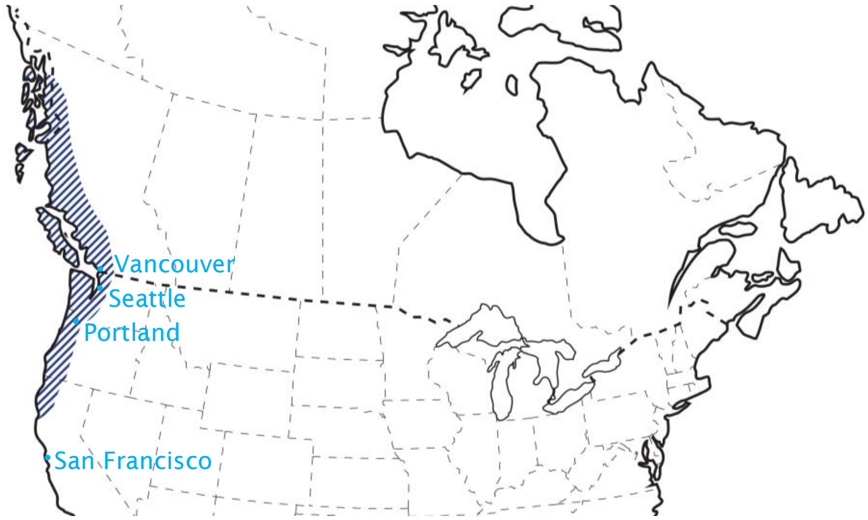



*Figure 8: Map of coastal Pacific Northwest where the climate is conducive to these types of attic mositure problems. Note that the focus of this document is on the west coast of North America, but other areas with similar climate conditions may also be at risk for these types of moisture issues.*

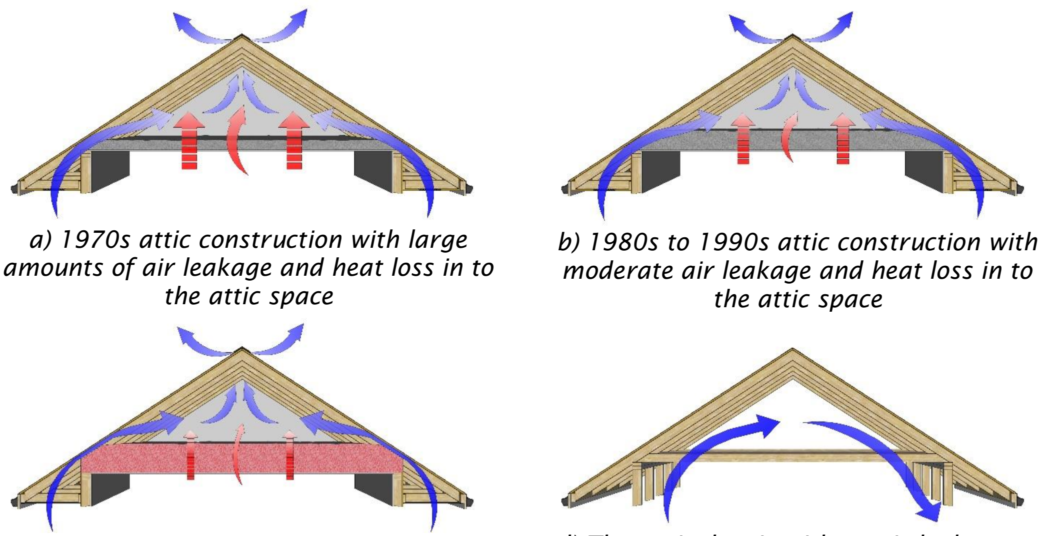
In Vancouver and the surrounding coastal areas, these types of vented wood-frame roof moisture problems have been commonly observed; however, in other areas of the coastal Pacific Northwest, widespread issues have not always been experienced despite perceived risk. In the Portland metropolitan area for example, while the climatic conditions combined with changing construction practices (i.e. increasing airtightness and insulation levels) appear to create an increased risk, vented wood-frame roofs in this area currently do not appear to exhibit these problems to the same extent that they have been observed further north. Designers and builders should, however, take this elevated risk into consideration, and consider appropriate mitigation measures.

## Why Didn't We See This Before?

The physics haven't changed, so one might wonder why this has seemingly become more prevalent recently. The current prevalence of this issue is likely in part due to the industry gradually identifying and subsequently mitigating many of the causes of more severe attic issues such as air leakage from ducts and from interior spaces. As these issues have been addressed, other underlying issues which were previously obscured, such as night sky condensation, become more apparent, but another industry trend has also contributed.

In recent years, a trend towards more airtight and highly insulated roof assemblies (R-40+) has been pursued to reduce building energy consumption, and this trend seemingly correlates with an increased frequency of attic moisture problems. While airtightness improvements have decoupled the vented space from interior moisture loads, increased airtightness and insulation have also reduced heat loss during cold weather, reducing the drying capacity of the roof sheathing. Consequently, phenomena that may previously have been masked by excessive heat loss in older, poorly insulated and air-leaky roofs can become apparent in modern well-insulated and airtight systems. This gradual decoupling of the vented space is illustrated for an attic in Figure 9, including the complete decoupling which was used for the purposes of the study.

Exacerbating this reduction in heat loss to the vented roof space are changes to plywood roof sheathing material properties over the past few decades (e.g. species and relative levels of heartwood and sapwood from later-growth timber) which likely also contribute to the reduced durability of these roof assemblies.



*a) 1970s attic construction with large amounts of air leakage and heat loss in to the attic space*

*b) 1980s to 1990s attic construction with moderate air leakage and heat loss in to the attic space*

*c) 2000s attic construction with minimal air leakage and heat loss in to the attic*

*d) Theoretical attic with no air leakage or heat loss in to the attic and unrestricted ventilation like used in the attic study*

*Figure 9: Schematics showing historical ventilation, insulation, and air leakage arrangements for attics (a, b, and c) and for a theoretical attic (d). Blue lines represent ventilation airflow into and out of the attics, red dashed lines and curved lines represent heat loss and air leakage respectively into the attics from the interior.*

## In Search of a Solution

Well understood and widely applied best practices for vented wood-frame roof design and construction, including airtightness and adequate ventilation, should always be the first method for addressing attic moisture problems. Some of these strategies are identified in the guide to *Best Practices for Air Sealing and Insulation Retrofits*. However, other causes of attic moisture problems including condensation due to night sky cooling cannot be prevented through these measures alone, and alternative solutions need to be identified and developed.

One potential solution is to simply avoid vented roof assemblies altogether. Often referred to as compact roofs, unvented[3] roof assemblies avoid many of the issues associated with venting a roof, but depending on the arrangement, can also present their own challenges. Figure 10 illustrates the relative risk of common wood-frame roof assemblies and indicates that vented roofs are typically higher risk.[4]

[3] Note that "unvented" sloped roof assemblies often do require venting, but this venting is provided behind the roofing material (i.e. shingle, concrete tiles, etc) rather than behind the wood roof sheathing.

[4] Note that this risk assessment is approximate, and the specifics of each individual project should always be taken into account when designing roof assemblies.

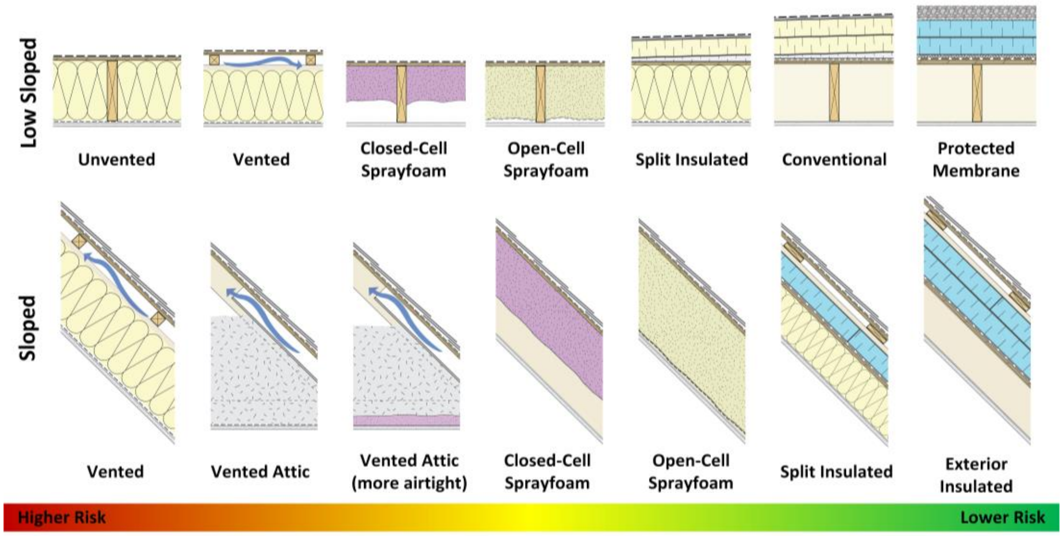



*Figure 10: Relative risk of different wood-frame roof assembly options illustrating reduced risk typically associated with split insulated or exterior insulated roof assemblies. (Higher risk left (red) and lower risk (green) right)*[5]

However, given the prevalence and cost-effect nature of vented roof construction (and in particular attics), it is unlikely that a move towards their complete elimination is practical. Consequently, a need exists for mitigation measures which can be incorporated as part of standard vented roof construction. Currently, the most promising options for this are wood treatment and surface coating products which work either by interfering with mold growth directly, or by preventing the absorption of the condensing water so as to avoid conditions conducive to mold growth. A third option is to use inorganic substrates for the roof sheathing. This type of risk mitigation approach is likely reasonable for standard residential vented attic construction.

While a number of economically viable products that may be appropriate for this application currently exist, as of yet, these products are unproven in long-term field monitoring studies, and initial studies have shown the performance characteristics necessary for this application to be demanding. Further work is ongoing to identify potential solutions to this significant industry problem.

For additional information on this and other topics, please visit our website, rdh.com, or contact us at contact@rdh.com.

## Additional Resources

- **Why Wood Frame Attics Get Wet & Mouldy in the Pacific Northwest** – Conference Paper from the 30th RCI International Convention & Tradeshow
- **RDH Blog Article – Re-Thinking Ventilated Attics: How to Stop Mold Growth in Coastal Climates**
- **Guide to Best Practices for Air Sealing and Insulation Retrofits** produced by RDH and published by the Homeowner Protection Office (HPO), a branch of BC Housing

[5] Note that this risk assessment is approximate, and the specifics of each individual project should always be taken into account when designing roof assemblies.