Don't Mess with Mr. Hyde:

Modern Hygrothermal Performance Assessment

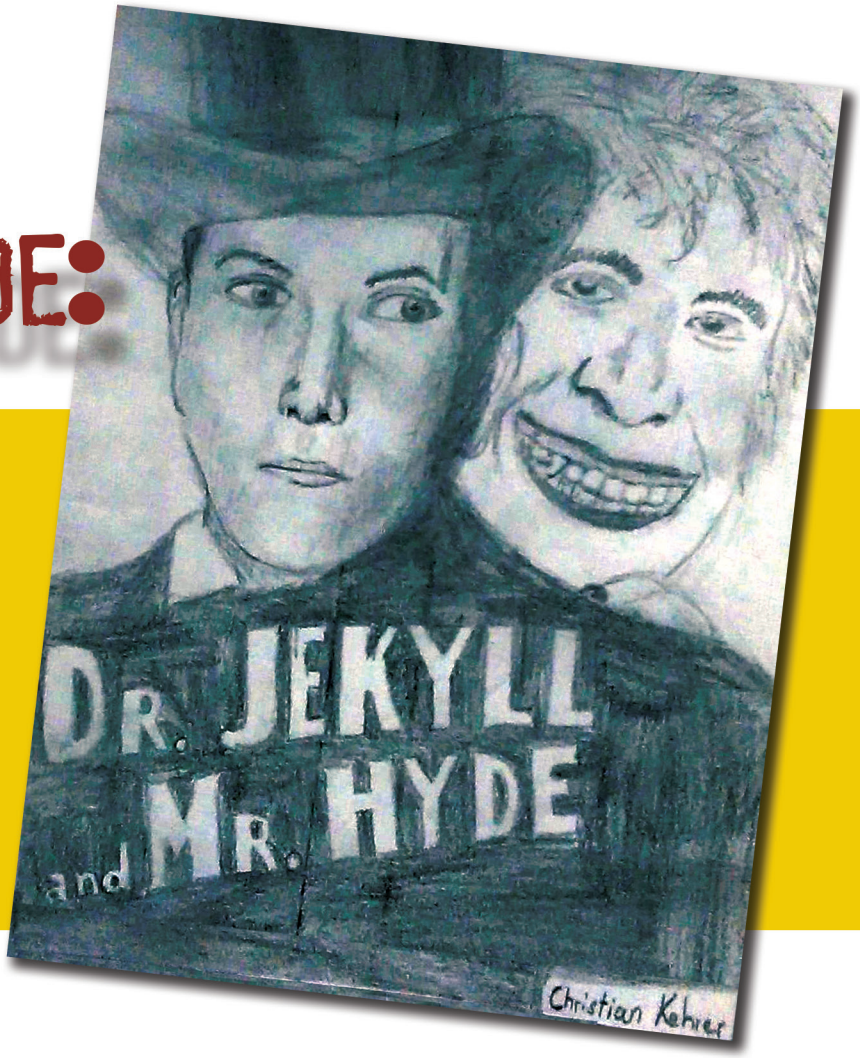

Figure 1 – Dr. Jekyll and Mr. Hyde, by Christian Kehrer.

By Manfred Kehrer

Recent changes in energy efficiency requirements make white roofing more and more popular, as it can reduce the cooling demand in warm and hot climate zones. Also, recent research has shown that the downside of the application of a cool membrane makes a huge difference regarding moisture management. Using the hygrothermal performance assessment tool WUFI, and based on the latest research findings, the author will show the consequences of white membranes applied to a residential wood deck construction.

According to the U.S. Department of Energy, 40% of the entire U.S energy demand is related to heating and cooling of the millions of buildings in this country, so it is probably a good idea to focus on increasing the energy efficiency of our buildings and building enclosures.

But who does not know the story of Dr. Jekyll and Mr. Hyde—a man with two opposing sides? The accompanying movie poster of the duo (*Figure 1*) has been drawn by my son Christian. Building science today has some similarities, called heat and moisture. Dr. Jekyll, who is the nice guy, saves energy on all of our personal heating and cooling bills, and we love him. But most people don't tell you that Dr. Jekyll comes in a package with Mr. Hyde, who is the bad guy in building science called moisture. The facts are pretty simple: Increased energy efficiency can include a higher risk of moisture failures. Why? Well, in order to dry moisture out of a building enclosure, you need to spend the evaporation energy of water. But remember, since we want to save energy, modern building enclosures often no longer provide for energy release. So the risk of moisture accumulation and failure is increasing. This is based on simple physics, which doesn't play favorites.

So how to deal with this dilemma? Well, that can be complicated. Building scientists weren't lazy the last three decades, and as the Europeans were forced to work on this problem back in the '80s, when their energy efficiency codes were getting stricter (and, as a consequence, they faced the Dr. Jekyll/Mr. Hyde issue earlier than building designers in this country), we have the solution today called Modern Hygrothermal Performance Assessment. A man named Dr. Hartwig Künzel made the important step to simplify the very complex physics of coupled heat and moisture transfer and developed WUFI® (Wärme Und Feuchte Instationär) at Fraunhofer IBP, Germany. WUFI, a numerical simulation tool for architects and engineers, is based on Künzel's work in 1995 and was significantly improved in 2006 and in 2008. WUFI is a tool to evaluate the potential for moisture accumulation in a building wall or roof and has been validated with field measurements all over the world.

So, let's go into some details now and see how WUFI Pro can help to keep Mr. Hyde under control. Most people know about cool roofs and their benefits in terms of cooling energy savings by reducing heat gain. These can be significant savings. In some states, cool roofs are mandatory for

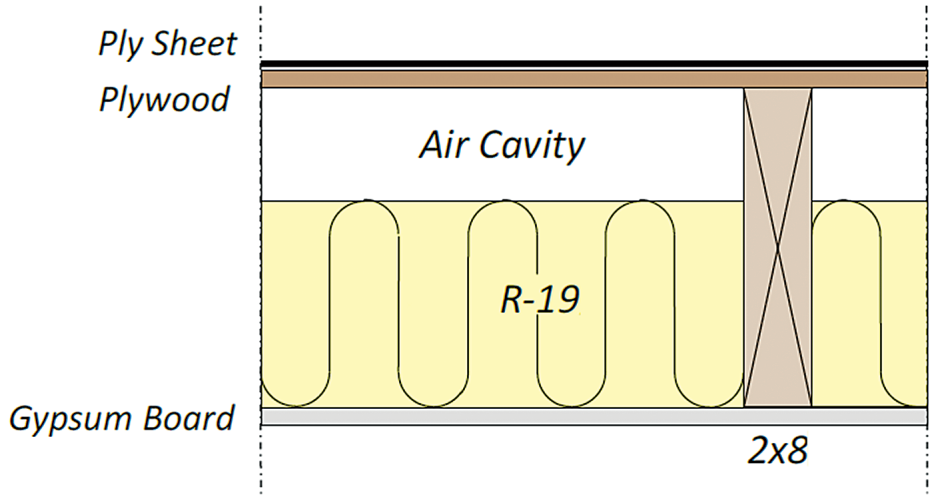

Figure 2 – Typical West Coast flat roof, wooden 2x8 construction with R-19 fiberglass insulation.

new construction and major roof replacement—e.g., California's Title 24.

However, cool roofs can have moisture problems, particularly if they are not fully adhered. Mechanically attached membrane systems can be lifted by wind forces, creating billowing. Billowing caused through wind uplift can draw indoor air through the joints and penetrations in the roof deck and deposit moisture underneath the roofing membrane. During cool exterior temperatures, this can result in condensation under the membrane. However, fully adhered roofs can also have condensation problems due to vapor diffusion. Further research shows that four main parameters affect this condensation potential: airtightness, indoor air moisture content, project location, and membrane color.

Figure 2 depicts a typical residential flat roof construction. This includes a membrane system over plywood with batt insulation below the roof deck. Physics proves that the color of the membrane makes a huge difference with this construction.

Figure 3 shows the results for a WUFI® Pro simulation for both white and black surfaces under these conditions and the moisture content in the plywood roof deck using San Francisco, California, as an example. Hutchinson, in 2009, found ice formation underneath partially attached cool roof membranes in cold climate zones during the winter, while an ex-colleague and

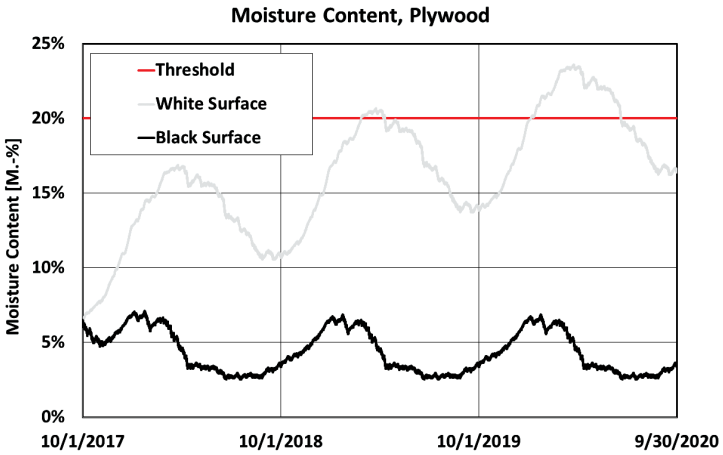

Figure 3 – Moisture content in the plywood for a roof with a white and a black surface.

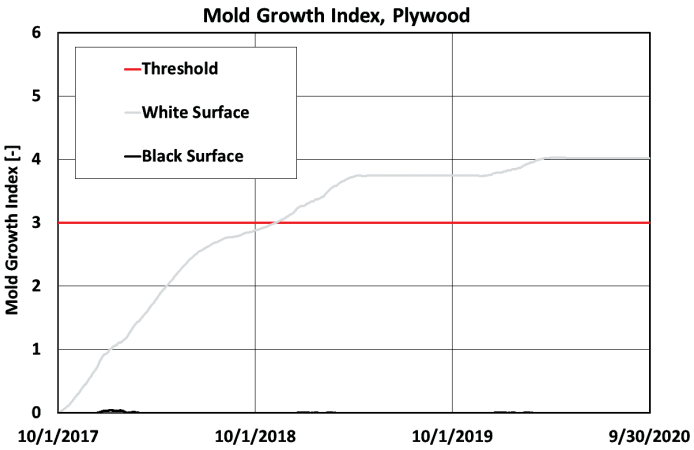

Figure 4 – Mold Growth Index according to the evaluation criterion of ASHRAE Standard 160-2016.

I (Kehrer and Pallin, 2013) have also shown that the selection of a cool membrane has a major effect on moisture performance. The construction with the white surface shows continuing moisture accumulation year by year, exceeding the threshold moisture content of 20 mass percent (M.-%) after less than two years, according to the *ASHRAE Handbook of Fundamentals*. This can result in severely deteriorated wood decks after a few more years.

Figure 4 shows an even more drastic analysis of the problem. According to ASHRAE Standard 160-2016, the Mold Growth Index, a model used to determine mold growth in building enclosures, should stay below 3.0. The construction with the white surface shows that this threshold is exceeded after about a year, while the black surface construction stays well below 3.0. Further details can be found in Pallin et al., 2013, "Hygrothermal Performance of West Coast Wood Deck Roofing Systems."

CONCLUSION

White roofing is a good option to reduce the demand of cooling energy for roofs, as the roof will stay cooler on average because of the solar reflection. The downside is that the lower roof membrane temperature increases the potential for condensation and provides less drying potential to mitigate moisture accumulation. When

using these roof membranes, particularly in residential construction, we need to be mindful of details that can overshadow the energy savings. These include air barriers, membrane attachment methods, reducing interior air moisture content, and surface temperatures. If we do not consider these effects, Mr. Hyde may come calling.

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Manfred Kehrer

Manfred Kehrer, a senior associate at Wiss, Janney, Elstner Associates, has been active in the field of building science for over 25 years. After more than two decades at Fraunhofer IBP, Germany, where he was leading the WUFI® software development team, he worked for the Oak Ridge National Laboratory for five years as a senior researcher, followed by a one-year period as president of the startup consulting company justSmartSolutions LLC. Kehrer has been the Official WUFI® Collaboration Partner for USA/Canada since 2011.

Coal Tar Sealants Facing Bans

Numerous states and municipalities are banning the use of coal tar sealants commonly used in the paving of driveways, parking lots, and roadways. Research indicates that coal tar sealants are a major source of polycyclic aromatic hydrocarbons, or PAHs. At high levels of exposure, these chemicals are known to be toxic. In 2015, the U.S. Geological Survey (USGS) did two studies that determined that runoff from pavement seal-coated with coal tar was toxic to aquatic life, had detrimental effects on DNA, and "are probable human carcinogens."

Photo by Barbara Mahler, USGS

An estimated 85 million gallons of the black, shiny, coal-tar-based sealant are applied to pavement each year, primarily east of the Continental Divide in the U.S. and parts of Canada, according to the USGS.

Anne LeHuray, of the Pavement Coatings Technology Council, claimed that coal-tar-based products last longer, protect better, and are proven products. Coal tar can also be applied in cold weather. The most common alternative to coal-tar-based sealants is an asphalt-based sealant, which LeHuray said does not protect as well as coal tar.

***— Durability + Design* and usgs.gov**