University of Wisconsin-Madison Engineering Professional Development

Something in the Air

The Truth about Moisture in Buildings

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How Buildings Get Wet

Like the answer to a complex equation, moisture enough to cause damage in a house or other structure comes from a convergence of factors. Questionable design choices. Careless construction practices. A mismatch of materials and geography. Anton TenWolde knows these factors matter, but he recognizes that grasping the basics of how things that should not get wet do get wet is the basis of any calculation.

He starts by discrediting the entrenched notion that controlling vapor diffusion will control most moisture problems. "Diffusion is hardly ever what is going on when you have moisture problems," TenWolde asserts. He explains most early research in this area focused on diffusion-the movement of water vapor through materials due to changes in vapor pressure-in part, because it was simpler to do the math on diffusion.

That research has led to a disproportionate emphasis on the water vapor permeability of various materials, allowing a minor problem to dwarf causes that are more significant. According to TenWolde, diffusion runs a distant third to both water leakage and water vapor carried by air movement as the bigger culprits behind the majority of moisture problems in buildings.

Water leakage tops the list. Rain and melting snow getting in through a breach in construction does millions of dollars in damage every year, TenWolde points out. He says he often sees leaks around windows or along rooflines where complicated designs and inappropriate detailing allow moisture to collect and seep in. "Imagine you are water, where are you going to go? My advice to designers and builders for avoiding this principal cause of moisture problems is 'don't create a funnel!'"

Preventing water leaks falls into the common-sense category of solutions, the research physicist suggests. Top buildings off with roofs pitched to allow for good runoff. Insulate attics to manage heat loss and prevent the formation of ice dams. Ensure adequate flashing around chimneys. Promote drainage by laying a foundation with proper grading.

Air movement, the second leading cause of moisture damage in buildings, is an aspect of TenWolde's own research. He cites water vapor flow by air leakage under normal air tightness conditions as likely to be 10-to-20 times larger than the flow by diffusion. Research indicates even extra-airtight buildings can experience more vapor flow from air leakage than from diffusion. Ultimately, TenWolde says, what designers and builders need to understand is that while air movement can speed drying, uncontrolled vapor flow is in fact a major cause of damage from moisture getting inside a wall or roof. The effect depends on the season and the air flow direction.

Clearly, nothing about this equation is simple, TenWolde observes. Air movement also acts in combination with diffusion. For that reason, it sometimes pays to pair solutions that address both and to do it right.

The marketplace heavily promotes vapor retarders as a way to control moisture problems. TenWolde notes these products are nearly useless unless installed properly and paired with an effective air barrier. The air barrier must be continuous and, free of tears and punctures. He agrees this can be difficult to avoid, but asserts that any perforations or open joints in an air barrier degrade its air tightness and create openings for moisture-laden air. Ultimately, a vapor retarder cannot be effective without an effective air barrier.

Other options for controlling moisture problems through air flow alone, TenWolde says, include blown-in cellulose insulation. Alternatively, closed-cell insulating foam fills a wall cavity so tightly, it is an air barrier and vapor diffusion barrier in one

Building a Case for Prevention

The basics of moisture control may not be on the radar screen for many designers and builders. All the same, researchers like TenWolde are determined to build a case for prevention that registers with the professions.

Some of TenWolde's newest data come from the FPL research-demonstration house located on the institute's research campus in Madison. A full-size residential structure built to support a variety of USDA research on building materials and systems, TenWolde and his colleagues have equipped the house with sensors they use to track air flow and the accumulation of moisture in a residential setting. He notes the FPL house has the advantage of being imperfect. "It's based on a standard floor plan, nothing special, and represents a somewhat-better-than average contemporary house under construction in this part of the country." Still, he says, it comes complete with shortcomings enough to provide good material for his and other studies.

Much of that material is observational and allows TenWolde to measure how changes in climate, materials, construction methods, and other elements provoke the incidence of damaging moisture.

He sees, for example, that geography has a clear impact on how moisture in buildings is controlled. This means that different regional climates dictate which methods and materials to use in construction. To illustrate this, TenWolde draws on the example of a single wall in the research house. He describes the wall as well insulated with airtight cellulose and constructed with a gypsum wallboard finished with latex interior paint. There is no interior vapor retarder. TenWolde predicts deterioration over time as moisture disperses from inside to outside during winter, largely because the house is maintained at high humidity during the heating season. However, despite the fact moisture will build up in the wall during cold months, he says effects from moisture are unlikely until spring, when temperatures are high enough to sustain decay and mold. In fact, he observes, the biggest challenge for walls-even in the Wisconsin climate-are the rains and high humidity of summer. Proper exterior envelope construction and adequate roof overhangs help prevent potential problems.

Climate-driven moisture problems would emerge in a shorter time for the FPL research wall in the sustained rain, heat, and humidity of the southeastern United States. In contrast, it would stand for a good long time in the dry southwest where adobe structures fare so well.

The rainy, low-sun environment of the Pacific Northwest would batter the research wall more than any other continental conditions. In this coastal region, features of both cold and constantly humid climates converge to create a complex, pernicious environment.

TenWolde suggests geographical location should leverage many design and construction decisions. Attic venting, recommended in cold climates, is less beneficial elsewhere. The application of vapor retarders should account for the prevalence of high or low humidity. Choice of materials must make sense, i.e., brick and other porous exteriors may stay wet in warm, humid climates. Other circumstances that affect moisture-control solutions include the activities planned for a building, the kind of equipment in operation, installation and maintenance of mechanical systems, and the scope of a ventilation system.

Improving the Drawings

TenWolde names the architect's design as a decision point where an understanding of the basics of moisture control could begin. "The drawings deal with structural issues, construction details, use of space, traffic flow, location of electrical and mechanical elements," he says. "What it doesn't show is how the design allows the builder to prevent unintended air movement through the building envelope."

Again, he turns to the off-the-shelf FPL house design as an example. It incorporates an I-beam to support the second floor that cantilevers out over the front porch, a difficult juncture to make airtight. Like any complicated design feature, TenWolde says, this detail does not take moisture management or energy conservation into consideration. Scrutiny of the drawings with an eye to potential problems might have produced a better solution.

Likewise, plans that allow space for ductwork inside the living space rather than relegating it to the attic incorporates a relevant tool of moisture control. Drawings should address adequate space for positive ducting to and from the second floor of a structure, TenWolde advises, and fresh-air returns should work.

Another moisture-prevention tactic is siting a new structure high enough to ensure rainwater and melting snow flow away from the foundation. TenWolde says response to recent moisture problems in southern states prompted architects designing homes in that part of the country to resurrect raised-floor systems, bringing the foundation up from grade.

Awareness in the planning stage about where and how moisture could become a problem is important. But it is not enough, TenWolde notes. Residential projects often are in the hands of subcontractors who focus naturally and narrowly on a single aspect of the job. There is little continuity between installers and rarely anyone monitoring the performance of the structure as a whole. Minimums established by codes are allowed to rule.

Important Role of Research

Current research on moisture prevention could play an important and practical role in the building industry. Beyond common-sense recommendations for correct installation of vapor retarders or proper site grading, TenWolde believes research can help designers and contractors understand and apply the finer points of moisture control.

"Scientists aid this effort by designing tools that allow architects to address complex problems-like the effects of air movement through the building envelope," he says. "We're also looking at ways to help them judge what combination of materials provides the right balance between wetting and drying out in certain climates and which construction practices to follow."

Noting that researchers initially talked in generic terms about qualitative measures, TenWolde adds, "We are in a better position now to quantify the impact of design and construction choices on moisture problems."

The challenge, TenWolde explains, has been finding a researchable issue that puts "moisture engineering" on a par with structural engineering. "Examining what moisture conditions an individual material or the building envelope will see during its lifetime qualifies as such-and is a far cry from the artificial talk of vapor barriers, which often is not based on observational research.

Using observed data, he says researchers can better predict how temperature, wind, rain, and other factors affect the life cycle of specific construction materials. They also can monitor the performance of the construction.

"The more we can look at the real thing, the more coherent data we can gather," he concludes. "I see our work resulting in simplified rules for preventing moisture problems based on solid research, rules that can be adopted nationally and applied across the industry."

Will there still be houses built in a flood plain or buildings without suitable building ventilation? Of course, says TenWolde, but he senses most architects and builders are interested in ideas that help them improve their practices and create failure-free facilities.

Anton TenWolde's research targets existing assumptions and poses alternatives that could rewrite industry standards and introduce workable solutions to moisture problems in buildings. His comments here touch on an in-depth presentation he makes on the topic in a seminar series offered by the Department of Engineering Professional Development at the University of Wisconsin-Madison. Learn more by visiting Courses or by calling 800-462-0876.

Written by Mary Maher

Innovative design and skilled construction can mark a house or corporate headquarters as a wonder. Yet these buildings may be all wet-literally-if the professionals behind them misconstrue the physics of moisture in the structural realm. Anton TenWolde directs building moisture and durability research at the USDA Forest Products Lab (FPL) in Madison, Wisconsin. A noted physicist and researcher, TenWolde has studied moisture in buildings for 20 years, applying the proofs of science to practical understanding of how moisture becomes a post-construction problem.

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