Moisture, Building Enclosures, and Mold Part I

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Abstract:

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Part 1 of 2

MOISTURE, BUILDING ENCLOSURES, and Mold

How water gets into a structure, why it doesn't leave, and how these architectural flaws become HVAC headaches

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Buildings leak. Conditioned air escapes, and outside air is sucked in. The relatively easy science of keeping unwanted water out of a structure is nearly a lost art. And many of the modern materials we use to build actually hinder the drying process once water enters. A typical new building has dozens of holes in the shell that don't show up in the blueprints because they were never intended. You may say to yourself, none of these problems technically fall within the purview of the mechanical engineer, and you're right. But keep two points in mind: Many of these problems translate into indoor-air quality (IAQ) complaints, which are your problem; and everyone involved in construction needs to develop a whole-building philosophy in order to improve how we build.

If such lofty goals don't appeal to you, think of your career. I speak from experience when I say that when you are called on the (wet) carpet for a water problem, it helps to be able to show that the problem was from poor architectural design, materials, or installation, rather than an HVAC "condensation" problem.

Learning to spot where breaches commonly occur in buildings is essential for mechanical engineers. With this knowledge, you may be able to prevent a catastrophe during the plan review. With this knowledge, you can ask to see the necessary architectural detail for determining if a water problem might exist while still early in a project—especially if you are representing the building owner. Simply tell the architect you need to see how much dehumidification you'll need for that unplanned natatorium they'll be building in the basement.

In this two-part series, I'll first discuss why these are pervasive problems in the construction industry and how they are inherited by HVAC technicians and engineers once the structure is occupied. I'll also discuss why keeping ground and rain water out of a building should be easy, but isn't, and what to do once water gets in. In the January issue of *HPAC Engineering,* part 2 of this series will review air control and pressurization, ventilation, and humidity control and will include some resources to help expand your knowledge of design and construction errors that lead to HVAC headaches.

THE DYSFUNCTIONAL CONSTRUCTION FAMILY

Controlling water problems in buildings should be easy. Keep the rain and ground water out. Design and construct the building enclosure to be able to dry when it gets wet—and make no mistake about it, it will get wet. Control the airflow across the building enclosure because air carries water, so build the building enclosure without holes—at least without big ones. Remember that as part of this air-control system, you have to control the air pressure across the building enclosure. Should buildings be pressurized or depressurized, or should you attempt the impossible to maintain a neutral pressure? I think you should pressurize building enclosures everywhere, but we'll get into that later. Lastly, ventilate and condition the building enclosure in a controlled manner to control humidity.

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All easy stuff, right? Unfortunately, it's not. Out of necessity, we divide up the responsibility of doing all of this among various professionals and tradesmen. The people involved don't speak the same language, or just don't speak at all. They don't know the same things, and too often, no one seems to know the entire picture. It's like working on a puzzle without having a picture on the box to go by, so you don't know until the end of a very inefficient process that some pieces are missing, while others don't belong at all. In other words, the construction team is a big dysfunctional family.

Often, those making the financial decisions know even less. They let salesmen talk them into the next great thing: "Sure this works, we have 5,000 systems in Lower Elbonia." Finally, we "value engineer" the project—a term that to me can be best defined as: "A process by which someone who has no clue about sound construction takes out the stuff we really need to make things work."

KEEP THE RAIN AND GROUND WATER OUT

Controlling rain and ground water are the most important factors in the design and construction of durable buildings and for the control of mold. Let me make something painfully clear: Air-conditioning and dehumidification systems cannot be used to control rain- and ground-water problems. It is not the job of the HVAC engineer to design rain- and ground-water-control strategies. There are no guidelines available to size systems to handle rain and ground water—except to make these systems really big, which is a bad use of energy and poor engineering. Don't even try it. Fix the rain problem and fix the ground-water problem with drainage. There are situations where installing a dehumidifier in a basement works well, but that is not what I define as a ground-water problem. You don't install a dehumidifier when there is running water or standing water in a basement.

The fundamental principle of rain- and ground-water control is to shed water by layering materials in such a way that water is directed downward and out of the building or away from the building.

How Mold Eats Walls

Leaky windows were not always such a big deal. More than a hundred years ago, exterior walls had hollow cores, or were made of solid masonry or lumber. If they got wet from a window leak, they could dry. Many were built with heavy timber framing with plank wall , or even balloon-frame wall with true two-by-fours sheathed with 1-by-6 in. diagonal boards that were sheathed on the interior with plaster on metal or wood lath. Whether these walls are uninsulated or insulated, they are very mold-resistant because both the materials and constructions can dry.

The composite materials that are used today have adhesives that can be digested by fungi we call molds. Mold will also digest sugars and starches in wood fiber, if the cell walls have been crushed or broken. Solid lumber has intact cell walls that cannot be penetrated by molds. Molds will grow on the surface, but the wood will retain its structural strength. Particle board, oriented-strand board (OSB a.k.a. waferboard), and medium-density fiberboard, as well as paper-covered gypsum board, are full of adhesives, which make them good "mold chow." Adhesives are used throughout these materials to give them form and to hold together the crushed, pulverized, or torn wood fragments or particles that make up the board. Mold digests the adhesives, and mold hyphae penetrate the resulting cracks and holes between wood particles. Structural integrity is eaten away, and so is the wall. Paper-covered gypsum board also has the adhesives and cellulose that offer food to molds at the expense of the wall.

Mycelium of a wood-rotting fungus growing under the siding of a house. The mycelium is essentially the digestive organ of the fungus, secreting enzymes designed to digest the substrate (such as a cellulose-based building material) so that the dissolved nutrients can be absorbed.

Mold growth behind vinyl wall covering.

Mold growth on vinyl wall covering.

DRAIN EVERYTHING

Gravity is the driving force behind water management and drainage. The "down" direction harnesses the force of gravity, and the "out" direction gets the water away from the building-enclosure assemblies, openings, components, and materials. In general, the sooner water is directed out, the better.

The most elegant expression of this concept is a flashing. Flashings are the most underrated building-enclosure component and arguably the most important.

Drainage also applies to materials. Water that is absorbed in a material cannot be drained away. We paint and stain wood siding so that water is not absorbed by it and can be drained from the siding surfaces. We damp-proof concrete foundations for the same reason.

Drainage applies to assemblies such as walls, roofs, and foundations, as well as to the components that can be found in walls, roofs, and foundations, such as windows, doors, and skylights. It also applies to the openings for the windows, doors, and skylights and to the assemblies that connect to walls, roofs, and foundations, such as balconies, decks, railings, and dormers. Finally, it also applies to the building as a whole. Overhangs can be used to drain water away from walls. Canopies can be used to drain water away from windows, and site grading can be used to drain water away from foundation perimeters.

Drainage is the key to rain- and ground- water control:

- Drain the site.
- Drain the building.
- Drain the assembly.
- Drain the opening.
- Drain the component.
- Drain the material.

In other words, drain everything.

WINDOWS

My advice to engineers is to thoroughly review architectural drawings, particularly the window-opening details and flashings. These openings cry for "pan flashings." Windows leak. I'm tempted to say always, but it's sufficient to say that windows leak frequently enough that you need to treat them as if they are going to leak. An under-window "gutter" (or "pan flashing") is essential to redirect this leaking water to the exterior.

WALLS

Review wall assemblies to make sure they have drainage planes: a membrane covering the wall behind the exterior cladding. This is real important when we get to brick veneers and stucco—especially synthetic stucco. Remember that there are only two kinds of stucco: stucco that has cracked and stucco that will crack. There are now some magnificent synthetic stucco systems available: "Drainable EIFS" (external insulation and finish systems). These work because they drain. Watch out for the non-drainable systems especially when they are used with windows. Mold heaven is when you combine a non-drainable stucco with a leaking window.

Photo A. Typical mold "pink spot" created when organism releases digestive enzymes that react with plasticizers in the wall.

It's not uncommon to find wall sandwiches made from OSB or paper-covered gypsum, steel studs, cellulose or fiberglass in the cavity (to keep water from draining away), paper-covered gypsum, and vinyl-covered wall paper to keep the wall structure from drying. Does vinyl repel mold? Not at all. As shown in "How Mold Eats Walls," mold will digest vinyl paper adhesive and grow into the paper as well.

LET IT DRY

In 25 years of being in the construction industry, I've concluded that we approach things backward. We focus entirely on preventing things from getting wet, which is a good idea, but we also need to provide a contingency plan by engineering the structure to let things dry after they get wet. The problem is that many techniques that prevent wetting also prevent drying. Vapor barriers are a prime example of this foolish thinking. Yes, vapor barriers stop vapor flow. But what if there is vapor in the assembly already? And remember that there are two sides to a wall: the outside and the inside. Walls can get wet from both the inside and the outside. Walls also can dry to both the inside and the outside. We seem to think that walls only get wet from the inside and that they can only dry to the outside—what I call "cold-climate chauvinism." We do the calculations for the winter, but the walls rot in the summer.

I love code recommendations. One of my favorites directs engineers to "put a vapor barrier on the warm side." Warm side when? In January or in July? We may need vapor barriers in Canada, but we don't need them in the Lower 48. In Canada, there are only two seasons: this winter and last winter. In the rest of the world, especially the air-conditioned world, moisture flow is from the outside in. This means that a vapor barrier installed on the interior of a wall assembly is on the wrong side.

If you don't believe me, open up a wall in Cincinnati in July and look on the cavity side of that polyethylene vapor barrier. What do you see and smell? Droplets of water and a bad odor. One sure way to make it worse it to install vinyl wall coverings on the inside of a wall. Notice all the pink spots—that's literally mold vomit. Mold exudes digestive enzymes that react with the plasticizer, giving you the color as seen in Photo A. Pull back the vinyl and you have black mold and mushy drywall (see "How Mold Eats

Walls”).

The hotel construction industry has refined these flawed design concepts into a recipe for mold and odor. You start with a steel-stud wall. Put a non-drainable synthetic stucco on the outside, fill it with fiberglass insulation, and install a plastic condom on the inside. Then fill the building with cold air in July when the outside is hot and humid. Did I mention the leaking windows?

And then we blame the HVAC engineer for the mold in the walls and for the mold smell in the hotel or in the school or in the office.

Is there any way to make this worse? Of course. Use paper-faced gypsum sheathing on the outside of the steel studs and glue the foam to it. We’re building paper buildings that get wet and can’t dry. Even the dumbest of the three little pigs didn’t build a paper building.

IS YOUR VAPOR BARRIER SMARTER THAN YOU?

So what to do? Don’t use vinyl wall coverings. Don’t use paper-faced gypsum. What about vapor barriers? Doesn’t code demand these? Code says install something that has a perm rating of one perm or less. The kraft facing on a fiberglass batt meets this requirement, but only when the RH the kraft facing sees is low—25 to 30 percent. What is interesting is that this kraft facing becomes vapor permeable as the RH it is exposed to goes up. In air-conditioned buildings, when the humidity is 50 percent—not atypical—the kraft facing is 10 to 20 perms. It’s a “smart” vapor barrier. It retards moisture in the winter and lets the wall “breathe” in the summer. That dumb plastic vapor barrier has a perm rating of 0.1 perms—all of the time (Figure 1). We’re talking two orders of magnitude in difference. Stay away from plastic-film vapor barriers, foil-faced fibrous cavity insulation, and especially foil-backed gypsum sheathing on the interior.

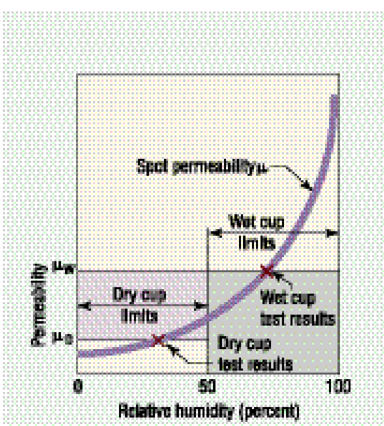

FIGURE1. A “smart” vapor barrier retards moisture in the winter and lets the wall “breathe” in the summer. In contrast to a simple plastic vapor barrier that has a perm rating of 0.1 perms year round.

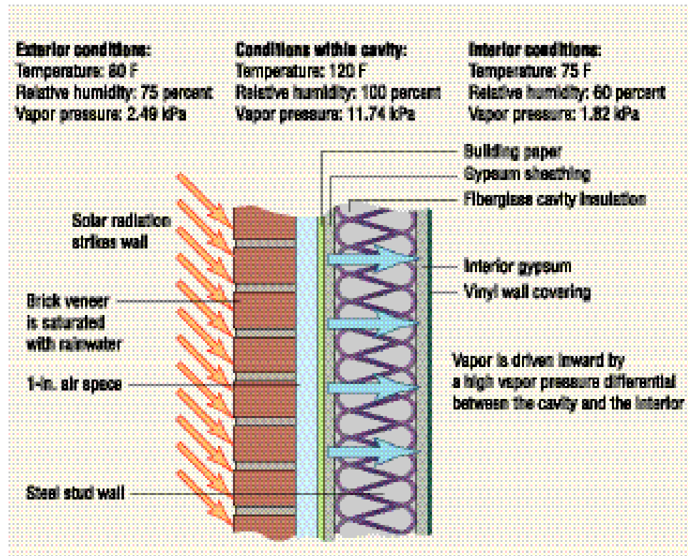

FIGURE2. In this design, the brick exterior can reach 120 F when exposed to the summer sun in many areas of the U.S. After a rain storm, the brick can become completely saturated and reach 100 percent RH. The vapor pressure in the brick is 11.74 kPa, a significant vapor pressure gradient with little chance of moisture removal.

THE REWARDS OF POOR DESIGN DONE WELL

I’ve tried to show how many of the decisions made without the input of a mechanical engineer during the design and construction phase lead to disaster. Here’s an example of how a series of bad decisions led directly to uncomfortable occupants. Let’s look at a rain-wetted brick veneer in July on the southwest side of a building on a sunny day at around 2 p.m. The outside temperature is 80 F at 75-percent RH. A psychrometric chart reveals that the outside vapor pressure is 2.29 kPa. Inside, the conditions are 75 F at 60-percent RH. Look at the psych chart again: The inside vapor pressure is 1.82 kPa. The difference between the inside and outside is not really such a big deal. But now look at the brick. It’s sitting at 120 F, and it is saturated, so it’s at 100-percent RH. At this point, the psych chart doesn’t apply because we’re literally off the chart. You have to turn to the steam tables at this temperature. The vapor pressure in the brick is 11.74 kPa. This is a serious vapor-pressure gradient. Behind the brick is an air space and it’s not likely to be a clear and well-ventilated air space. In this real-world situation, the amount of moisture being removed is zero (Figure 2).

What’s next in line of the incoming steam? Probably felt building paper. It is permeable—after all, a building has to breathe. Unfortunately, it breathes both ways. So inward the moisture vapor flows. Next is the exterior gypsum, which is permeable, followed by the fiber-glass cavity insulation. No problem, the vapor flows right on through. What’s next? Well, sometimes you get the polyethylene vapor barrier, which condenses the vapor and the condensate runs down the wall and rots, rusts, and corrodes the bottom plate. Other times, you get more gypsum board covered with impermeable vinyl wall covering—followed by the pink spots, the mold, and the mushy drywall. So what does this tell us? You need a vapor barrier on the outside with a brick veneer, not on the inside. This absolutely contradicts typical practice and building codes. And, of course, it’s all the HVAC engineers fault because the HVAC engineer didn’t design the right humidity-control system—and we all know that mold comes from high humidity. Humidity, mold, and HVAC engineers—inseparable.

About this Report

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