Part 2 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

By **JOSEPH LSTIBUREK, PhD, P. Eng.**
Building Sciences Corp.
Westford, Mass.

In the first half of this series, which appeared in the December 2001 issue, I discussed many of the pervasive problems in the construction industry and how they directly lead to indoor-air-quality (IAQ) problems. While many of these design flaws—poor drainage, leaky envelopes, and construction materials that fail to shed water—are not the typical design concerns of an HVAC engineer, the IAQ problems that result will be squarely placed at the HVAC engineer's feet. Therefore, mechanical engineers need to understand the roots of these problems in order to defend their work if IAQ becomes a problem once the building is occupied, and the architect and contractors are gone.

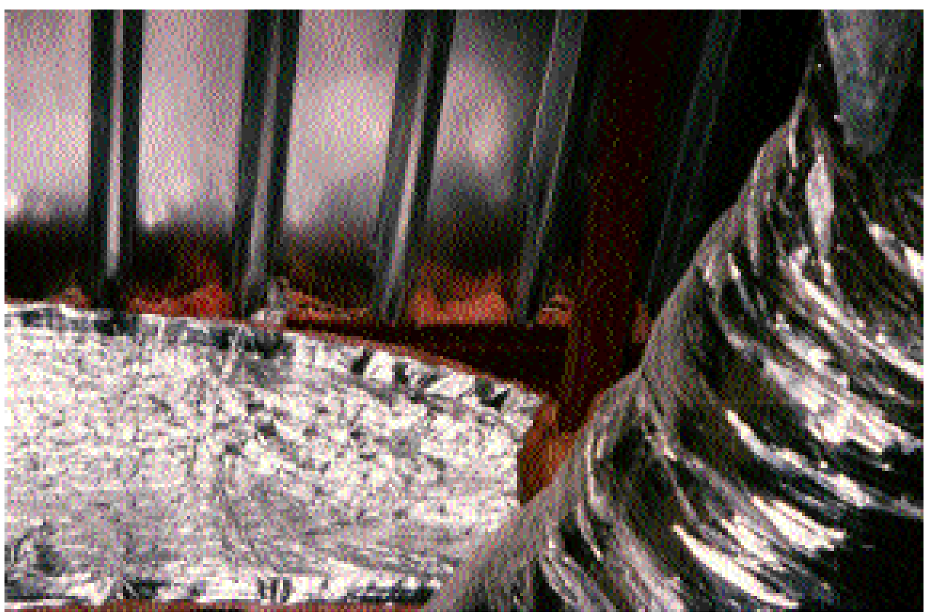
Learning to spot where breaches commonly occur in buildings is essential for mechanical engineers. With this knowledge, you may be able to prevent a catastrophe during the plan review. With this knowledge, you can ask to see the necessary architectural detail for determining if a water problem might exist while still early in the project. In this article, I will review air control and pressurization, ventilation, and humidity control and provide some resources to help expand your knowledge of design and construction errors that lead to HVAC headaches.

CONTROL THE AIR—NO BIG HOLES

The purpose of a building enclosure is to contain conditioned air and keep outside air from entering. It shouldn't have to be said, but the following concept is one that escapes many in the construction industry: You cannot enclose air with a sieve. Nor can you condition a sieve.

Unfortunately, this is what HVAC engineers are asked to do all of the time. Proof of this may be just above your desk at work. Poke your head above the

Continued on page 80



An example of the lack of air control at a fluted roof where roof or floor meets the exterior wall. Mineral wool within flutes does not stop air.

HPAC Engineering *Editorial Advisory Board member Joseph Lstiburek, PhD, P. Eng., is an internationally recognized authority on moisture-related building problems and indoor-air quality. Lstiburek, principal of Building Sciences Corp., a Boston-based consulting firm, has conducted forensic investigations and served as an expert witness on building failures. He is a member of ASHRAE, serving on the technical committee for Standard 62-1999,* Ventilation for Acceptable Indoor Air Quality. *He can be reached at* joe@buildingscience.com.

Sample construction details to keep water out

The Massachusetts Board of Building Regulations and Standards (BBRS), with the financial support of the State's gas and electric utilities, commissioned the Boston Society of Architects to develop a series of sample construction details in support of the new Massachusetts energy code for commercial, institutional, and high-rise (more than four stories) residential structures, including hotels and motels of any height—in other words, all buildings other than low-rise residential. The key difference in all of them is the new requirement for designing an air barrier into the building envelope.

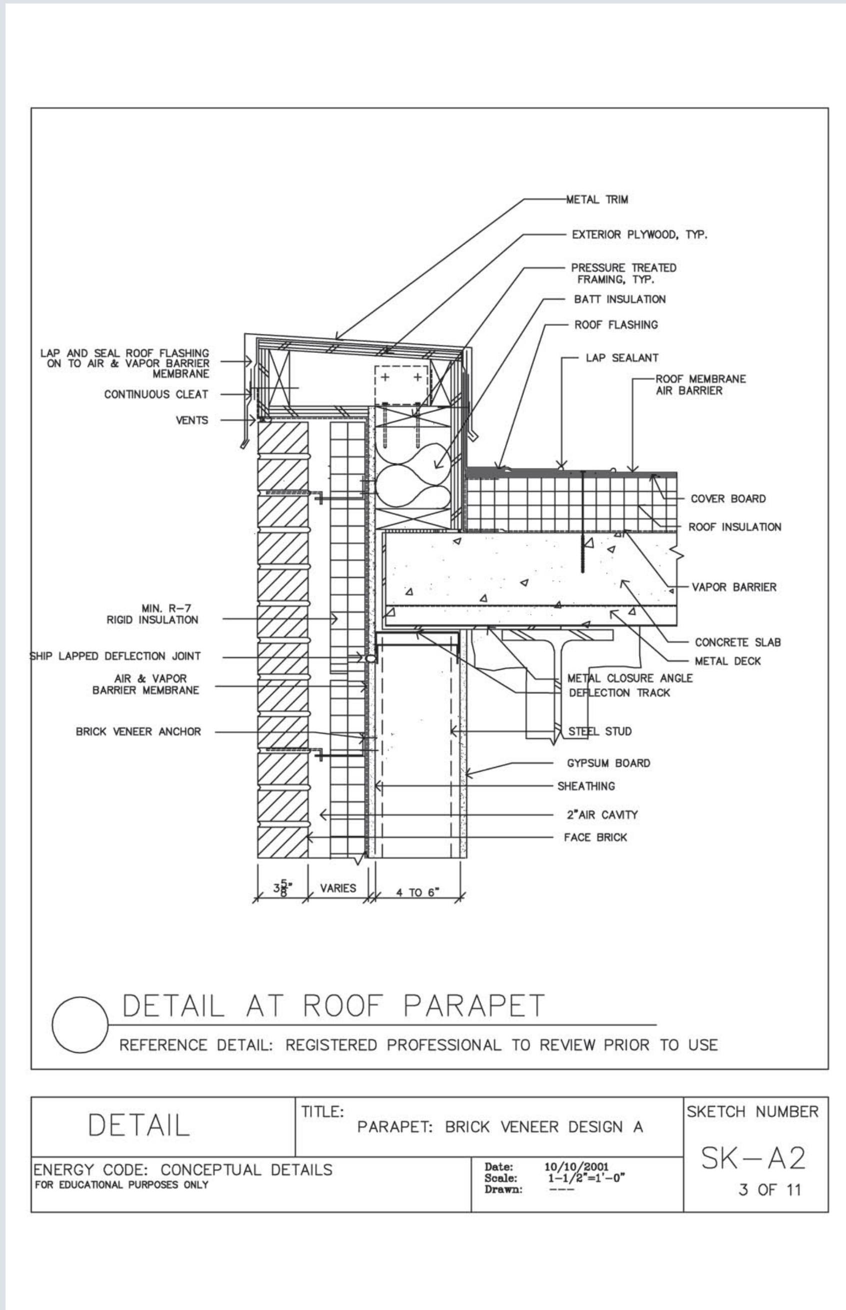
Certain assumptions were made about design conditions and other elements that could make the samples incorrect for some applications. Of course, the responsibility for a suitable and workable design remains with the professional designer of record.

Each sample set contains a narrative description of its assumptions, a discussion of advantages and disadvantages, and alternative materials that might be used. All materials discussed are generic, and no preference of one product over another is implied.

To access the sample construction details, visit www.state.ma.us/bbrs/sample_details.htm

This figure shows detailing for a steel stud wall with brick veneer insulated with rigid foam sheathing. The foam sheathing is installed on a membrane that acts as a drainage barrier, air barrier, and vapor barrier. Notice that the parapet-wall detailing does not allow warm air from inside the building to enter the parapet wall cavity and that the drain plane extends to the cap of the parapet wall. A metal coping with drip edges is flashed to the roofing and extends down below the top of the brick veneer.

This wall is resistant to rainwater intrusion and condensation problems.



This drawing is part of "Brick Veneer Design -A," available at the BBRS Web site, which also includes details for the roof edge, parapet, foundation, and the window head, jamb, and sill. This particular design is the work of Wagdy Anis, AIA, of Sheply Bulfinch Richardson and Abbott; Mark Kalin, FAIA, FCSI, of Kalin Associates Inc.; Jeff Wade AIA, CSI, of Building Envelope Technologies Inc.; and Steven Rigione of HKT Architects Inc.

Continuity of the air barrier from the building foundation to the roof is the main focus in this sample design plan. The design is based on a maximum of 35-percent interior relative humidity during the winter and normal exterior conditions in Massachusetts.

Continued from page 77

ceiling tile into a dropped ceiling and look toward the outside wall. Does the gypsum board run up to the underside of the next floor? Is the joint at the underside of the floor sealed? Probably not. Typically, someone shoves some mineral wool into the flutes, and they're gone.

Cantilevers present an even greater problem. Compounding the problem is that the HVAC engineer is trained to turn the dropped ceiling into a return-air plenum so that we can suck air out of the wall cavities through the flutes. But at least with the mineral wool in the flutes we clean the air as it whistles in—the big dust particles are captured.

Another problem is structural steel at a 45-degree angle, such as a sway brace. This usually means that there will be holes in the interior sheathing (usually gypsum board). Another common problem area is above the ceiling in the plenum, wherever there are pipes or wires penetrating an interior wall or the exterior wall sheathed on the interior with gypsum board. In these instances, air can and will flow through the wall penetrations. Additionally, although these holes could have been drilled with a bit slightly larger than the pipe or conduit, they are usually made with an 8-lb sledgehammer. These penetrations aren't often sealed, which is also likely a violation of fire codes. Firestopping materials are good sealants for these types of penetrations.

Fiberglass insulation is a filter, not an air-barrier. Note the dark markings (filtered dust) in the material.

This leads me to another real annoyance: The attempt to stop airflow with fiberglass insulation. Fiberglass insulation does not stop airflow. Fiberglass insulation is not an air barrier. To stop airflow, you need something rigid, such as gypsum board, concrete, sheet metal, or a membrane adhered to gypsum board.

HOLE HUNTING

Where are the big holes in buildings? You can find them all over. I particularly like parapets and port corcheres. Cantilevers and dropped-ceiling assemblies are likely hole hideouts, as well. How about elevator penthouses and the elevator shaft? Of course, window-to-wall connections should be high on your list of suspects when hunting for holes. We have enough trouble keeping the rain out of these joints. Air leakage at window "seals" is legendary. Of course, the windows themselves don't leak air, but the connections between them and the rest of the wall do. Stuffing or "chinking" this gap with fiberglass once again is like trying to stop airflow with a filter.

Holes can almost always be found at awnings, facades, and covered walkways, where the framing system joins the wall. Air barriers for these constructions often are poorly constructed or forgotten altogether.

So what is the HVAC engineer supposed to do? I recommend that you specify an airtightness requirement for the building enclosure and that the design of the HVAC system be based on specified envelope-performance characteristics. This would require that the envelope be commissioned. In other words, actually require that the building not leak air. This would require coordination and cooperation with the architect and the contractor—I can dream can't I?

CONTROL THE AIR BY PRESSURIZING

Buildings should not be depressurized. They should be slightly pressurized to between 2 and 5 pascals (convert to inches of water:1 in. of water is 250 pascals). This is true in most of the U.S., but not in Canada (and parts of the U.S. that might as well be Canada). A rule of thumb is that if your locale is over 8,000 degree days (base 65), you shouldn't be pressurizing your buildings. Exceptions to this rule of thumb include building spaces with unavoidable and large humidity sources within the structure, such as pools, and commercial kitchens.

In low-rise buildings, weather sometimes can override this low-pressure difference, but that's OK because this is a temporary situation. In high-rise buildings, pressurization is more complicated. In cold weather, everything below the neutral pressure plane will be running negative unless you have isolated the floors well and do not have vertical ductwork that runs more than a few floors. The sidebar "Managing Pressure Differentials in High-Rise Buildings" provides more details and a good reference for accomplishing this.

MAKE IT TIGHT

Buildings should be pressurized with conditioned air that is brought into a building in a controlled manner in a known location. With this approach, you can actually filter air in a meaningful way. Most of us put filters in equipment to protect the equipment. If we pressurize buildings with filtered air, we actually are doing something good for the occupants, not just the equipment. Of course, in order to pressurize we actually need an enclosure, which brings me back to a recurring theme: You can't pressurize a leaky building unless you have really big fans and a fabulously wealthy client who can afford the operating expenses. With a tight enclosure, you don't need big fans. Do it right—make it tight.

Unfortunately, we tend to install devices such as rooftop exhaust fans for restrooms and mechanical and/or electrical rooms. These devices run all the time. Unfortunately, unit ventilators that supply air do not run all of the time. The result is a building that is depressurized. One solution is the installation of makeup air units installed with preconditioning so that the exhaust air is replaced. Unfortunately, these often get "value-engineered" out of the design by the client's representative, who argues that these units are too expensive. My only advice to mechanical engineers at this point is to dig in their heels and fight. Do you want to design a system that works or one that doesn't work? How would this approach fly in other industries? Does the automobile industry build models without brakes in order to save customers a pile of money?

VENTILATE AND CONTROL HUMIDITY

Some believe dilution is the solution to indoor pollution. In reality, dilution often is the cause of indoor pollution especially in southern states. The more dilution you have, the more outside moisture you bring in. Unless the air is dry, air conditioning will lower the temperature of a huge mass of inside materials below the outdoor-air dewpoint temperature. Any air that infiltrates from outside, or which is not mechanically dehumidified, is wetting the materials. Condensation will appear on nonporous surfaces—this is obvious to behold. However, adsorption will occur on porous surfaces, which is less obvious but equally onerous. A can of cold beer pulled out of a refrigerator will sweat, but if you pull a 2-by-4 or a brick out of the fridge, it probably won't sweat; however, it will adsorb water.

You can only dilute with dry air, which means preconditioning. Also, you have to make sure that there are no places where air is being sucked in from the outside. I say separate the sensible control system from the ventilation and humidity-control system. In fact, I think an ideal system would include independent control of temperature, humidity, and ventilation. Depending on who you ask, I'm either thinking way ahead of everyone else or insane.

Managing Pressure Differentials in High-Rise Buildings

For high rise buildings, you need to pressurize all floors when it is cold. Several steps are needed to accomplish this:

- Seal between floors.
- Seal the corridors so the elevator shafts are their own isolated zones.
- Seal fire-egress stair chases. These need to be sealed so you have two tall towers that serve isolated floors.
- Air-side mechanical equipment has to be distributed so each system serves only a few floors. By spreading the systems around, you can more easily deal with the stack effect by pressurizing each floor, thus segmenting the stack effect.

Reference: "Building Science for a Cold Climate," by Neal Hutcheon and Gus Handegord, National Research Council, Canada, 1995.

CONCLUSION

Controlling water problems in buildings should be easy, but we make it hard by convoluting the design and construction process and pointing fingers from start to finish. HVAC engineers often take the blame for "condensation problems," which can be seen, smelled, and touched, even if the root causes of the problem are poor drainage, poor envelope design, and construction flaws. The goal of this two-part article was to provide HVAC engineers with knowledge to pressure owners, architects, and contractors to keep up their end of the construction process regarding moisture control.

The plan is simple, the materials available, and the results of proper practice immeasurable. To recap:

- Keep the rain and ground water out.
- Let it dry if it becomes wet.
- Make it tight—You cannot control air until you enclose air.
- Control the air by pressurizing (when it makes sense to do so).
- Ventilate, and control humidity.

The first three measures are primarily the responsibilities of the architect and contractor. The last two are the responsibilities of the HVAC engineer and contractor. Only if the first three steps are completed adequately can the second two steps be cost-effectively achievable. As mechanical engineers, your success is dependent on the work of others, so it's to your professional benefit to make sure steps 1-3 are done correctly.

FURTHER READING

HPAC Engineering has published many articles on moisture problems within structures and the litany of resulting problems. These include:

- August 2001, Lew Harriman and Terry M. Brennan, "Better Dehumidification for Commercial Buildings."
- September, October, and November 2000, Donald P. Gatley, PE, "Dehumidification Enhancements for 100-Percent-Outside-Air AHUs," Parts 1-3.
- June 1998, William G. Acker, "Water Vapor Migration and Condensation Control in Buildings."
- July 1997 Burge, H. A., "The Fungi: How They Grow and Their Effects on Human Health."