The physics of indoor air quality©

An interview by Michael Fallarino with Antoni TenWolde
Supervisory Research Physicist
US Forest Products Laboratory
Engineered Wood Products and Structures

Tell me about your work at the FPL.

"I've been there since 1980. I was originally hired as part of a group of four scientists who were going to look into energy in housing. Then the climate for energy conservation completely changed in the 1980s. And the team leader died within half a year after I joined. It was a very nice team to start with. We had another physicist, and an architect, and a wood technologist. Then the architect also died within a couple of years and the third person retired. So we went from a four member team to a single act.

We slowly started rebuilding about ten years ago and now we have a team of three. At the time our original team crumbled, I counseled the leadership that we should become less active in energy conservation because so many other organizations were dealing with that. I suggested that we should focus on moisture and durability. We always had activities going on in that area—that was part of the original vision of our work.

So I began to focus exclusively on moisture issues in buildings. We were one of the few in the 80s to concern ourselves with that. We tended to do exposure studies—build test buildings and measure moisture accumulation in walls, primarily. We collected quite a bit of data on moisture accumulation with and without vapor barriers here in Madison. And we had a study where we did the same thing in a southern climate, and that produced some interesting results. That was one of the first studies to measure moisture in a southern climate.

Then we became more interested in airflow. It became obvious that airflow was a major issue in any wood frame cavity or structure. We then began to make attempts to quantify the amount of airflow that goes into a cavity. That's very difficult to do—an order of magnitude more difficult than trying to measure diffusion. When you think you are measuring diffusion you're measuring the results of air movement.

[diffusion is moisture moving purely by differences in water vapor pressure—water moves from a place where there is more molecules to where there is fewer molecules. But air movement is an air flow following a difference in air pressure differences; that can be moving in any direction.] So air flow can bring in drier air or wetter air depending on which way the air flow is going. *It takes very, very small air flows to equal or surpass the amount of* *flow you get by diffusion. I'm talking about airflows that would be much, much lower than anything you would be interested in for energy conservation.*

You can have very small airflows that bring significant amounts of moisture into a structure but do not appreciably change the temperature regime in that structure. In the old days we had wind whistling through the cavities. There was so much air flow that both temperature and humidity were dominated by the airflow. So there usually wasn't any problem in those walls. But the minute you get more airtight, you can end up with a very concentrated airflow with all the moisture being delivered in one place. And that can result in some problems. However, I'm not arguing against air tightness. I think it's an absolute must these days.

There are recent studies from Canada that show that leaky houses have the greatest contamination with mold spores and other contaminants. It's clear that if you have a leaky house you have no idea where that fresh air is coming from— and it may very well *not* be fresh air. There is a lot of polluted air coming out of building cavities and out of the soil in the basement, and it could very easily be loaded with mold spores. The beauty of building airtight and then providing positive ventilation with a mechanical ventilation system is that you know where the air is coming from.

It's a little puzzling to me that here in the 21st century, the place where we spend most of our time—our homes and our bedrooms—do not have designed ventilation. We don't know where the air is coming from in that bedroom. It's quite amazing, actually.

Did you get your education here or in Europe?

Both. I had a Master's degree in physics from Delph University when I came to this country, then I went to the University of Wisconsin at Madison and got another Master's degree in Environmental Management. My degree in physics was an engineering/physics degree. In Holland I would have been able to call myself an engineer. I was looking at energy conservation in industry. I had a small grant from the FPL to look at energy use in building materials. I was looking at wood and steel and how much energy they consumed per unit of product to produce. I've always enjoyed lab work and doing data analysis.

What does ASHRAE stand for?

The American Society of Heating Refrigeration and Air Conditioning Engineers. This is a group that deals with designing HVAC equipment in buildings. When you put insulation in a building you change the characteristics and needs of that building. Very early they got into the business of load calculation. When we started putting insulation into buildings people noticed very quickly that paint was peeling off. It was then that the insulation manufacturers came up with the idea of putting a vapor barrier on. So an insulation and vapor retarder committee was begun. Over time, moisture management became a major part of the duties of that committee. That has now taken on a life of its own.

Until recently, we always felt within ASHRAE that moisture had to be dealt with in terms of load. But it wasn't until the mold issue came up that ASHRAE became significantly more interested in moisture control. Until then, mold was a sub-issue associated with load calculation. As indoor air quality issues began to rise about a decade ago, it became clear that moisture was an issue that needed to be dealt with as an important consideration. In the United States, ASHRAE has always been the place to go to get information about moisture control issues.

If you wanted to go to a university to learn about building physics and flow dynamics in buildings, I think you'd be hard-put to find it. Mechanical engineers know ducts and systems but I don't think they know very much about how their systems influence the building. On the other hand, many European universities have building physics curriculums. But here, there isn't even a definition that I know of in English called building physics. For instance, the University of Leuven in Belgium has a building physics department with many Ph.D. students in the curriculum. And Germany has many universities where they have been teaching this for a long time. The northern European countries in particular have produced text books on moisture and heat flows. But here, there doesn't seem to be a good mechanism to bring science into the realm of residential building construction. The *Build America* program is a recent exception. But there doesn't seem to be a direct way to communicate these insights to the builder. You can try to influence the codes, which is difficult to do.

My goal is to get the experts on one page and elevate the level of discussion of this whole topic. We need good textbooks and good resource materials out there. That would be an important step. *Eeba.org* is trying with builder guides that are adjusted to fit different climate zones. There are now four guides. My interest is to get the technical and scientific recommendations that underlies all of this up to the next level. Many of these recommendations are still seat-of-the-pants that lack rigor.

How important to the health of the inhabitants is the airflow in a structure? Why should we be concerned about it?

Indoor air quality is a factor. We need to know where our indoor air is coming from. But we also need to examine this from a durability perspective. If we don't deal with airflows correctly, we can induce them in a way that we don't want occurring. Those airflows can then start carrying large amounts of moisture into the building envelope. An example is all these hotel and motel failures where mold is growing on the vinyl wall coverings between the vinyl and the gypsum. This has been a phenomenon associated with large negative pressures in the hotel room, and commonly the wall cavity, due to the design of the ventilation system. If the outdoor air being pulled in is moist, you will induce a situation of moisture condensing on an interior wall, especially an air conditioned one. If the wall has vinyl wallpaper on it the moisture will accumulate behind the vinyl wallpaper and can't dry out. So negative pressures and vinyl wallpaper can be a disaster. If there was positive pressure in those walls that would never happen. So negative pressures especially in hot, humid climates is a big problem.

This can also be a big problem with brick veneer walls. For example, after a rainstorm if the sun comes out it can generate a lot of water vapor that can be sucked into a building with negative pressure. So pressure is incredibly important in that respect. So if you have negative air pressure, and you have mold growing in the wall, where is your fresh air coming from? It's most likely being sucked through that wall with mold growing in it, then it enters the airstream. From there, spores can be distributed everywhere. So it's very important to have control of airflows and air pressures.

How much effect on materials can airflow within a structure generate?

I'm less sure about that. There may be materials that are offgassing that you might not want in your fresh air supply. Sometimes airflow can be good in that it can dry out materials that have gotten wet. It all depends on where the airflow is coming from and how dry it is. It's bit of a wildcard.

What do think about as paint as a whole system?

I view it as a way to keep liquid water out of the materials. But we've also found that once liquid water gets in, paint may slow down the drying process. if you have a paint failure and liquid water is getting into the system—especially in a back-primed system—it won't dry out as fast. It depends upon the permeability of the paint film.

I would suggest that rather than back-priming that a water repellent be applied on the back of the wood. The goal of back-priming is to prevent liquid water from being absorbed into the back of the material.

I view siding essentially as a rain screen. It should catch ninety-nine percent of what's coming at it, but over its lifetime its not going to able to keep everything out. So a certain amount of water inevitably gets behind the siding. I'm still not convinced that back-priming is the best solution to that problem. When we looked at water penetration problems on a project we did in Florida we found that the water that got through around windows and so on tended to pond on top of the next course. There it has an opportunity to seep into sheathing. In most cases, it ran sideways until it found a place to leak to the next level. So it would sort of run sideways and run down, run sideways and run down, until eventually it finds a place to run out.

The best thing for the siding would be to have the water run straight down the back and out. The best way to accomplish that would be to use furring as a spacer between the siding and the sheathing—the rain screen concept. Many people are now advocating the rain screen concept on the premise that siding should be ventilated. That way any water penetrating the siding could spread out or run back out without undue wetting of the next surface, which is really the weather barrier that is applied to the sheathing. That brings up the concept of installing that weather barrier perfectly and integrating it with the flashing around windows. But it should form a second line of defense—not a first line.

In general, are there any conclusions that you could draw that might suggest how future construction methodology could change to create more optimum interior environments as well as a more ecologically sustainable building platform?

First, I would like to see designs that take the drying ability of the construction into consideration. Over the life a building you can almost guarantee that a roof or a wall will get some water in it and it would be helpful if that fact were taken into consideration during the design phase rather than locking that moisture in. It's not just important how wet things get, but how long they stay wet. It doesn't take long for mold to start growing. But if the design allowed the moisture to be redistributed so that the moisture content of the materials dropped below the point at which mold can form, that would be an important consideration. You can't design for catastrophes but you *can* design for the occasional rainstorm that is so severe that if a few ounces of water enter the wall, it will be dissipated. We can design for that and we *should* design for that.

Second, I would like to restress the idea that more thought needs to go into the ventilation of residential buildings. There's a lot known about it, but we're still officially allowed to rely on openable windows. This relates directly to air pressures in the structure.

The third thing is to pay a lot of attention to foundations and the drainage of foundations. Often the battle is lost at the very start of the building project when the foundation is neither high enough above grade nor properly draining. It's obvious with many new structures that one part of the foundation will end up below grade at some point and the paint at that point will subsequently fail. That is something that is not very well handled right now—no one's giving it much thought. Frequently the specifications aren't mindful of this point and the foundation subcontractor is in too much of a hurry to pick it up. This is actually where most of the water vapor comes from: not from plants, not from people—it comes out of the foundation. My guess is that the average foundation will produce about ten pounds of water vapor per day that will infiltrate the structure. It completely dominates the indoor humidity picture. That will be especially so if you have a wet, leaky basement.

Paint dealers are often confronted with the results of water penetration and many may jump to erroneous conclusions about attic ventilation and vapor barriers. In my opinion much paint failure is caused by water infiltrating the siding and not vapor passing through the wall. Siding is meant to be a rain screen but not a rain barrier. We're talking orders of magnitude in the difference between siding infiltration and vapor barrier infiltration.

Often we don't know the real history of a building. Sometimes problems are caused by modifications to the building that completely alter the airflow pattern and cuts the airflow and ventilation rate by a factor of five or six. You can achieve a lot more with building ventilation than you can with attic ventilation or vapor barriers. Excellent ventilation can even preclude the need for vapor barriers and attic ventilation.

The US Forest Products Laboratory in Madison, Wisconsin is a great national resource for research and contemporary thinking regarding wood use and wood preservation, including the subtleties of indoor air quality. Their invaluable website can be accessed at http://www.fpl.fs.fed.us/ and contains a searchable database. This interview with Antoni TenWolde was conducted during the spring of 2003.