Building Science Introduction - Moisture Flow

Building Science Introduction

Many aspects of building design, construction, and operation can affect the health and comfort of the people in the building. This introduction focuses on three particular areas:

- Air Flow
- Heat Flow
- Moisture Flow.

For each of these issues, the introduction explores causes, control measures, and effects on both buildings and occupants. This introduction defines many of the theories behind the ENERGY STAR New Homes requirements.

Moisture Flow

Controlling moisture flow in a building has significant impacts on occupant health and safety, comfort, building durability and energy efficiency. This section will cover the basics of moisture and its effects on the house system. It will also discuss how geographic location and house type can affect choices of moisture control strategies.

Applied building science is concerned with four different moisture transport mechanisms and the effects of that moisture flow:

- Bulk water movement (rain, snow, or groundwater)
- Capillary action (capillarity)
- Air transported moisture
- Vapor diffusion

Bulk Moisture

Bulk moisture movement (or liquid flow) has the potential to be the most damaging moisture transport mechanism confronted by a building. Typically thought of as rain or snow, bulk moisture movement also includes flowing groundwater. Three conditions are required to allow bulk moisture flow into a building:

- A source of water
- A hole in the building envelope
- A driving force such as gravity or air pressure

In most locations, there will be water present during at least part of the year. The keys to controlling that water are to direct it away from the home and to seal any holes that water might come through.

Directing water away from the home is accomplished by proper grading, drainage, gutters, and downspouts. Proper sealing is done by meticulous attention to flashing and caulking details, and door and window installation.

Capillary Action

Capillary action refers to the ability of water to travel up against the pull of gravity through a porous material. One common example of this action is water “wicking” up through a paper towel, following the direction of the paper fibers. Although not as serious as bulk water movement, capillary forces are both powerful and rather secretive, since they often work in the dark of a crawlspace, causing significant damage to a building without the occupant’s knowledge.

Opposite to what one might expect, capillary action prefers small holes or pores, rather than larger ones. Large pore sizes, such as those found in some forms of pea gravel and coarse sand, can actually serve to “break” the flow of capillary water. Smaller pores though, such as those found in concrete and brick, provide excellent paths for such wicking action to occur.

Since concrete is commonly used in building foundations, we often see evidence of capillarity in basements and crawlspaces. The concrete footings wick the water up from the ground, where it then travels up the foundation wall. Evidence of capillary action is often seen on many older brick foundations as a white line visible a foot or so above the ground. This white line is caused by a process known as efflorescence, which occurs when water that is drawn up by capillary action evaporates, leaving behind a residue of salts, minerals, and other materials. Plastic sheeting placed in footing holes prior to pouring of concrete can help to prevent groundwater wicking.

Capillary action is also an important issue above-grade. Even two nonporous materials, if placed closely enough together, will provide a channel for capillary action to occur. One common example of this occurs with lapped wood siding. Rain water striking the side of the house will run down the siding to the edge. Capillary forces can then draw the bead of water up and behind the siding, thus wetting the back side of the siding. Obviously, such forms of capillarity can be hard to observe until serious damage has already occurred.

Capillary action can best be controlled by providing a capillary “break” such as plastic, metal, damp-proofing compound or another impermeable material, or by leaving air spaces that are too large for capillarity to occur.

Air-Transported Moisture

Air-transported moisture (in the form of water vapor hitchhiking on air) can leak into, or out of, buildings. As noted earlier, both uncontrolled pressure sources (such as wind or stack effect) and controlled sources (fans and air handlers) can move significant amounts of moist air past a building’s envelope through holes. Leaky ductwork can cause moisture problems by not only increasing the amount of infiltration, but by drawing air in from the humid crawlspace or basement areas. As this humid air travels through a building, the moisture in it will condense on any surface whose temperature is below the dew point.

The amount of condensation that forms is dependent upon several factors: inside versus outside temperatures, the relative humidity, and the speed of the air moving across the condensing surface. Colder surfaces (like windows and poorly-insulated walls) condense moisture more easily; slower-moving air allows more time for condensate to form. And obviously, the higher the relative humidity, the more moisture available in the air in the first place.

Decreasing the effects of air-transported moisture also depends on several factors. The best defense is to keep moist, outside air out of the building through effective sealing against infiltration, sealing the ductwork, and pressure-balancing the HVAC system. Proper use of exhaust fans in all bathrooms and kitchens helps to remove moisture-rich indoor air at its source. Preventing cold spots through adequate heating and air movement removes potential sites for condensation.

Vapor Diffusion

Even without leaks, small amounts of moisture in the form of water vapor can pass directly through a building’s envelope, through a process called diffusion. Vapor diffusion from a damp or wet basement into the living space can significantly increase the moisture levels inside a home.

The amount of vapor diffusion that occurs in a building is determined by two things: the driving force that pushes it (known as the “vapor pressure differential”), and the permeability of the material the vapor is passing through. Most materials (even glass) are unable to completely stop vapor diffusion; thus, calling something a “vapor barrier” is a bit of a wrong label. The current trend in building science is to refer to materials as “vapor retarders,” meaning that while they slow down the movement of water vapor, they do not completely halt the process. Materials that significantly slow down the vapor diffusion process are said to have low permeability, or simply “low-perm.” Typical building codes consider a material to be a vapor retarder if it has a perm rating of 1.0 or less.

Vapor retarders are often applied in the crawlspace of a building to prevent ground moisture from evaporating and traveling up into the home. Many building codes require applying such vapor-retarding materials under wall board to prevent vapor diffusion from bringing water into the structural assemblies. In cold climates during the heating season, pressure differential drives the vapor from the inside of the building to the outside. In Minnesota, the vapor barrier is generally installed on the interior face of the wall studs. In warm climates during the cooling season, this vapor drive is from the outside of the building towards the inside – thus, in Miami, vapor retarders are often applied on the outside of buildings. Besides the perm rating of the material, the effectiveness of a vapor retarder is also a function of its surface area. A vapor diffusion retarder that covers 80% of a building is said to be “80% effective.”

Effects of Moisture Flow

Effects of Moisture Flow on Occupants

Health and Safety

Moisture is not often thought of in terms of occupant health and safety. Yet indoor air quality professionals consider moisture to be a “pollutant” that can have a significant impact on the occupants’ health. Moisture is the key ingredient for mold and bacteria growth. Not only are these fungi odorous, unsightly, and a cause of wood rot, but they can also cause asthma and allergic reactions in many individuals. There are even well-documented cases linking certain airborne fungi to more serious health problems, including cancer, birth defects, immune system suppression and tissue poisoning. Instances of “sick building syndrome” are often related to mold growth in buildings.

Excess moisture (particularly in the air) also provides a favorable environment for dust mites and cockroaches, serious sources for asthma and allergy problems. Though people don’t usually react to the creatures themselves (except to maybe scream and reach for a rolled-up magazine), roach and dust mite droppings can cause asthma and allergic reactions in many people. Another unfortunate side-effect of these creatures’ presence is that they often bring about increased use of insecticides. Young children in particular can be extremely susceptible to such poisons and can suffer effects such as allergic reactions.

Comfort

Since moisture, in the form of relative humidity, plays such a key role in how we perceive comfort, it is a primary driving force in determining how to operate building systems. According to ASHRAE, the comfort zone for buildings in the winter is between 68º and 75ºF at a relative humidity of 30% to 60%. During summer conditions, the comfort range is found between 72º and 78º F at 25% to 60% relative humidity.

Effects of Moisture Flow on Durability

Moisture is a common cause of building degradation. In fact, much of what we know about applied building science today originates from early work investigating moisture impact on buildings. While the severity of moisture problems varies greatly depending on climate, few regions in North America are free from concerns about moisture in buildings.

Moisture can attack a building's durability on many fronts, from wet crawlspaces to leaking roofs. Moisture-rich air can even become trapped in building structural assemblies, possibly leading to mold growth, rot, or insect infestation. Entire industries have developed that specialize in combating these various moisture problems.

More Info.

Access to some references may require purchase from the publisher. While we continually update our database, links may have changed since posting. Please contact our webmaster if you find broken links.

References and Resources*

1. **ENERGY STAR Certified Homes Building Science Introduction**
   Author(s): U.S. Environmental Protection Agency
   Organization(s): EPA
   Publication Date: January, 2011
   Document outlining building science principles about air flow, heat flow and moisture flow in homes.

*Publication dates are shown for formal documents. Dates are not shown for non-dated media. Access dates for referenced, non-dated media, such as web sites, are shown in the measure guide text.

Last Updated: Friday, August 1, 2014