Air Barriers Role In Preserving IAQ

By John F. Straube, Ph.D.
Associate Member ASHRAE

It is widely recognized that airborne agents such as volatile organic compounds (VOC), some mold spores, particulate matter and other microorganisms affect indoor air quality (IAQ). Much of the IAQ press deals with the health impact of these contaminants and means to reduce their generation. Another important part of a holistic approach to IAQ is exclusion of pollutants.

John F. Straube, Ph.D., is a professor at the Department of Civil Engineering and School of Architecture, University of Waterloo, Waterloo, ON, Canada.

Most contaminants, from whatever source and however generated, are transported by airflow into the conditioned space. Diffusion is the only other practical transport mechanism, but the large molecules and relatively gigantic particles involved move so slowly through porous materials that diffusion is rarely, if ever, a significant mode of pollutant transport. Hence, the understanding and control of airflow is important to IAQ.

The air-barrier system (ABS) is the element used to control the flow of air through building enclosure systems such as walls, roofs, floors and windows. This article will introduce air-barrier systems, airflow within enclosures and describe their role in IAQ.

Why Air-Barrier Systems?

The most important reasons why ABS are provided in enclosures include moisture control, energy savings, comfort and health. Each are discussed in this article.

Moisture control

Water vapor in outdoor (warm weather) or indoor (cold weather) air can be deposited by condensation within the enclosure and cause serious problems. Air leakage condensation can provide the moisture and heat to support mold growth on interstitial building surfaces. Although there are other sources of moisture inside walls (notably rain), air leakage condensation is one of the most significant sources.[1]

Many designers (and a remarkable number of building codes) still believe that a vapor barrier is all that is required to control interstitial condensation. In fact, the diffusion of water vapor through common building materials rarely causes damaging wetting. Many strategies, including the simple application of paint over drywall, are available for controlling diffusion wetting. Hence, relying on vapor barriers to control interstitial condensation is not only dangerous it is always incorrect.[2]

An air-barrier system must be used to prevent the movement of air into all wall and roof enclosures in all climates.[3] Although one can sometimes use vapor barrier materials like polyethylene sheet as part of an air-barrier system, this is not always the case. It is critical that designers and building investigators clearly distinguish between wall or roof elements that control airflow and those that control vapor diffusion.

Energy savings

Air leaking out of a building must be replaced with outdoor air which requires energy to condition it. A significant proportion of space conditioning energy consumption in many well-insulated buildings is due to air leakage through the building enclosure. Convective circulation and windwashing both reduce the effectiveness of thermal insulation and, thus, increase energy transfer across the envelope.

Comfort and health

Cold drafts and the excessively dry wintertime air that results from excessive air leakage directly affect human comfort. Portions of the interior of the enclosure that are cooled by cold winds blowing through

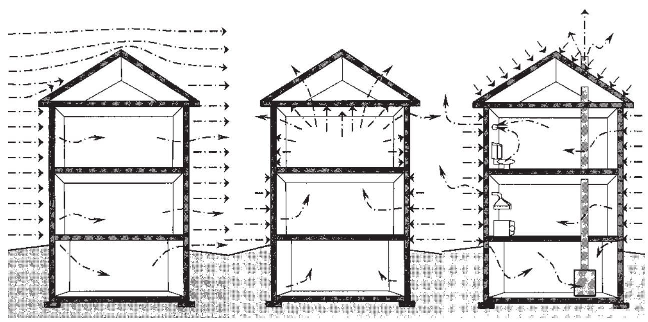

Figure 1: Force driving airflow across building enclosures.

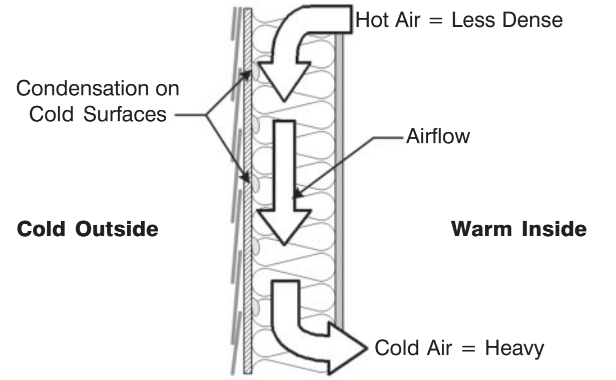

Figure 2: Internal cold weather convection loop causing condensation and pollutant transport.

insulation promote condensation that supports biological growth. Finally, air movement from within the enclosure or from the exterior often will carry pollutants in the form of radon, soil gas, mold spores, particulates, and exhaust gases into the conditioned space. Choosing an interior air-barrier system (such as airtight drywall approach) will also prevent off-gassing products within an assembly from entering the indoor space.

Forces Driving Airflow

What drives the airflow that is the source of so many IAQ and other problems? Airflow is always driven by air pressure differences. What is often not appreciated is how little pressure and how small a crack is required to move air. A 0.02 in. w.g. (5 Pa) pressure acting over 1 ft (0.305 m) long, 0.125-in. (3.2 mm) wide crack will drive about 5 cfm (2.4 L/s) of airflow.

There are three sources of pressure differences across enclosures: wind, stack effect and mechanical equipment.

Wind pressures act on all exterior sides of a building, creating suctions on some sides of a building and pressures on the other. The hourly average magnitude of these wind-induced pressures is typically in the range of 0.02 – 0.04 in. w.g. (4 – 10 Pa) for sheltered buildings close to the ground and from 0.04 – 0.2 in. w.g. (10 – 50 Pa) higher above any ground shelter.

Stack effect pressures are generated by differences in air density with temperature (i.e., hot air rises and cold air sinks). The air within a building during cold weather acts like a bubble of light, hot air in a sea of dense, cold air. In warm weather, the situation is reversed, although air-temperature differences are usually less. Stack-effect pressures increase with height and with temperature difference between inside and outside. Actual pressures due to stack effect range from only 0.01 in. w.g. (2 Pa) in hot-weather housing to well over 0.16 in. w.g. (40 Pa) in cold-weather high-rise buildings.

Mechanical equipment in the form of appliances that supply or exhaust air to the building modify the pressure within it. Exhaust-only ventilation (including clothes driers, combustion appliances, range hoods, bath fans and HVAC systems) results in a net negative pressure acting across the building enclosure.

At every location on a building enbclosure, the pressures from the different sources can be added arithmetically to generate a total net pressure. If the net pressure is an inward driving pressure, the air flowing inward through the enclosure will draw potentially polluted outdoor and within-wall air pollutants into the building. Pressurizing a space will force air outward through the enclosure, causing potentially serious condensation problems in cold weather.

From an IAQ standpoint, reducing the pressure difference as much as possible should be the goal, a goal that can only be reached by careful design and operation of all systems. Balanced mechanical systems and airtight compartments in high- rise buildings can be used to deal with mechanically-induced and stack-effect pressures. A small over-pressure has the advantage of excluding pollutants but must be coupled with an excellent ABS in cold climates. Increasing the airtightness of the enclosure (by providing a good ABS) will dramatically reduce the amount of air that flows through the enclosure for the same pressure difference.

Functional Requirements

Several different materials, joints and assemblies are combined to provide an uninterrupted plane of primary airflow control in buildings. The combination of materials required means that air-barrier *system* is the preferred term. Regardless of how air control is achieved, the following five requirements must be met by the air-barrier system:

1. Continuity. This is the most important and most difficult requirement. Building enclosures are *3-D systems*! ABS continuity must be ensured through doors, windows, penetrations, around corners, at floor lines, soffits, etc.

2. Strength. If the ABS is, as designed, much less air-permeable than the remainder of the enclosure assembly, then it must also be designed to transfer the full design wind load to the structural system. Fastenings can often be critical, especially for flexible non-adhered membrane systems.

3. Durability. The ABS must continue to perform for its service life. Therefore, the ease of repair and replacement, the imposed stresses and material resistance to movement, fatigue, temperature, etc., are all considerations.

4. Stiffness. The stiffness of the ABS (including fastening methods) must reduce or eliminate deflections to control air movement into the enclosure by flapping and pumping. The ABS must also be stiff enough that deformations do not change the air permeance (e.g., by stretching holes around fasteners) and/or distribute loads through unintentional load paths.

5. Impermeability. Naturally, the ABS must be impermeable to air. Typical recommended air permeability values are less than 1.3×10^{-6} m^3/m^2/Pa or Q< 0.1 Lps/m^2 at 75 Pa (0.3 in. w.g.). Although this is an easy property to measure, it is not as important as might be thought. In practice, the ability to achieve other requirements (especially continuity) are more important to performance, and the air "permeance" of joints, cracks, and penetrations outweighs the air permeance of the solid materials that make up most of the area of the ABS.

Internal Airflow

Air-barrier systems are used to control the flow of air *through* the enclosure. Controlling airflow *within* the enclosure is also important. Internal airflows can short-circuit thermal insulation with the attendant increase in heat transfer and risk of moisture deposition. More importantly for IAQ, airflow within the enclosure can transport pollutants from within the wall or roof into the conditioned space. Both thermal buoyancy (i.e., stack effect within small cavities) and differential wind-pressures cause natural and forced convective airflows *within* building enclosures. Providing an excellent air-barrier system will not necessarily control these problems, since no airflow need occur through an ABS for either of these phenomena to cause performance problems.

Internal Convection

Internal convection is simply a case of stack-effect driven air loops within enclosures, almost always vertical enclosures. A classic case occurs in basement systems, which usually have a good air-barrier system in the form of a concrete wall, but have an unsealed framed wall on the interior. Warm air enters at a small crack near the top of the wall (almost always present) and is cooled as it approaches the exterior concrete wall. This cooled air falls, sometimes condenses, and is pushed out the unsealed base of the wall, transporting mold spores and other pollutants into the conditioned space.

The solution to this type of looping, which can occur in warm weather as well, is a reasonably well-sealed interior surface and/or dense, impermeable insulation that completely fills all voids (e.g., spray foam, dense pack cellulose). Locating the air-barrier system at the interior drywall layer provides an airtight interior layer.

Windwashing

Wind pressures vary over the face of a building. If air flows through the cladding, it can then flow through low-density air-permeable insulation. Windwashing is the term given to this phenomenon. It can cause very cold interior surfaces (in cold weather), which attract surface condensation. In warm weather, the humidity in the exterior air can condense on the exterior face of air-conditioned interior drywall, again resulting in condensation on this vulnerable material.

The solution to windwashing problems is the application of a reasonably air-impermeable barrier on the exterior of air-permeable insulations (such as housewrap, or taped rigid foam sheathing), or the use of low air permeance insulations (such as foams and high-density cellulose). The air barrier system can also be applied directly behind the cladding to control windwashing.

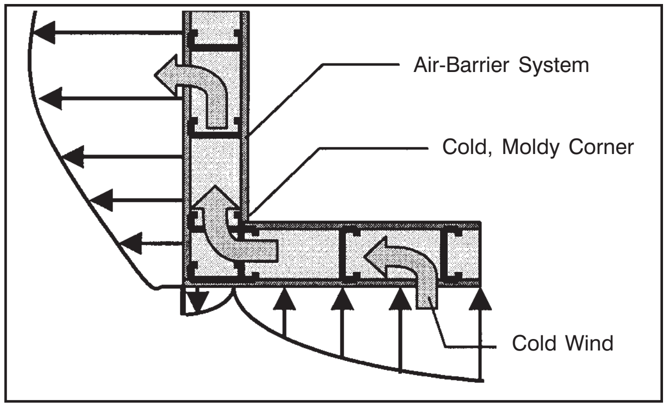

Figure 3: An interior air-barrier system's windwashing potential.

As can be seen from the two examples given, a single plane of airtightness (the air-barrier system) is required somewhere within all enclosure systems. However, the interior and the exterior surface may require a certain degree of airflow resistance if air permeable insulation or air voids are present in the assembly.

Conclusions

Airflow control is important for several reasons: to control moisture damage, reduce energy losses, and to ensure occupant comfort and health. Airflow across the building enclosure is driven by wind pressures, stack effect and mechanical air-handling equipment like fans and furnaces.

Design for airflow control involves much more than just providing a single plane of airtightness (an air-barrier system) — internal convective loops and windwashing are additional airflow mechanisms that can cause IAQ problems.

A continuous, strong, stiff, durable, and air impermeable air-barrier system is required in all buildings to control airflow. Air barriers are important and necessary components of almost all building enclosures in all climates, whereas vapor barriers are typically less important components that may or may not be needed. Enclosure assemblies and buildings should also be vertically and horizontally compartmentalized, may require secondary planes of airtightness to control windwashing and convective loops (such as those provided by housewraps and sealed rigid sheathing) and require air impermeable insulations or insulated sheathing.

It should also be noted that increased airtightness *must* be matched with an appropriate ventilation system to dilute pollutants, provide fresh air and control winter humidity levels.

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