5.3.6.5 Air infiltration, exfiltration, and air barriers

Infiltration and exfiltration are air leakage into and out of a building respectively, through cracks or joints between infill components and structural elements, interstices around windows and doors, between the sill plate and foundation, through floors and walls, at the top and bottom of walls, and at openings for building services such as plumbing. Approximately 5 to 20% of air leakage occurs at doors and windows, and 20 to 50% occurs through walls. Infiltration and exfiltration are often a major source of energy loss in buildings. Exfiltrating air carries away heating and cooling energy, while infiltrating air may bring in moisture and pollution as well as reduce the effectiveness of a rain screen wall system.

Moisture can move into or across a wall assembly by means of vapor diffusion and air movement. Diffusion is a slow, controlled process driven only by vapor pressure differentials, and rarely causes any significant moisture accumulation. Air migration occurs from air pressure differentials independent of moisture pressure differentials. If air, especially exfiltrating, warm, humid air, can leak into the enclosure, then this will be the major source of moisture. *Condensation due to air movement is usually much greater than that due to vapor diffusion for most buildings*. However, when air leakage is controlled or avoided, the contribution from vapor diffusion can still be significant. In a well designed wall, attention must therefore be paid to the control of both air flow and vapor diffusion.

An air barrier and vapor retarder are both needed in a properly designed building envelope, and in many instances a single material can be used to provide both of these as well as other functions. The principal function of the air barrier is to stop the outside air from entering the building through the walls, windows, or roof, and inside air from exfiltrating through the building envelope to the outside. This applies whether the air is humid or dry, since air leakage can result in problems other than the deposition of moisture in cavities.

Uncontrolled air (and its associated water vapor), exfiltration in cold climates and infiltration in hot, humid climates can wreak havoc on the structure, causing corrosion and structural damage, mold and bacterial growth, and energy loss. It can also create HVAC problems by disrupting indoor air pressure relationships and degrading indoor air quality (IAQ), which can lead to health problems for sensitive individuals.

Atmospheric air pressure differences between the inside and outside of a building envelope exist because of the action of wind, the density difference between outside cold heavy air and inside warm light air creating a “stack effect”, and the operation of equipment such as fans. The pressure differences will tend to equalize, and the air will flow through holes or cracks in the building envelope carrying with it the water vapor it contains. A thorough analysis of air leakage is very complex, involving many parameters, including wall construction, building height and orientation.

Air barriers (sometimes called air retarders) will reduce infiltration and exfiltration. They reduce the potential for moisture problems due to moist air migrating into a building. This moisture can be warm humid air from outside during the summer or warm conditioned air from inside in the winter.

An air barrier is required to have a leakage rate less than 0.06 cfm/ft^2 at a differential pressure of 0.3 in. H_2O (1.57 psf) according to ASTM E1677, “Standard Specification for an Air Retarder (AR) or Material or System for Low-Rise Frame Walls.” This value however is considered high for buildings in Canada where a value of 0.004 cfm/ft^2 at 0.3 in. H_2O is sometimes required. This is the maximum air leakage for a total assembled air barrier system (total wall system or main areas plus joints) when tested according to ASTM E2178, “Standard Test Method for Air Permeance of Building Materials.”

Materials such as precast concrete panels, polyethylene, gypsum board, metal sheeting or glass qualify as air barriers since they are low air-permeable materials when joints are properly sealed; concrete block, acoustic insulation, open cell polystyrene insulation, or fiberboard are not. Air permeances of selected materials are presented in Table 5.3.16.

Materials and the method of assembly chosen to build an air barrier must meet several requirements if they are to perform the air leakage control function successfully.

1. **Continuous.** The air barrier must be continuous throughout the building envelope. For example, the low air permeability materials of the wall must be continuous with the low air barrier materials of the roof (e.g., the roofing membrane) and connected to the air barrier material of the window frame. All of the air barrier components should be sealed together so there are no gaps in the envelope airtightness. Where interior finishing (drywall) serves as the air barrier, if it is not finished or continuous above suspended ceilings or behind convector cabinets, there will be large gaps in the air barrier system’s continuity. Connection should be made between:
   a. Foundation and walls.
   b. Walls and windows or doors.
   c. Different wall systems, such as brick and precast concrete, or curtain wall and precast concrete, and corners.

d. Joints in gypsum wallboard and precast concrete panels.

e. Walls and roof.

f. Walls, floors and roof at construction, control, and expansion joints. The interior air barrier above a dropped ceiling needs to be connected to the underside of the above floor.

g. Walls, floors, and roof to utility, pipe, and duct penetrations.

2. **Load Capacity.** Each membrane or assembly of materials intended to support a differential air pressure load must be designed and constructed to carry that load, inward or outward. This load is the combined wind, stack, and fan pressures on the building envelope. If the air barrier system is made of flexible materials, then it must be supported on both sides by materials capable of resisting the peak air pressure loads; or it must be made of self-supporting materials, such as board products adequately fastened to the structure. The air barrier should be designed so that adjacent materials are not displaced under differential air pressures. Tape and sealant must also resist these pressures and have long-term resistance. Concrete is the ideal material for an air barrier because of its durability and strength in resisting these loads. Sealant between panels and at joints must be designed to resist these loads.

3. **Joints.** The air barrier of each assembly should be joined to air barriers of adjacent assemblies in a manner allowing for the relative movement of the assemblies and components due to thermal and moisture variation, creep, and structural deflection. These joints in the air barrier and joints at penetrations of the air barrier system should be of low air permeability materials.

4. **Durable.** The air barrier assembly must be durable in the same sense that the building is durable, and be made of materials that are known to have a long service life or be positioned so that they may be serviced from time to time.

5. **Vapor Permeance.** When a vapor retarder is used on the inside of insulation in a cold or mixed climate [see vapor retarder section, page 423], an air barrier used on the outside should be permeable to water vapor. If both the inside vapor retarder and the outside air barrier are not permeable, then a "double vapor retarder" condition is created. Moisture that gets between the two through rain penetration or leakage through joints will not be able to readily evaporate and disperse to the interior or exterior. Vapor permeability allows moisture behind the air barrier to exit the wall by vapor diffusion to the outside. According to ASTM E1677:

   "In a moderate to cold climate the opaque wall must either be permeable to water vapor, or when the permeance of the materials on the exterior is less than 1 perm it may be beneficial to insulate on the outside. When the exterior is permeable, moisture vapor from the opaque wall can escape to the outdoors without accumulating in the wall. When the exterior is insulated, the temperature of the opaque wall is increased to minimize wall moisture accumulation. Designers should evaluate the amount of insulation necessary to keep condensation from forming in the wall assembly when the air barrier is rated as a vapor retarder less than 1 perm and exterior applied."

Building Pressure. In warm humid climates, a positive building pressure will help prevent the infiltration of humid air. In cold climates the building pressure should be neither strongly positive or negative. A strong negative pressure could pull in combustion products from street traffic. A strong positive pressure could drive moisture into the building walls and other elements.

Adequate Ventilation. Because concrete buildings have less air leakage, heating and cooling systems should have adequate air intake systems to provide fresh air in buildings. This is more critical in concrete than steel frame buildings because there is less air leakage. Without an adequate intake source, concrete buildings are under negative pressure, potentially resulting in poor indoor air quality. In all cases, guidelines of ANSI/ASHRAE Standard 62[1] should be followed for proper ventilation of indoor air.

Application. The location of the air barrier in the wall system is dependent on the wall construction and climate. Precast concrete as a material acts as an air barrier and has a negligible air leakage and infiltration rate. A properly designed and constructed precast concrete building will save energy due to this low infiltration. This requires the air barrier be continuous by sealing joints between precast concrete panels, openings at connectors, around door and window frames, and at penetrations. The building envelope should provide continuous resistance to air flow through joints at floors, ceilings, and roof. Gypsum wallboard can act as an air barrier if the floor/wallboard and ceiling/wallboard joints are tightly fitted and sealed with a joint sealant.

Air barrier membranes and building wraps such as Tyvek® are being used more frequently in new construction. They are not required in precast concrete buildings because the concrete acts as an air barrier and has a lower air permeance than many of the available membranes and wraps (see "breather type membranes" in Table 5.3.16).

In cold climates (Zones 5, 6, and 7), it is strongly recommended that the visible interi-

1 ASHRAE Standard 62-2004, "Ventilation for Acceptable Indoor Air Quality," American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, www.ASHRAE.org

or surface of a building envelope be installed and treated as the primary air barrier and vapor retarder. A concrete panel with the concrete on the indoor surface generally serves this dual function as air barrier and vapor retarder. Where floors and cross walls are of solid concrete, it is necessary to seal only the joints, as floors and walls themselves do not constitute air paths. Where hollow partitions, such as steel studs, are used, the interior finish of the envelope can be made into the continuous air barrier. Where this is impractical, polyethylene film should be installed across these junctions and later sealed to the interior finish material. Where it is impractical to use a concrete panel system as the continuous air barrier system, an interior finish of gypsum wallboard, or plaster, painted with two coats of vapor retarding paint, will provide a satisfactory air barrier/vapor retarder in many instances.

While it is preferable that the air barrier system be placed on the warm indoor side of an insulated assembly, where thermal stresses will be at a minimum, it is not an essential requirement. (This does not necessarily mean on the inside surface of the wall.) The position of the air barrier in a wall is more a matter of suitable construction practice and the type of materials to be used. However, if an air barrier membrane is used and is positioned on the outside of the insulation, consideration must be given to its water vapor permeability, as discussed in Item No. 5. One rule of thumb is to choose an air barrier material on the outside that is 10 to 20 times more permeable to water vapor diffusion than the vapor retarder material on the inside of the wall.

In warm and humid climates (Zones 1A, 2A, and 3A), an air barrier (or low air-permeance materials properly sealed) on the outside of the wall works well because it helps prevent the infiltration of the warm humid air. An architectural precast concrete panel with appropriate joint sealant will serve as an air barrier in this climate. Exterior surfaces should be less permeable than inside surfaces, once again, to help reduce the amount of moisture entering the walls. Note that this is the opposite of what is recommended for cold climates.

In mixed, dry warm, and cool marine climates (see Table 5.3.11), an air barrier (or properly sealed low air-permeance materials) is recommended. An architectural precast concrete panel with appropriate joint sealant will serve as an air barrier in this climate.

Table 5.3.16 – Measured air leakage for selected building materials[1].

Material	Average leakage, cfm/ft^2 of surface at 0.3 in. H_2O
Solid precast concrete wall	No measurable leakage
Aluminum foil vapor barrier	No measurable leakage
6 mil polyethylene	No measurable leakage
Extruded polystyrene insulation	No measurable leakage
Closed cell foam insulation	0.0002
3 in. polyicynene	0.001
$^1/_2$ in. fiberboard sheathing	0.31
Breather type building membranes	0.0022 – 0.71
Uncoated brick wall	0.31
Uncoated concrete block	0.41
1 in. expanded polystyrene	0.93

[1]National Research Council, Canada www.nrc-cnrc.gc.ca