The Air Barrier Defined

R.L. Quirouette

Introduction

Many building performance problems can be traced to air leakage through the building envelope. These problems range from high heating costs and poor temperature control in occupied spaces to rain penetration and the spalling of brick on exterior walls. Many of these problems result not from poor construction practices, but from the designers' poor understanding of the forces involved, the properties of the materials used, the performance requirements of the finished building envelope, and the construction process itself. Misunderstanding these crucial factors gives rise to assumptions that are not valid and to expectations of levels of performance that cannot be achieved by the materials and/or systems. Weaknesses thus get built into the finished product at the conceptual stages, and are carried through the preparation of the working drawings and into the construction process.

A wall section or a construction detail incorrectly designed – because of the selection of materials, their incorporation into the system or their interconnection – will not perform as expected, no matter how carefully the wall or detail is built. But invariably when problems occur, the quality of workmanship and the ability of the material to perform as intended are questioned first, the design only second.

It may be unfair to blame the material supplier or the builder; it may be equally unfair to blame the designer. Did he or she have access to all the building science information needed to make design decisions based on sound principles?

The Vapour Barrier

For many years, designers were taught that the vapour barrier was a major requirement for insulated walls in order to control the diffusion of water vapour into the colder reaches of these walls, where it could condense and stain the finished surfaces or, worse, initiate the deterioration of the affected materials. When it became obvious to researchers in the 1960s that air leakage into the walls and roofs was a more important source of water migration, authorities began calling for a "continuous vapour barrier." This new terminology was supposed to somehow get rid of all the hidden holes causing so many moisture-related problems. The expression "air/vapour barrier" then began to appear in the literature, raising the hope that this component would finally put a stop to all moisture flow through the walls and roofs of a building. This, unfortunately, did not happen, so it has become necessary to take apart this concept of the "continuous air/vapour barrier" and go back to basic principles.

A vapour barrier is a material that offers a high resistance to the diffusion of water vapour. It is used to separate an environment which is at a high vapour pressure from an adjacent one at a lower vapour pressure. For best results, it is important that the vapour barrier be continuous, but it does not have to be perfectly continuous. Unsealed laps or minor cuts do not affect the overall resistance to diffusion significantly. The vapour barrier must also be located on the warm side of the insulation or at least in a location in the wall near enough to the warm side to remain above the dew point temperature of the indoor air during cold weather.

The Air Barrier

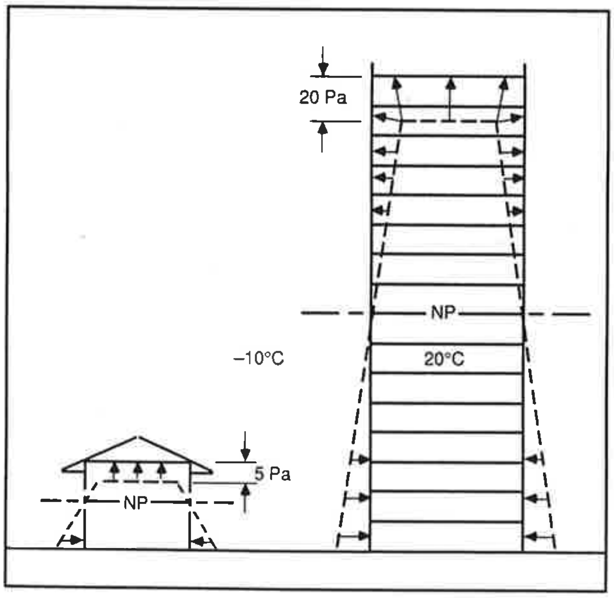
The principal function of the air barrier is to prevent both the infiltration of outdoor air into a building and the exfiltration of indoor air to the outside. This applies whether the air is humid or dry. Air leakage can cause problems other than the deposition of moisture in the walls, such as loss of energy and infiltration of rain.

The Mechanism of Air Leakage

For air to flow in and out of a building, two conditions must be fulfilled: there must be a hole in the envelope and there must be an air pressure difference across the wall at that location. The hole need not be directly through the wall but can follow a tortuous path inside the wall. The pressure difference, on the other hand, can result from one or more of three possible causes: stack effect, wind, and fan pressurization.

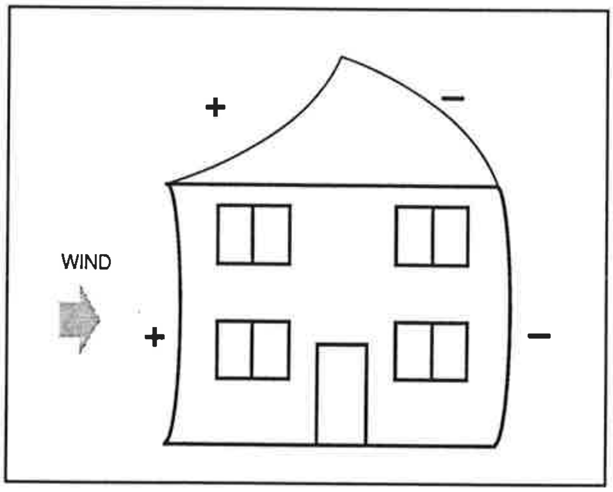
Stack effect results from the difference in air temperature between indoor and outdoor air during the heating season. Warm air, being lighter than cold air, rises in a building, creating a suction at the base and exerting an outward pressure at the top. The higher the building, the greater the pressure difference across the walls and roof. The suction is greatest at the base, decreasing as the building rises to a neutral pressure plane somewhere between the ground floor and the roof. Above the neutral pressure plane the pressure becomes positive (active outwards) and increases with height, reaching its highest value at the roof. The quantity of air entering the building below the neutral pressure plane is equal to the quantity of air leaving the building above that level (Figure 1).

Figure 1 Stack effect



Wind, like stack effect, is a natural phenomenon. Wind increases the positive air pressure acting against a building on the windward side, and produces a negative pressure on the leeward side and on the walls parallel to the wind direction. The wind also exerts a suction on flat or low-sloped roofs and a positive pressure on the windward side of steeper-sloped roofs (Figure 2).

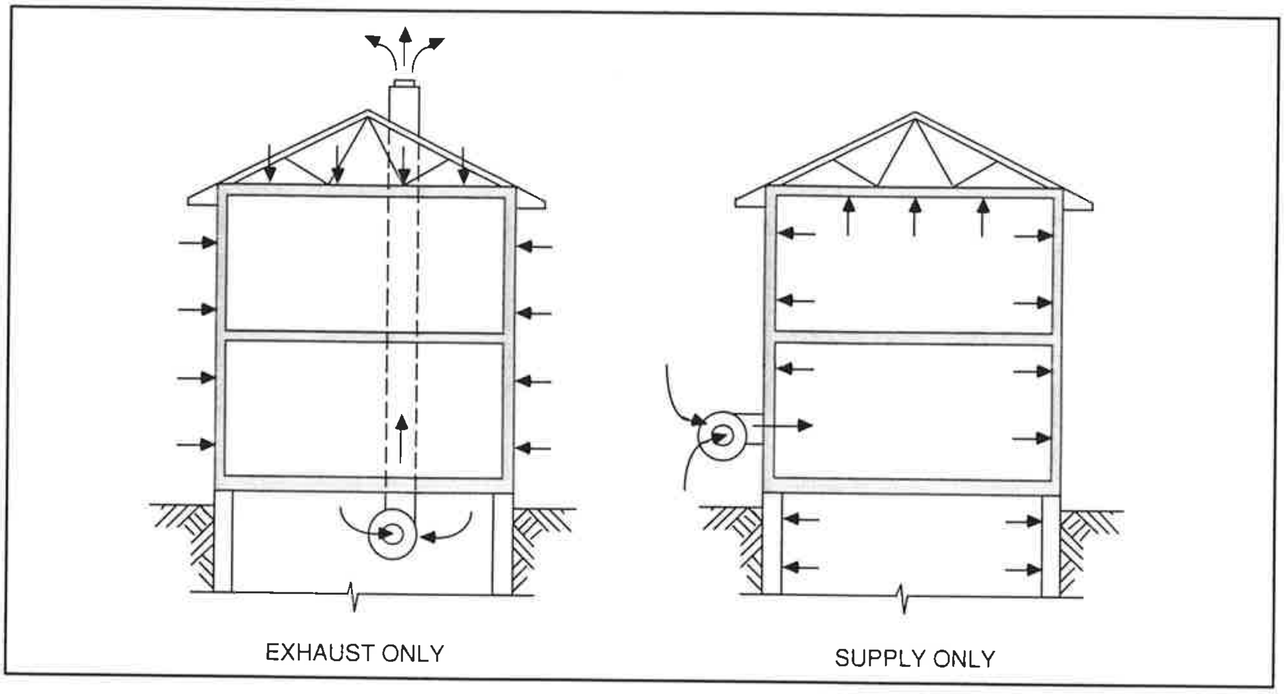
Figure 2 Distribution of wind pressures on a house



Since the wind in most regions of the country does not blow strongly all that often, its importance does not reside in the increased air leakage that it causes, but rather in the large pressures it can exert on those components in a building envelope that otherwise offer a high resistance to air leakage. If the difference in air pressure across a component exceeds its strength, that component may cease to be useful as an air barrier.

Fan pressurization. Most buildings rely on some form of ventilation system to exhaust contaminated air. This system may run continuously, or may be operated automatically or manually. Ventilation systems can be of three types: a) exhaust only, resulting in a lower air pressure inside a building relative to the outside and increased infiltration; b) supply only, raising the pressure inside a building and increasing exfiltration, and c) balanced, with both supply and exhaust being operated by fans (Figure 3). Even in a balanced system, the amount of air supplied may be increased or decreased relative to the amount being exhausted, increasing or decreasing the inside pressure accordingly.

Figure 3 Influence of fan operation on internal pressures



In a highrise building, for example, the pressure may be increased to reduce the suction at street level and facilitate the opening of exterior doors. On the other hand, in buildings where occupancy requires or generates high humidity levels, such as art galleries and swimming pools, the inside pressure may be reduced so as to decrease the flow of warm moist air into the walls and roof.

Air Barrier Requirements

If the air barrier is to perform its intended role, it must meet a number of requirements: continuity, structural integrity, air impermeability, and durability. An air barrier may consist of a single material or of two or more materials which when assembled together make up an air impermeable, structurally adequate barrier. Keeping this in mind, we shall examine all four requirements separately.

Continuity

Continuity means more than being without holes. Because the component that performs the role of the air barrier changes from the wall to' the window to the roof, continuity means that all these assemblies must be connected together so as to ensure that there is no break in the airtightness of the envelope.

Case Study No. 1

A primary school had severe condensation on the window mullions in some classrooms. The moisture was damaging the window sill as well as the drywall underneath. The windows in this 25-year-old building had recently been replaced. The new windows were mounted in typical curtain wall sections which extended the full two storey height of the school. The investigation determined that the cold outside air was entering the building between the mullions and the masonry walls, cooling the mullions as it did. Moisture from within the room condensed on the cold mullions, running onto the apron and down the face of the wall.

To correct the problem, it was necessary to remove the brick on either side of the windows to the full height of the mullions and seal the gap between the mullion and the inner wall. This was done using urethane foam, which sealed the cracks, to provide continuity between window frame and wall and at the same time provide a thermal break over the metal components in the cavity.

Structural Integrity

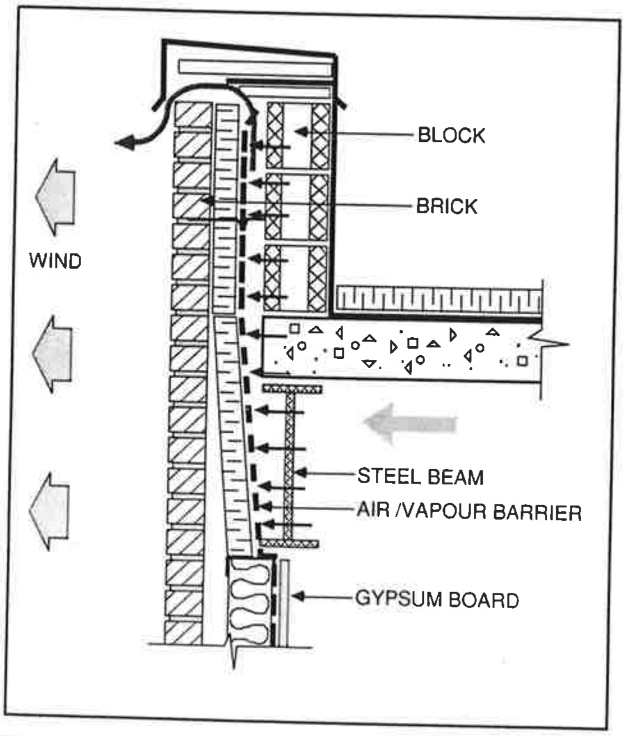
The component designed to be the air barrier must itself be capable of resisting the imposed load or must be supported by one that can. It must be capable of resisting the strongest wind load acting either as a pressure or suction without rupturing or breaking away from its support. The air barrier must not detach itself from its support or fail in creep under a sustained pressure resulting from stack effect or fan pressurization or exhaust. The air barrier and its support must be sufficiently rigid to resist displacement.

Case Study No. 2

The owners of a new shopping center noticed wetness on the walls and ceiling of some of the stores following a heavy rainstorm. The construction consisted of a steel frame with concrete roof deck. Walls below the roof beams were made up of insulated steel studs with drywall finish on the inside and masonry veneer on the outside. The parapet was of masonry construction. A rigid insulation was used to insulate the top of the wall, from the top of the steel stud to the top of the roof deck. This insulation was spot adhered to a polyethylene air and vapour barrier, which was attached to the top of the stud wall and extended to the underside of a plywood plate supported by the block parapet at the top.

When the parapet wall was opened, the investigators noticed that the rigid insulation had pulled away from its original location and was now leaning against the back of the brick veneer (Figure 4). The polyethylene air and vapour barrier was itself sagging in the cavity, having pulled away from its fixing at the top. The investigators concluded that because the air barrier (the polyethylene) was not supported throughout its breath and length, it had moved back in the cavity under a leeward wind. When the wind direction was reversed, the bottom portion of the polyethylene spanning between the top and bottom flanges of the spandrel beam was simply pushed into the cavity, pulling the polyethylene downward. It is this movement of the polyethylene in both directions which caused the insulation to move away from it, and caused the polyethylene to sag and tear in the cavity.

Figure 4 Displacement of an inadequately supported air barrier



Air Impermeability

A major requirement of an air barrier is that it offer a high resistance to air flow. While absolute air impermeability may not be required, materials such as glass, sheet metal, gypsum board, cast-in-place concrete and a properly supported polyethylene sheet offer a much higher resistance to air flow than do more porous materials such as concrete blocks, fibreboard sheathing, and expanded polystyrene insulation. A second major consideration is that individual panels be joined into an airtight assembly. The joints between gypsum boards can be taped quickly and effectively, sheet metal panels can be lapped with tape, precast panels can be sealed with rope and sealants, etc.

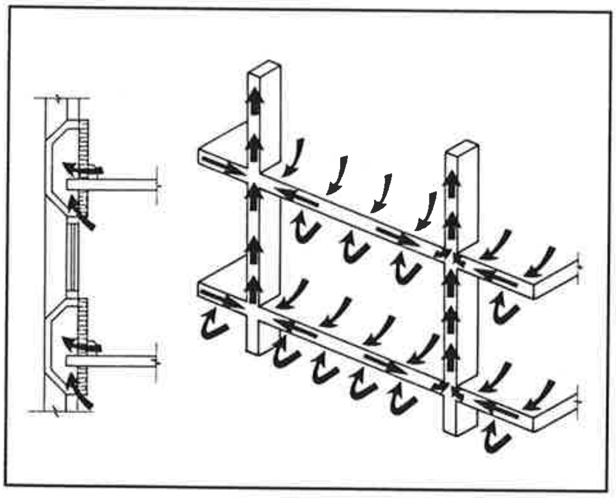
Case Study No. 3

Every spring the residents of some ground floor apartments in an 18 storey condominium experienced severe water problems. The water would first show up on the floor along the outside walls and would soon start running towards the center of the rooms. The building managers tried for several years to determine the cause of the problem but were unable to come up with an explanation.

An examination of the building drawings provided the following information: the building structure was of cast-in-place concrete frame and the building was clad in precast concrete panels consisting of U-shaped column covers and C-shaped spandrel panels. The infill wall panel behind the spandrel consisted of an insulated block wall with gypsum board finish. As is common in such buildings, the entrance lobby and all corridors were pressurized.

A closer inspection of the exterior walls revealed that the concrete blocks behind the convector cabinets in the apartments had been left exposed. It became clear as the investigation progressed that air from the apartments could escape through the block wall behind the convectors and into the space between the infill wall and the spandrel beam (Figure 5). The air then moved up behind the column covers, which were opened at the top though protected from rain and snow infiltration. All other joints in the façade were caulked. Moisture contained in the air would condense on the back of the precast, where it collected as frost and ice as long as the temperature remained cold. As soon as the outdoor temperature rose above freezing for a few days, the ice melted and the water ran down the back of the precast. Unable to drain at the bottom because of blocked weep holes, the water seeped into the building through the walls.

Figure 5 Air leakage paths through spandrel and column cavities



The problem in this case arose because of the air permeability of the exterior wall components, which allowed air to flow through. Had the gypsum board finish been carried through behind the convectors, the problem would not have occurred.

Durability

The airtightness system must outlast the building itself. For this to happen, the materials used must have a proven track record or the material should be positioned in such a way that it is accessible for inspection and maintenance.

Durability is not an intrinsic property of a material but depends largely on how a material reacts to a specific environment such as moisture, temperature, ultra-violet radiation, and to the presence of other materials (incompatibility). A material also often sees two different environments during its service life, one during construction and another after the building has been completed. The environment the air barrier sees only briefly during construction may nonetheless be detrimental to the long term performance of some of the materials that compose it. These materials should always therefore be adequately protected from rain, heat, ultra-violet radiation, cold, and mechanical damage during construction.

Conclusion

A single material may combine the roles of air barrier and vapour barrier or these roles may be performed by two different materials or systems. If one material is to combine both functions, it must meet all the requirements of both functions, including proper positioning within the wall assembly so as to prevent condensation. The final decision regarding the design of the air and the vapour barriers should be based on practical considerations. Continuity and structural integrity are such important properties of an air barrier that there is little point in asking a contractor to compromise on them.

The air barrier as a separate requirement is not a new concept, but its development and application will require an adjustment in the way walls are designed and built and in the types of materials used.

There is no doubt, however, that excessive air leakage has been, and remains, the cause of many building failures in Canada. We ought not to overlook the obvious simply because we do not have all the answers. It is by working together – designers, material manufacturers, builders, and researchers – that we shall develop the answers. We hope that by defining the requirements of both the vapour barrier and the air barrier and by giving examples of failures resulting from air leakage, we have established a recognition of the need to consider air leakage as a phenomenon requiring special attention at both the design and construction stages. The price to pay for neglecting it is high.