CONTINUOUS INSULATION, AIR BARRIERS AND MOISTURE CONTROLS – NEW OPTIONS FOR HIGH PERFORMANCE BUILDINGS

P. Duffy

ABSTRACT

As codes and standards requirements evolve to more stringent requirements for air leakage control, thermal performance, and moisture control, a new set of options are appearing for designers to consider. It’s not just about Materials, it’s about Assemblies and Systems for making them work. Are there ways to simplify things? What about redundancy? What about cost? This session will look at options for various types of commercial and residential assemblies with a view to maximizing performance and making them work without excessive cost and performance problems.

BACKGROUND

The 2012 Ontario Building Code Part 5 and 2010 National Building Code Part 5 each contain more meticulous language than ever before detailing specific requirements for environmental separations (i.e. building envelopes) including requirements for:

- Thermal protection
- Air leakage control
- Vapour diffusion control
- Protection against wind-driven rain
- Protection from surface water and water in the ground
- Sound transmission

Taken individually, at least some of these requirements could be seen as specifications for new sub-systems or elements within assemblies. Most code developers would see them as clarification of the function of design elements that have always been required. Regardless, the more complex wording is prompting many designers to look at building envelope design in new ways.

The Code requirements give rise to the design of a number of fundamental elements in building envelope assemblies including:

- Thermal Insulation Layer(s)
- Air Barrier(s) and Weather Barrier(s)
- Vapour Barrier(s)
- Water Resistant Barrier(s)
- Drainage Layer(s)

A “brute force” approach to design could result in the need to provide a separate layer fulfilling each of these design functions individually. This would almost certainly add cost and may not result in optimal performance if certain aspects are not seen as “systems”, that is, design elements that require more than one material in an assembly to be effective.

Code language requiring a “systems” approach to various issues raises the need for a comprehensive solution to that certain issue. As an example, the Code requires an Air Barrier System. An Air Barrier System differs from an Air Barrier Material in that, though many materials can provide resistance to air flow (e.g. sheet
goods, certain insulation products, peel and stick, spray-applied and trowel-applied membranes, etc.), it
takes an integrated design—including sealants, transition membranes and other materials—to achieve
continuity.

So it is very possible to envisage a situation where each of the Code-required functional elements even result
in situations where several new materials and components are being introduced to complicate building
assemblies. Fortunately, however, a number of innovative designers have recognized that there are a number
of materials available that can perform multiple functions thereby limiting duplication and helping to control
costs. Designers may then elect to have multiple materials duplicate a particular function but that redundancy
is a conscious decision.

**Performance Requirements for Functional Elements**

The implementation of the Code requires that performance requirements be laid out for each functional
element:

1. **Thermal Insulation:**

   Insulation products have historically been specified in terms of R-Value/ RSI-value (i.e. the
   performance of a material in a hot plate apparatus such as that used in ASTM C518 and other
   similar methods.) While this metric is useful for comparison purposes, it measures performance
   in a laboratory setting under optimal performance conditions. For some materials and in most
   assemblies, heat and air can flow through and around insulation, partially negating some of its
   performance. The test measures heat flow in a single dimension (through the material) but heat
   flows in three dimensions so the results can be misleading.

   Some authorities have tried to develop a more comprehensive *Thermal Metric*, combining air
   leakage, heat and moisture flow in real world assemblies to assist designers in improving
   assemblies but progress has been slow. It’s not that it is scientifically impossible, but standards
   development requires consensus, and that process, combined with complexities in how certain
   phenomena should be tested and reported, creates delays. While there might not yet be the level
   of consensus needed to develop a standard and reference it in Code, some important findings
   are available to designers:

   - Air leakage can result in as much as a 70% reduction in performance of some products.
   - Insulation levels throughout much of North America are at a level where the required
     insulation cannot be easily met with cavity insulation alone.
   - A layer of *continuous insulation* on the exterior of a building improves the performance
     of a building in at least two ways—it not only provides additional thermal insulation, it
     reduces thermal bridging through the structural frame of a building.

   There may be additional benefits in terms of energy performance and moisture control
   depending on products used and their positioning in the assembly.

2. **Air Barriers and Weather Barriers:**

   The need for air leakage control arises not only from the need to protect insulation from air
   leaks that would degrade its performance, but also from the desire to limit the potential for
concealed condensation in building assemblies. At various times in the year, air leakage can transport vast quantities of moisture into areas where it could cause significant problems such as corrosion, rot, mould and mildew.

The Code specifies performance for Air Barrier Materials to ASTM E2178 but recognizing that assemblies may need an integrated design including multiple materials to control air leakage. The code also requires an Air Barrier System be incorporated into the design. Assembly tests such as ASTM E2357 and whole building tests may be used on smaller buildings to verify performance of a proposed system.

Recognizing that wind may “wash” through some materials, some designers incorporate external air barriers or multiple air barriers—some oriented towards the interior, others oriented towards the exterior (e.g. air barriers and weather barriers) to contain vulnerable elements and protect them against air leakage.

3. Vapour Barriers:

Vapour diffusion will occur through assemblies when there is a difference in vapour pressure between the interior and exterior of a building. Vapour flows from an area of high vapour pressure to an area of low pressure. In colder climates, cold outdoor air contains little moisture and the moisture it does contain will be at low vapour pressure, so the net vapour flow is generally inside to out. In warmer climates the reverse is true, so the net vapour flow is outside to in.

In colder climates, it has been accepted practice to require vapour barriers oriented towards the inside of a building to protect assemblies from vapour diffusion. In warmer climates, exterior elements typically are more resistant to vapour flow. This raises the spectre that products and assemblies designed for one climate may not be suitable for another.

Also, vapour flow is the primary mechanism for drying building elements, so it is essential that at least one path (inward or outward) be provided for drying all building elements. This is where the avoidance of “double vapour barriers” became an important element of good design.

Understanding the vapour permeability of materials using a method similar to ASTM E 96 is a key design criterion. Code Compliant vapour barriers are defined as materials have a permeance of 60ng/s/m² by that test.

4. Water Resistive Barriers:

Regardless of climate, precipitation causes damage in most climates. NRC building digests were among the early promoters of “rain screen” design as a defense against wind driven rain and snow. The modern spin on that design includes a Water Resistive Barrier at depth into the wall, protected by a drainage cavity and vented cladding.

Water resistive layers can come in a variety of forms:

- They can be low permeance membranes
- They can be low permeance, low water absorption insulation products
They can be other materials, lapped and sealed so as to minimize the ingress of moisture.

Regardless of material, proper layering and sealing is required to resist water ingress.

5. Drainage Layers:

Below grade, similar design elements are needed to deflect moisture away from moisture sensitive materials. The terminology and typical products that are used are somewhat different, but similar to what is provided to avoid wind-driven precipitation above grade. The intent is that exterior moisture at grade and below be deflected and carried to perimeter drainage schemes that protect the insulated assemblies of the basement.

With so many requirements for thermal, air leakage, vapour and moisture control, as well as a myriad of products to fill these functions, it is easy to see the potential for misapplication of materials and systems. It is also possible to see the impact on cost based on ever more complicated designs incorporating more and different materials into assemblies fill design requirements.

Integrated Design

Construction budgets are seldom unlimited, so it becomes necessary and desirable to integrate functional requirements defined above into key elements of designs.

1. Integrated Air / Vapour Barrier:

One of the earlier attempts at integrated design concepts dates back to the Super Energy Efficient housing of the late 1970’s and 1980’s. Sealed Polyethylene was used as both continuous air barrier and vapour barrier in these designs. While the approach resulted in many examples of successful building envelope designs for low rise buildings, a number of lessons were learned:

- Application in details where polyethylene passed through assemblies in the middle of the insulated layer or on the “cold side” of the assembly raises the possibility that vapour will be “trapped” condensing on the vapour barrier that is inappropriately oriented.
- Other materials including air sealing electrical boxes, sealants and caulking, tapes and transition membranes and breathable membranes are needed to assure continuity in air barrier are needed to complete the design details.
- Because of much higher stack, wind and mechanical pressures, Sealed Polyethylene really isn’t an acceptable solution for high-rise construction.

The approach also led to many years of confusion in Codes and Standards over what was mistakenly referred to as the “Air/Vapour Barrier”.

2. A) Integrated Insulation/Air Barrier:

This approach is one that typically uses spray foam as a cavity insulation product on the interior of a building. Spray foam typically performs well as a code compliant air barrier material but would require the use of other materials to make the air barrier continuous. As an air barrier, spray foam holds advantages over sealed polyethylene in that it is structurally self-supporting and it adheres readily to many substrates, fewer transitions are required, it bridges larger gaps.
in assemblies quite readily, and it eliminates convective air flow through insulation. Typically
the supplemental air sealing work that is required primarily involves caulking at wall/floor
intersections, built-up structural elements, and some transition around windows and doors.
Low Density (0.5-1.5 lbs/cu.ft.) spray foam is typically the product of choice because it tends
to be the lowest cost spray foam alternative, it is flexible and will move with the building thereby
maintaining an air seal, and it adheres well to adjacent surfaces.

B) Integrated Insulation/Air Barrier/Vapour Barrier:
A variation of the above uses Medium Density (1.5-2.5 lbs/cu.ft.) spray foam at thicknesses
over 38mm (1 1/2”) or XPS/foil faced polyurethane/polyisocyanurate boards to act as an
integrated insulation/air barrier and vapour barrier on the interior of the assembly. These
approaches have the advantage incorporating the vapour barrier into the insulation and air
barrier scheme. However, there is typically a significant cost premium for doing this.

The Medium Density Spray foam approach will typically involve fewer steps because there is
no need to seal board joints and penetrations. So typically, boardstock products get used as
integrated products on the interior only for specific applications such as blocking headers, etc.

3. A) Integrated Air Barrier/Water Resistive Barrier:
This has been a popular design approach for many years. Many manufacturers have a number
of “peel and stick”, trowel and spray applied materials that can provide these functions.
Notwithstanding the fact that detailing is simplified because these materials are applied to
sheathings and planar surfaces on the exterior of the building, their application tends to be
labour intensive and this adds to cost.

In most Canadian climates, if kept within the insulated layer, the membrane can be of a vapour
impermeable (i.e. Vapour Barrier) type. If the membrane is oriented more towards the “cold
side” of the assembly, a more vapour permeable material will be needed to avoid a “double
Vapour Barrier” entrapping diffusing moisture. So design decisions are linked to insulation type
and placement.

B) Integrated Continuous Insulation/Vapour Barrier/Air Barrier/Water Resistive Barrier:
Given the importance of insulation to design of the integrated Water Resistive Barrier/Air
Barrier, a number of designers are utilizing spray foam on the exterior as a Continuous
Insulation as well as Air Barrier/Water Resistive Barrier. This is an application where only
Medium Density Spray Foam (i.e. not Low Density) is appropriate. As previously indicated, at
thicknesses over 38mm (1 ½”) it can also be a Vapour Barrier as well.

The fact that designers are relying on one material to provide 4 barriers in a wall assembly
suggests careful thought has to be given on how this material is detailed and applied. Also, a
number of other materials such as sealants, transition membranes, mechanical termination strips
e tc. would be required to successfully implement a proper solution.

Other systems are also entering the market including board insulation products with taped/sealed
edges, and other details similar to medium density spray foam. These have the advantage of
more precisely controlling the thickness of the insulated layer such that claddings can be directly
applied over the surfaces of the insulated layer. However, the fact that the design is reliant on
tapes and sealants inaccessibly located towards the wall exterior, yet concealed within the
cladding of wall assemblies, raises questions about long term durability and performance.

4. Other Integrated Approaches:
If one is willing to deviate from traditional cavity wall and staged wall construction, a number
of integrated design options exist including:

- Exterior Insulation Finish Systems
- Structurally Insulated Panel Systems
- Curtain Wall Systems

The idea of integrating design functions creates unique challenges specific to each approach.

Redundancy
Many designers like the idea of redundancy for some of the important aspects of their barrier designs. Ideas
like redundant air barriers (e.g. primary air barrier, secondary weather barrier) have already been suggested.
In general, redundancy benefits a design unless:

1. Temperature and vapour pressure gradients between the barriers that create the possibility of
concealed condensation.
2. Layering or detailing prevents drainage.
3. There are compatibility issues between materials/systems.

However,
1. Computer programs such as WUFI can be used to give insight into transient phenomena such
as condensation that may not be readily seen.
2. Mock-ups can be used to solve complex detailing issues.
3. Most material suppliers can give insight as to what materials are compatible with theirs.

The design process is indeed getting more complex as Codes and Standards become more detailed as to
design intent. More elegant solutions are possible as designers gain more insight into the attributes of some
of the key design choices at their disposal.