

Air Barriers: Walls Meet Roofs

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Abstract:

This paper briefly reviews what an air barrier is and why it is needed, the design influences on and the functional requirements of air barriers, and then documents through case study format the ways to achieve continuity between walls and roofs. The basic environmental influences on the enclosure managed by air barriers in buildings are the air pressures on the building enclosure. The air barrier system provides the air-tightness of the building enclosure by absorbing the air pressures on the building enclosure and transferring those forces without displacement or rupture to other building enclosure systems and finally to the building's structural frame. The air barrier must continue to perform its functions for the intended service life of the enclosure assembly. A case study, the Worcester Trial Court building in Worcester, MA, designed by Shepley Bulfinch Richardson and Abbott, Architects, with Wiss, Janney, Elstner Associates, Inc, Engineers, Architects and Material Scientists, acting as Roof Consultants providing quality assurance during the construction phase, will be used as a case study to demonstrate continuity of air barriers, specifically the continuity between walls and roofs.

Benefits of Air Barriers:

Continuous air barriers provide the pressure boundary that separates the interior environment from the exterior, including below grade components of the enclosure. Controlling infiltration and exfiltration enables the HVAC system to perform as designed without disruption, enhances human comfort, saves energy, controls condensation, and reduce the likelihood of pollutant entry into buildings and the migration of pollutants within buildings. They improve the wind performance of certain roof systems¹, and are an essential component of high-performance building enclosures² for buildings that are fully heated and/or conditioned.

The four basic requirements of air barriers are:

- Air impermeability
- Continuity
- Structural support
- Durability

Air Impermeability:

Air barriers are composed of materials that are air impermeable to a great degree. Materials that have an air permeance of 0.004 cfm / ft² at 1.57 psf (0.02 L/s. m² at 75 Pa) or less when tested to ASTM E 2178 meet the basic requirement for maximum allowable air permeance.

Continuity:

Materials are assembled together with tapes and sealants, or applied as self-adhering sheets, or fluid-applied to form opaque assemblies. Assemblies should meet a maximum air permeance of $0.04 \text{ cfm} / \text{ft}^2 @ 1.57 \text{ psf}$ ($0.2 \text{ L/s.m}^2 @ 75 \text{ Pa}$) when tested to ASTM E2357.

Assemblies are connected together with flexible air impermeable joints to form an air barrier system. An air barrier system (the entire building enclosure, including below grade components) should meet air permeance criteria of $0.4 \text{ cfm} / \text{ft}^2$ at 1.57 psf ($2 \text{ L/s.m}^2 @ 75 \text{ Pa}$) of the thermal envelope pressure boundary when tested to ASTM E 779 or similar test.

Structural performance:

The air barrier must be rigidly supported to transfer the design wind loads (negative and positive) safely without tearing, widening of holes at fasteners, or displacement against adjacent materials.

Durability:

Since the air barrier is often inaccessible within the envelope layers, it needs to last as long as the intended service life of the assembly.

Air Leakage through the envelope:

Unlike the moisture transport mechanism of diffusion, air pressure differentials can transport hundreds of times more water vapor through air leaks in the envelope over the same period of time. Air leaks can be one of three different modes:

- Diffuse flow, such as flow through air permeable materials
- Orifice flow, such as flow through a crack between the window frame and the wall.
- Channel flow: Channel flow is by far the most serious from a condensation standpoint. Air moving through the building envelope materials can encounter a dewpoint temperature and can condense within the envelope in a concentrated manner, wherever those air leaks may be (fig.1).

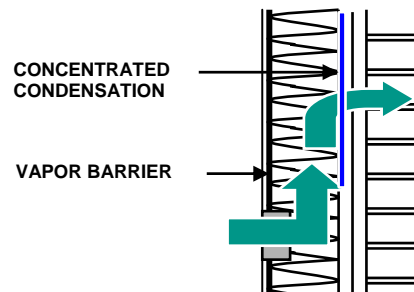


Figure 1

Air pressures on buildings:

There are three major air pressures on buildings that cause infiltration and exfiltration:

- Wind Pressure
- Stack Pressure

- HVAC Fan Pressure

Wind Pressure

Wind pressure tends to pressurize a building positively on the façade it is hitting, and as the wind goes around the corner of the building it cavitates and speeds up considerably, creating especially strong negative pressure at the corners, and less strong negative pressure on the rest of the building walls and roof (Fig 2, Fig 3.)

Stack Pressure

Stack Pressure is caused by a difference in atmospheric pressure at the top and bottom of a building due to the difference in temperature, and therefore the weight of the columns of air indoors vs. outdoors in the winter, and reversed for buildings in hot climates with air conditioning indoors. Stack effect in heating climates can cause infiltration of air at the bottom of the building and exfiltration at the top, as seen in Fig. 4. In Cooling climates, the reverse happens.

Fan Pressure

Fan Pressure is caused by HVAC system pressurization, usually positively, which is fine in cooling climates but can cause incremental envelope problems to wind and stack pressures in heating climates. HVAC engineers tend to do this to reduce infiltration, and with it pollution and disruption of the HVAC system design pressures.

Figure 5 shows each of these pressures on its own, and a combined diagram.

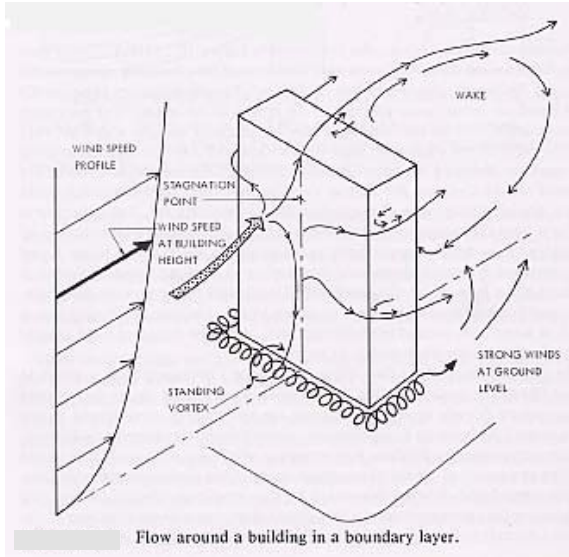


Figure 2³

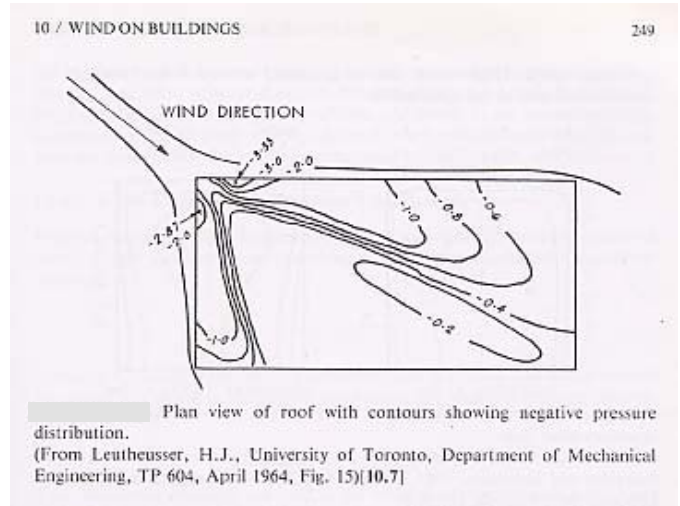


Figure 3

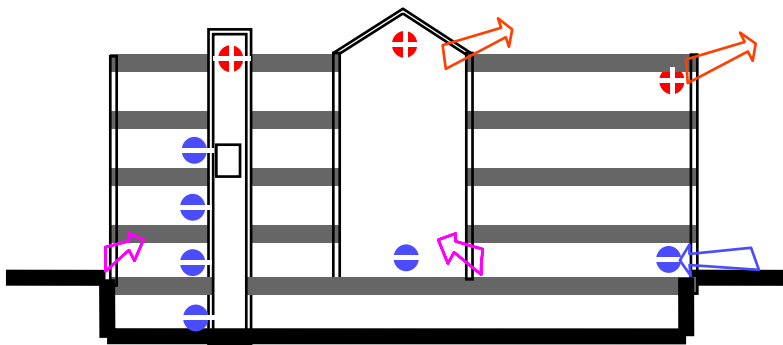


Figure 4

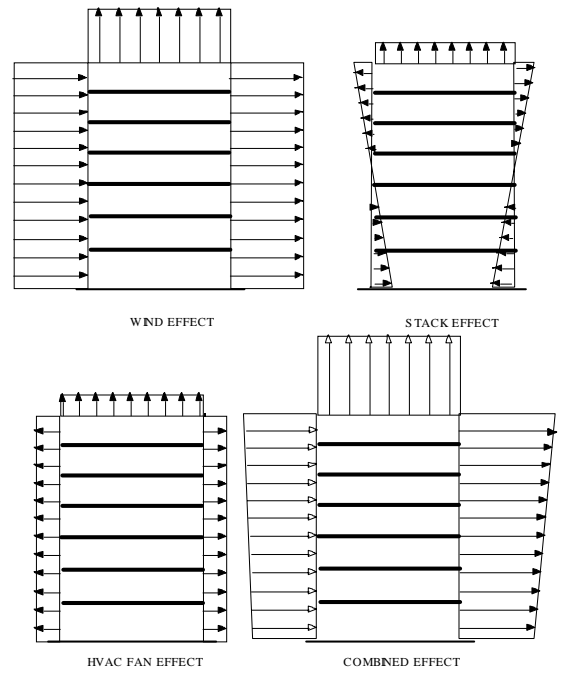


Figure 5

Code Requirements:

Massachusetts, since 2001 has had air barrier requirements in the building code⁴.

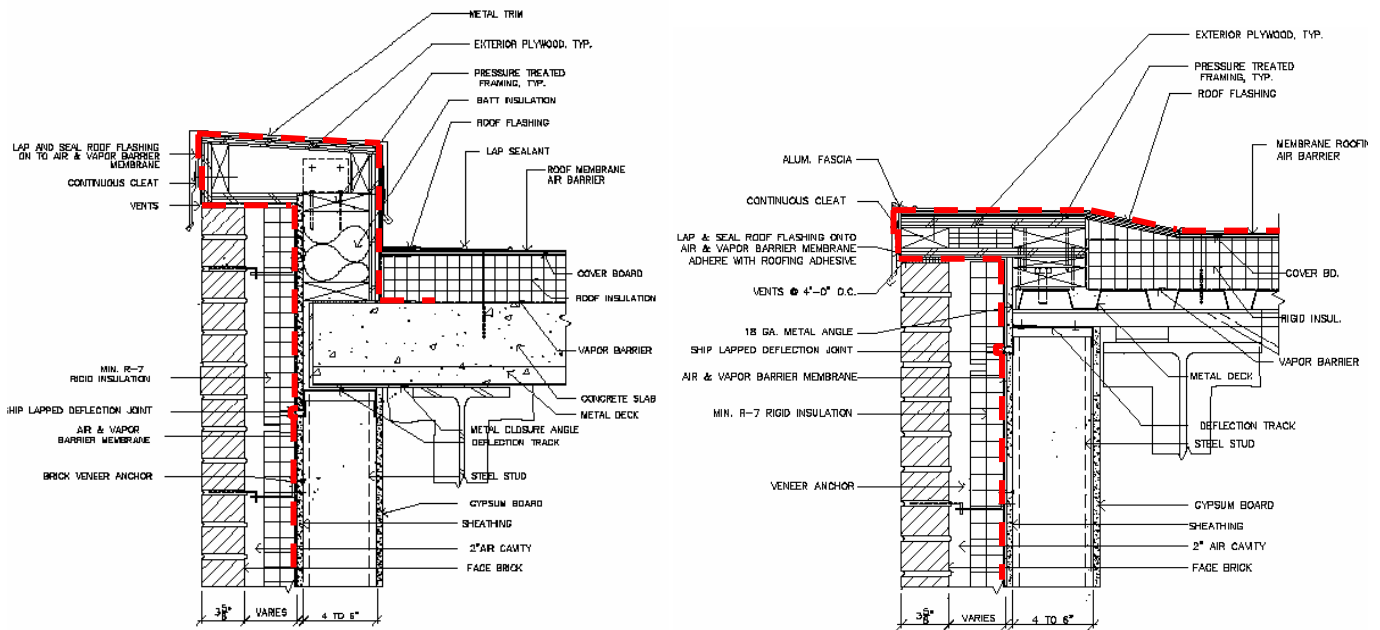
Those air barrier code requirements are summarized as follows:

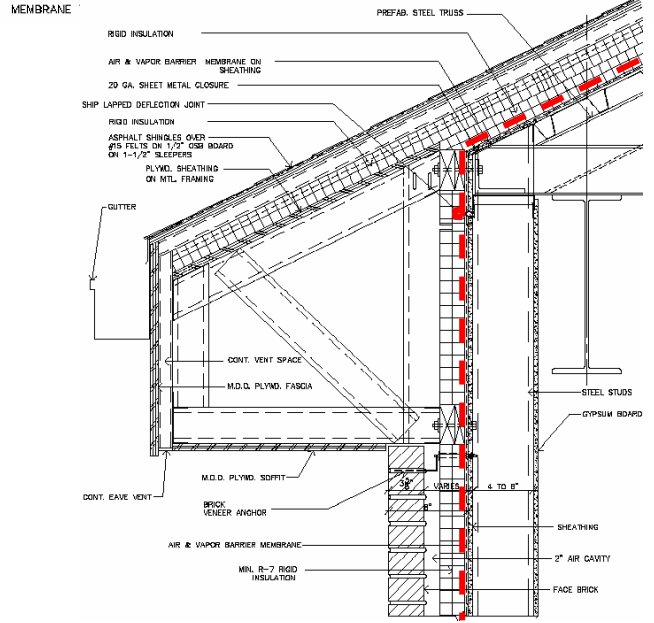
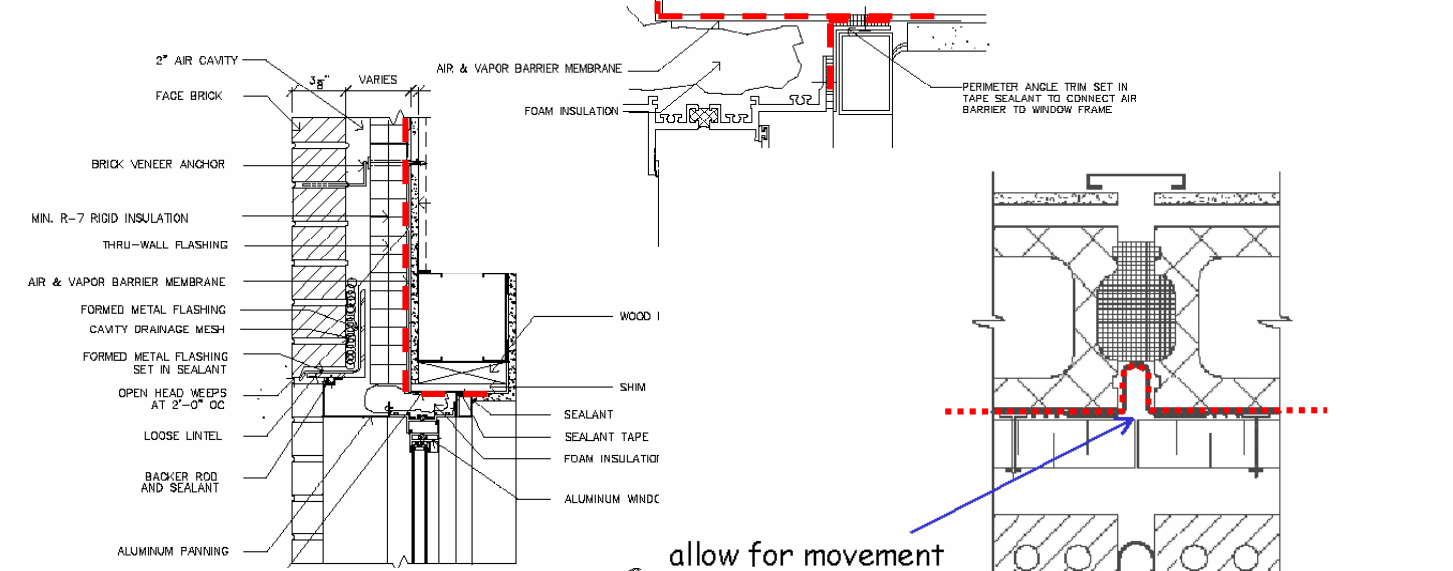
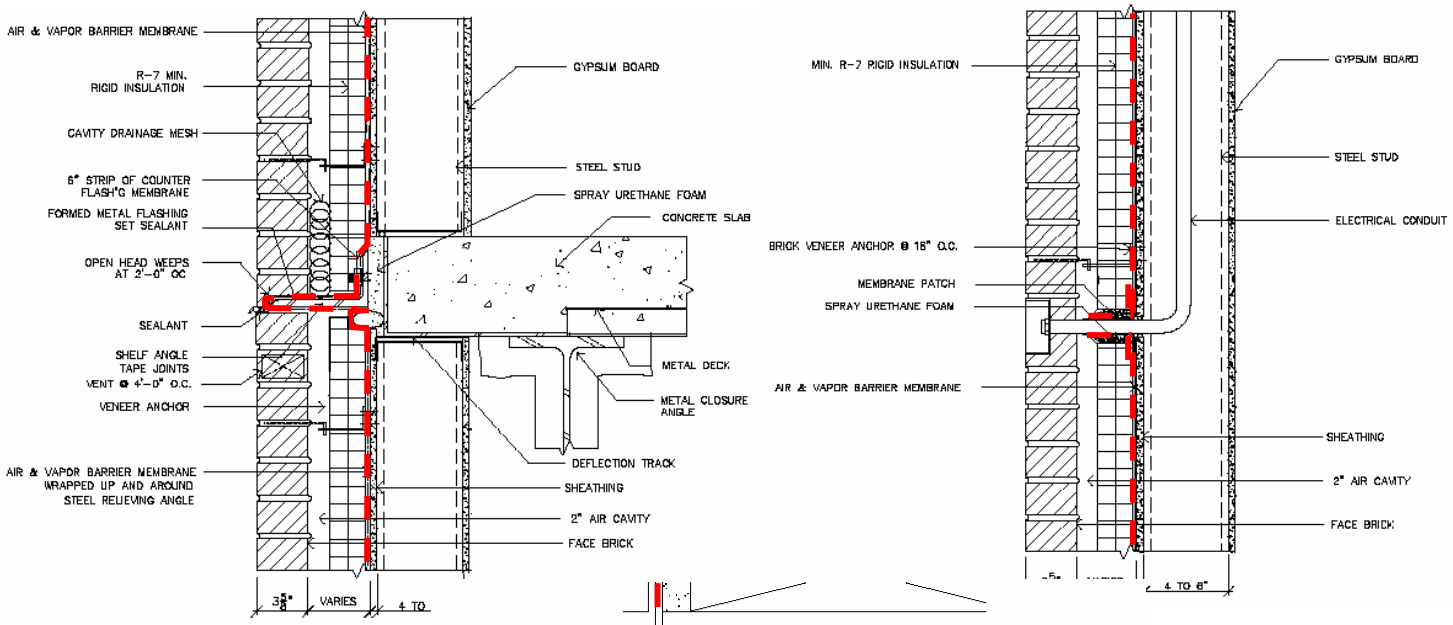
- A continuous plane of air-tightness must be traced throughout the building envelope with all moving joints made flexible and air-tight
- The air barrier material in a system must have an air permeance not to exceed 0.004 cfm / sf at 0.3" wg (1.57 psf) [0.02 L/s.m² @ 75 Pa]
- The air barrier "system" must be able to withstand the maximum positive and negative air pressure to be placed on the building and transfer the load to the structure
- The air barrier must not displace under load or displace adjacent materials.
- The air barrier material used must be durable or maintainable
- Connections between roof air barrier, wall air barrier, window frames, door frames foundations, floors over crawlspaces, and across building joints must be flexible to withstand thermal, seismic, moisture and creep building movements; the joint must support the same air pressures as the air barrier material without displacement.
- Penetrations through the air barrier must be made airtight
- Provide an air barrier between spaces that have significantly different temperature and/or humidity requirements.
- Lighting fixtures are required to be airtight when installed through the air barrier
- To control stack pressure transfer to the envelope, stairwells, shafts, chutes & elevator lobbies must be decoupled from the floors they serve by providing doors that meet air leakage criteria for exterior doors, or the doors must be gasketed
- Functional penetrations through the envelope that are normally inoperative, such as elevator shaft louvers and atrium smoke exhaust systems must be dampered with airtight motorized dampers connected to the fire alarm system to open on call and fail in the open position.

Of course there are many products formulated to qualify as air barriers materials. Some of these, as well as specifications, technical help, etc. can be found at <http://www.airbarrier.org>

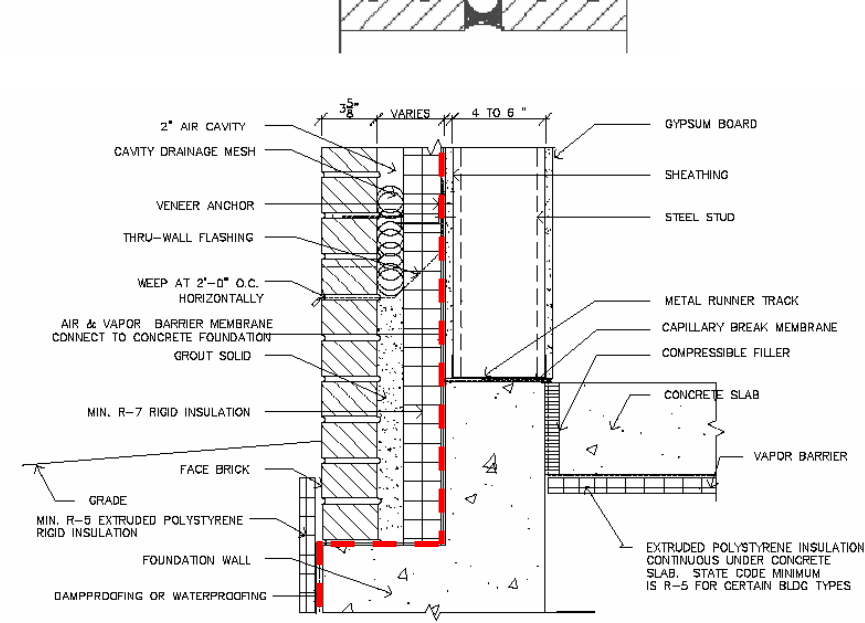
Location of the air barrier:

The air barrier, unlike the vapor retarder (since its function is to stop air, not control diffusion) can be located anywhere in the envelope assembly. It can be on the warm in winter side, in which case it can also control diffusion and would be a low-perm vapor barrier material. In that case, it is called an air/vapor barrier. Or it can be on the cold side of the wall, in which case it should be vapor permeable (5-10 perms or greater). Vapor retarders, when used, must always be placed on the high vapor pressure side of the insulation⁵. Follows are a few examples of air barrier system design continuity and structural integrity, taken from the reference details published by Massachusetts at <http://www.state.ma.us/bbrs/energy.htm>





allow for movement



Air barriers on the exterior side: Air barriers that are subject to thermal changes are more difficult to keep airtight for the life of the building, because of the integrity of the jointing tape or sealant over a long period of time. The best tapes for non-moving joints are:

- Silicone (extruded) bedded in wet silicone.
- Wet silicone reinforced with fiberglass mesh.
- Other fluid-applied elastomeric air barriers products, reinforced with fiberglass mesh.
- Self-adhering modified bitumen with surface properly primed.

In short, if you can avoid the above, the building will be more durable longer.

Roof air barriers:

The roof membrane can be considered an air barrier since it is designed to withstand wind loads, if it is fully adhered. Mechanically fastened and ballasted roof systems, because they displace and momentarily billow or pump building air into the system, do not perform the required functions of containing air without displacement. In those cases, another air barrier must be provided in the system. Either a self-adhering modified bitumen air and vapor barrier on the inboard side of the roof system (interior conditions and weather-dependent), or 2 layers of asphalt felt mopped down with asphalt, or similar air barrier. Those layers must be designed to withstand design wind loads without displacement. One of the vital concepts, that of continuity with the wall air barrier, is paramount. A pre-construction conference on roofing must include a discussion of the connection between the roof air barrier and the wall air barrier, and the sequence of making that air-tight and flexible connection. It is also important to ensure compatibility between materials coming together. Penetrations into roof systems such as ducts, vents, roof drains, etc. must be dealt with perhaps using spray polyurethane foam or other sealant, or membranes to air-tighten those penetrations at the selected air barrier layer.

Case Study:

Worcester Trial Court, Worcester, MA

Architect: Shepley Bulfinch Richardson and Abbott

The Worcester Trial Court in Worcester Massachusetts is designed to house 27 courtrooms for Superior, District, Juvenile, Housing, Probate and Family Courts. There are five floors and penthouse, totaling 427,000 square feet. It is the first CM at risk project undertaken by the Division of Capital Asset Management in the Commonwealth of Massachusetts.

Worcester Trial Court is a steel framed structure with concrete floors, brick, cast stone, EIFS and glass walls with a series of high sloped and low slope roof areas. The high sloped roofs are standing seam lead coated copper panels with cornices, soffits and internal gutters. The low sloped roof areas consist of three roof types, a TPO fully adhered membrane, Built-up roofing membrane installed in hot asphalt and a modified bitumen roofing system in cold adhesive. These roofs are terminated at metal edges, parapets and rising walls with internal drains and scuppers. All of the roofs incorporate high levels of insulation, six inches of extruded polystyrene insulation or polyisocyanurate insulation.

We will review photos from the construction of the roofing systems with attention to the terminations and integration with the air barrier systems. References will be made to the construction details. Locations examined will be the wall roof intersection at the parapet walls, the roof edge and the rising wall locations. The sloped roof to the skylight construction will be shown. Intersection of the air barrier wall against the underside of the metal deck will be examined to illustrate modifications required for field conditions. The following are sample photographs of the conditions during construction.



Figure 1. The Worcester Trial Court under construction with finished metal roofing in place

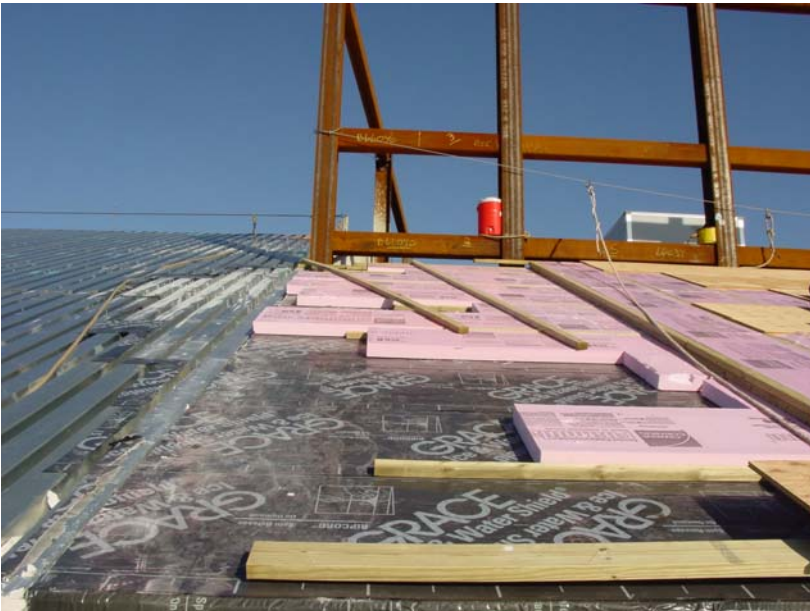


Figure 2. Structure, vapor retarder, insulation and decking under construction

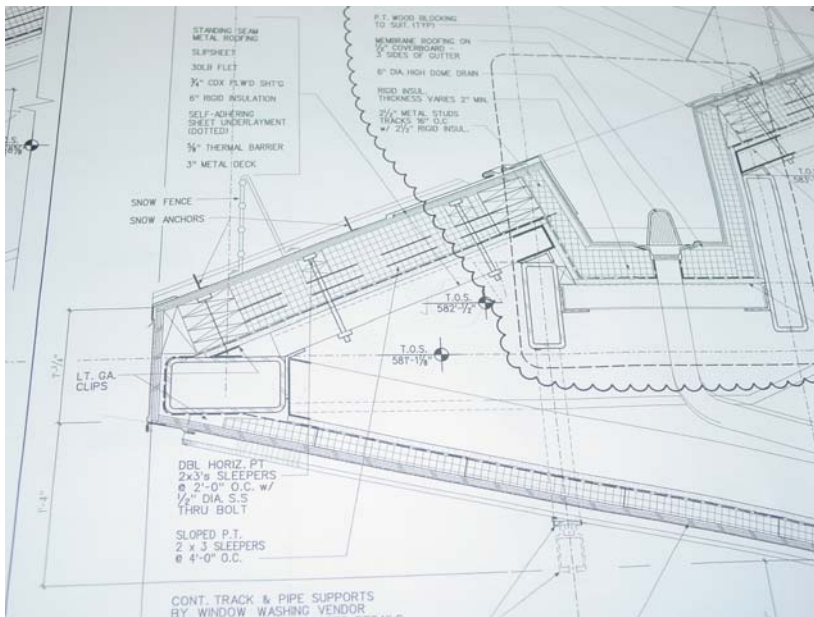


Figure 3. Detail of sloped roof edge.

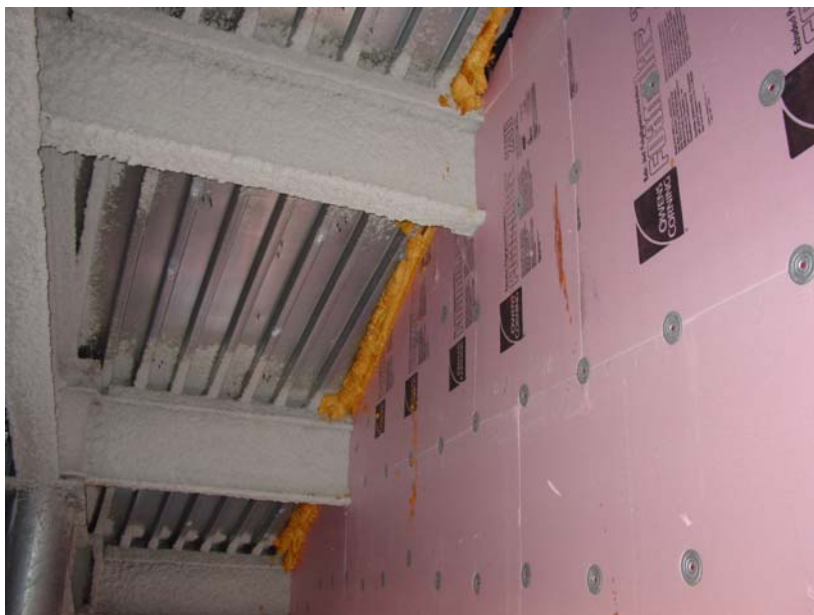


Figure 4. Modified detail of diagonal wall meeting underside of metal deck. Note foam filling flutes of deck.



Figure 5. Air barrier on wall at roof edge, extends under cornice.

Conclusion:

An air barrier *system* is an essential component of the building envelope of fully heated and/or conditioned buildings, so that those buildings' mechanical systems can perform as intended, and the enclosure be durable and sustainable. Building codes should require air barriers systems, and building designers and builders should be aware of the consequences of ignoring building air-tightness.

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William Waterston, AIA, RRC is a Senior Associate and Project Manager for Wiss, Janney, Elstner Associates in their Boston area office. He has experience in project management, construction document preparation, and specification writing. With over 15 years of specific experience in roofing products and systems, his knowledge of modified and built-up roofing systems is extensive. Mr. Waterston's work at WJE includes the investigation, evaluation, and design of roofing and waterproofing systems. Bill is an active member of the Building Envelope Committee of the Boston Society of Architects.

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- ⁴ 780 CMR 1304.3
- ⁵ ASHRAE Handbook of Fundamentals 2005