NIST reports that up to 43% of heating and 26% of cooling energy used by buildings is added due to infiltration.

“Predicted potential annual heating and energy cost savings for these (commercial) buildings ranged from 2% to 36% with the largest savings occurring in the heating-dominated climates of Minneapolis and Bismark.”

Steven J. Emmerich, Timothy P. McDowell and Wangdy Anis
“Investigation of the impact of Commercial Building Envelope Air Tightness on HVAC Energy Use”

Controlling Air Flow

Brief History
• First work in 1940s at University of Minnesota - resulted in building paper used as “drainage plane” (i.e., breathable membrane now known as a “water-resistant barrier”) • Increased levels of insulation started being used in 1960s, resulting in moisture in walls • As a result, vapor retarders incorporated starting in 1970s, but still had failures • Discussions of “airtightness” started in 1980s and with initial implementations in 1990s in Canada (NBCC) • Original air barrier – polyethylene, then ½ inch drywall • In 2001, an “air barrier” became a requirement in the Massachusetts building code

Air infiltration & exfiltration
• major cause of rain penetration • uncontrolled, untreated infiltrating air • waste energy, increased condensation & envelope deterioration • limits transfer of noise, odor, fire and smoke • disrupts ability to control indoor humidity • disrupts interior HVAC design pressures (comfort, infection control and IAQ problems)

The Air Barrier:

• Below Grade Waterproofing
• Waterproofing at Grade &/or elevated decks
• Exterior Wall
• Roof

Air / Moisture Barrier concept:
Provide a continuous air barrier assembly that has an air leakage not to exceed 0.040 cubic feet per square foot per minute under a pressure differential of 0.13 in. water (0.37 pounds per square foot) or 0.082 cubic meters per square meter per second under a pressure differential of 1.57 pounds per square foot (75 Pascals). Tested in accordance with ASTM E 2357. Assembly shall perform as a fluid drainage plane flashed to discharge condensation or water penetration to the exterior. Assembly shall accommodate movements of building materials by providing expansion and control joints. Assembly shall accommodate movement of building materials at such locations, changes in substrate and perimeter conditions.

Assembly shall be capable of withstanding positive and negative design wind, fan and stack pressures on the envelope without damage or displacement, and shall transfer the load to the structure.

Assembly shall not displace adjacent materials under full load.

Assembly shall be joined in an air tight and flexible manner to the air barrier material of adjacent assemblies, allowing for the relative movement of assemblies due to thermal and moisture variations.

ABAA, Specification 07261 – Air Barrier, Part 1.2, B Performance

What is an air barrier?
• Principal material identified in a building assembly as being the primary plane of air tightness

A continuous plane of air-tightness must be traced throughout the building envelope with all joints made air-tight
Assembly shall be continuous over the entire building enclosure, joined in an airtight and flexible manner to the air barrier material of adjacent assemblies, allowing for the relative movement of assemblies due to thermal and moisture variations and creep, and anticipated seismic movement.

Assembly shall be capable of withstanding forces of positive and negative combined design wind, fan and stack pressures on the envelope without damage or displacement, and shall transfer the load to the structure. Assembly shall not displace adjacent materials under full load.

**Potential Approaches to Air Barrier:**
- Interior using gypsum board or plastic sheeting
- Exterior using sheathing
- Exterior using an air barrier assembly

**Definition:**
- **Material:** Air leakage of the air barrier may not exceed 0.02 L/(m²·s) @ 75 Pa (0.004 cfm of air per ft²) at a pressure difference of 0.3 inches of water 1.57 psf) per ASTM E2178 (which equates to the air permeance of ½ inch thick drywall)
- **Assembly:** Air leakage of the air barrier assembly may not exceed 0.2L/(s·m²) @ 75Pa. (0.04 cfm/ft² @ 1.57 psf) test combines the primary air barrier material with supporting air barrier accessories such as transition membranes and sealants to form a complete air barrier assembly per ASTM E2357

**Misconceptions:**
- It’s not necessarily a vapor barrier...the terms are not interchangeable!
- Air barrier will control the passage of air from/between spaces...more than one?

**Standard:**
- ASTM E2178 (CAN/ULC-S741)
- ASTM E2357 (CAN/ULC-S742)

**Code Compliance:**
- Air barrier compliance option: IECC 2012, C402.2.2.3 (achieve 0.1)
- Whole building: the completed building shall be tested and the air leakage rate of the building envelope shall not exceed 2.0L/(s·m²) @ 75Pa (0.40 cfm/ft² @ 1.57 psf) per ASTM E779 or equivalent


**Exterior Air Barrier Assembly:**
- The air barrier can be located anywhere in the enclosure assembly.
- On the warm side, it can be a combination air and vapor barrier
- If it is located on the cold side, it should have a permeance at least 10 times the permeance of the vapor barrier

**What are Air Barrier Materials?**
- Modified bitumen membranes
- Drywall
- Poured concrete
- Glass
- Metal
- Polyethylene film
- Sprayed polyurethane foam
- Extruded polystyrene
- Some non-perforated building wraps
- Fluid applied one and two component materials

**What are NOT Air Barrier Materials?**
- Concrete Masonry Units (CMU)
- Expanded polystyrene foam
- Building paper
- Open cell foam
- Some housewraps
- Perlite board
- Fiberboard
- Glass fiber rigid board
- Cellulose insulation
- Most damp-proofings
PENCIL TEST – the continuity of barriers

ASHRAE Zones

- Gradient of pressure
  - air
  - vapor
- Humidity
- Temperature

solutions

permeability

choice is informed by material environment function

options

- Vapor Permeable: >10 Perms
  - The higher the Perms, the higher the vapor permeance, and the higher the diffusion
- Vapor Retarders: < 10 Perms
  - Class I: 0.1 Perm or less
  - Class II: 0.1 < Perms ≤ 1.0
  - Class III: 1.0 < Perms ≤ 10

Many air barrier materials are non-permeable to vapors and may be unintended vapor barriers
options

Self-Adhered Membrane (Permeable)

options

Self-Adhered Membrane (Impermeable)

options

Fluid Applied Membrane

options

Pre-Applied Fluid Membrane

options

Integral Water Repellant & Fiberglass Facer

options

Spray Polyurethane Foam (SPF)
Below Grade Waterproofing

- Restricts the passage of water through an element even in the presence of hydrostatic pressure.
- Waterproofing materials must be impervious to water and have a low permeability. Can be used in combination with a below slab vapor barrier.
- May be adhered (fully bonded), or partially adhered or loose laid (unbonded)
  - Sheet HDPE (High Density Polyethylene) forms integral bond with concrete
  - Sheet Bentonite membrane forms impermeable layer in contact with moisture and under compression
  - Sheet rubberized asphalt membrane adhered to free standing walls
- Typical designs:
  - Positive side – Pre-applied or post applied to structure
  - Wall Only design
  - Perimeter drainage systems vs. underslab drainage
  - Negative side – Applied to interior of structure

Below Grade Waterproofing System design:

- Positive Side Waterproofing, such as “bathtub” design.
  - Must resist hydrostatic pressure
- Wall Only Waterproofing, with perimeter &/or under slab drainage & vapor barrier

Below Grade Waterproofing

- Restricts the passage of water through an element even in the presence of hydrostatic pressure.
- Waterproofing materials must be impervious to water and have a low permeability.
- May be adhered (fully bonded), or partially adhered or loose laid (unbonded)
  - Fluid applied
  - Sheet membrane
  - Traffic coating – not considered waterproofing
- Typical locations include:
  - Plaza
  - Terrace
  - Balcony
  - Planters
  - Water Feature / Fountains

Waterproofing

- Bonded systems minimize concern of lateral migration of water. These systems localize leaks and confine defects to small areas. They are fabricated in the field.
- Unbonded materials easily span cracks and construction joints. These systems allow lateral migration of water at any defective area. They are placed/assembled in the field.
Waterproofing Materials
- Conventional “built-up” membranes
- Bentonite
- Hot-applied modified asphalt
- Cold-applied elastomeric
- Elastomeric sheet goods, EPDM, PVC
- Modified bituminous membranes

Built-Up Membranes
Advantages
- Multiple plies create redundancy
- Proven track record of performance
Disadvantages
- Emissions control
- Non-elastic

Fluid-applied Systems
Advantages
- Good adhesion to concrete surfaces
- Proven track record of performance
Disadvantages
- Airborne emissions control
- Sensitive to moisture during installation
- Restricted by Fire Code in some areas

Elastomeric Sheet Systems
Advantages
- Installation speed
- Less sensitive to substrate moisture
- Readily accommodate substrate movement
Disadvantages
- Single line of defense
- Sensitive to puncture damage
- Minor workmanship defects are problematic

Modified Bituminous Systems
- Elastomeric characteristics
- Include both SBS and APP chemical formulations and variable scrim reinforcement choices
- Attachment methods include self-adhered sheets, adhesives, heat-welding, and hot-mop applications

Additional System Components
Protection Board
- Protect membrane from construction traffic
- Asphalt-based lamimates
- Coordinate installation with flood testing

Drainage Course
- Prefabricated drainage mats
- Stone, aggregate, or pea gravel

Thermal Insulation
Installed above membrane:
- Regulates temperature of membrane
- Additional layer of protection
- Extruded polystyrene board
  - Compressive strength
  - Moisture resistance
Exterior Wall Assemblies:

The vertical components assembled to create the walls of the building envelope:

- Drainage Wall Systems
- Pressure equalized rain-screens
- Barrier Wall Systems
- Skylight and Glazed Canopies

Drainage Wall Systems

- A wall cladding system that is comprised of a primary drainage plane and an exterior weathering plane, i.e. masonry veneer
- Typically non-load bearing
- Flashings control and direct moisture to exterior
- Resists water infiltration by deflection and drainage cavity
- Commonly “design-bid-build” procurement method

Drainage Wall Systems

Air/Moisture barrier & Drainage Plane
Continuous insulation
Cladding Flashing

Contemporary Wall Systems

Pressure Equalized rainscreen walls
- Typically Unitized or “stick-built” Curtain wall
- Non-load bearing, engineered
- Resists water infiltration by equalizing differential air pressures across the depth of the wall assembly, often compartmentalized
- Typical complex designs developed with assistance from specialty contractor or consultant

Drainage Wall & Drying

- Drying of Assembly
  - Orientation & Exposure
  - Level of saturation
  - Repetition of wetting cycles
    - Indoor/Outdoor
  - Temperature/Humidity
  - Physical Properties Wall Components
  - Color of Materials
  - Vapor Permeance
  - Air movement
Contemporary Wall Systems

Engineered attachments
Accommodates own movement
Unitized curtain wall

Precast Concrete panels with punch openings

Contemporary Wall Systems

Barrier walls
- Curtain wall, precast concrete, thin stone, metal panels, composite panels
- Non-load bearing
- Resists water infiltration by deflection only
- Often reliant upon sealant to achieve greater transparency

Engineered system
Relies upon sealant at joints between panels

Contemporary Wall Systems

Sealant profile
width : depth
2 : 1

Backer Rod
width : depth

Perform field adhesion tests

Fenestration

Window: An opening constructed in a wall or roof to admit light or air to an enclosure, usually framed and glazed with glass mounted to permit opening and closing. (From the old Norse word "vindauga", which is formed from "vinder", wind, and "auga", eye. Therefore a window is an "eye for the wind").
- T-105.5 S. 2.8.4.7.2

Storefront: A glazed opening at lower floors, constructed to withstand excessive use and enhanced visibility. Typically inside glazed.

Window wall: "A type of metal curtain wall installed between floors or between floor and roof and typically composed of vertical and horizontal framing members, containing operable sash or ventilators, fixed lites or opaque panels or any combination thereof".
- AAMA CW-DG-1-96

Curtain wall: Any building wall of any materials which carries no superimposed vertical loads, i.e., any "non-load bearing" wall.
- AAMA CW-DG-1-96
DRAINAGE / RAIN SCREEN

- Gasket or sealant bead
- Weep hole
- Glass or solid infill panel
- Internal seals required in glazing channel
- Glazing channel designed to collect and drain any water that penetrates past exterior back to outside

Performance Characteristic

PRESSURE-EQUALIZED

Greater Outdoor Pressure
Lesser Indoor Pressure

Air Space
Air Seal

Performance Characteristic

curtain wall

Any exterior building wall, of any material, which carries no superimposed vertical loads, i.e., any non-bearing wall

Types of glazed curtain wall:
- stick built – field fabricated (screw spline or shear block)
- unitized – shop fabricated and field erected
- point supported glass – field erected

Typically exterior glazed.

Resists water infiltration by equalizing differential air pressures across the depth of the wall assembly, often compartmentalized.

Typically complex designs developed with assistance from specialty contractor or consultant

metal curtain wall:

“An exterior curtain wall which may consist entirely or principally of metal, or may be a combination of metal, glass and other surfacing materials supported by or within a metal framework.”

“AAMA CW-DG-1-96”

“Stick” built or “knock-down”

- inside glazed
- exterior glazed

Typical Curtain Wall Components (Stick System)

1. Anchors – WL & DL
2. Mullion
3. Horizontal rail
4. Spandrel panel
5. Vision glass

“AAMA CW-DG-1-96”

End Dam Seal at Mullion/Rail Intersection
Isometric of Pressure Plate System

“unitized”
- shop fabricated
- field erected

Engineered attachments

Accommodates own movement
Window wall: "A type of metal curtain wall installed between floors or between floor and roof and typically composed of vertical and horizontal framing members, containing operable sash or ventilators, fixed lites or opaque panels or any combination thereof."

Traditional Wall Systems

Mass walls
- Masonry, Stone, Terra Cotta
- Load bearing
- Multiple wythe with solid collar joints
- Resists water infiltration by deflection and absorption

Traditional Wall Systems

Roof Systems

• Low Slope Designs <2:12
  - Single-ply
  - Conventional B.U.R.

• Steep Slope Designs >3:12
  - Shingled Materials
  - Standing seam metal
Water Shed
Gravity Allows Quick Water Runoff
Underlayment Required

- Shingles
  - Bituminous
  - Synthetic
- Slate
- Tile
- Cedar Shakes
- Metal

Steep Slope

- Increased reliance on referenced standards
  - FMG / UL
  - Manufacturer’s Details (establishes a base line standard)
- Enhanced awareness of perimeter edge behavior
- Sustainability – Alternative shingle materials & “cool” metal coatings

Standing Seam Metal Roofing

Shingle & Tile Roofing

Water Barriers
Water Infiltration Prevented by Water Tight Membrane

- Built-up
- Single Ply
- Metal
- Protected Membrane Assembly
- Sprayed Polyurethane Foam

Low-Slope (Conventional Materials)

- Popularity in the design community remains strong
- Proven track record of success
- Attractive installed cost parameters
- Inherent redundancy in a field manufactured membrane
- Exposed Membrane Assembly
- Protected Membrane Assembly

**Exposed Assembly**

- New Construction
- Recovery

**Protected Membrane Assembly (PMA)**

**Built-Up Roofing**

- Smooth Surfaced
- Gravel / Slag Surfaced
- Reflective Surfaced
  - Aluminum
  - Cool Roof Coatings
- Asphalt
  - Hot applied
    - Types I thru IV
  - Cold applied
- Coal tar pitch

**Hot Applied - Gravel Surfaced**

**Hot Applied - Granule Surfaced**
Common Problems – Blister Formation

Common Problems - Poor Q/A during installation

Common Problems – Flashing Defects

Common Problems – Flashing Defects

Modified Bitumen Roof

Modified Bitumen
APP (Atactic Polypropylene)
SBS (Styrene Bituadiene Styrene)
Modified Bitumen Disadvantages

Modified Bitumen

Under-torched
Over-torched

Single Ply Membrane Systems

- Thermoset
  - EPDM
- Thermoplastic
  - PVC, TPO, KEE & others

Single Ply Configurations

- Adhered
- Mechanically fastened
- Ballasted

Single-ply designs

Adhered

- Substrate important - cover board required
- Solvent or water based adhesive
- Spray foam adhesive, proprietary cold adhesive, asphalt mopping adhesive
- Moisture diminishes adhesion
Adhered

Adhered

Mechanically Fastened

- Reinforced membrane required
- Wind uplift engineering required
- Air barriers essential with steel decks
- Seam integrity must be perfect

Mechanically Fastened

Mechanically Fastened

Mechanically Fastened

Mechanically Fastened
Mechanically Fastened

Ballasted

- Difficult to maintain and repair
- Ballast requirements often conflict with structural deck load capabilities
- Wind uplift engineering required

Single Ply Issues

Perimeter Restraint Requirements
Green Roofs

Intensive (typ. 8” to 4’ growth media) and extensive (typ. Min. 2”, max. 7” growth media) green roof. Refer to FLL’s “Guideline for the Planning, Execution and Upkeep of Green Roof Sites”, 2002, www.fll.de

Verify mutual compatibility of roofing and plantings, and provide protection from root penetration into the roofing membrane.

PMA Configurations

- Membrane adhered to deck
- Membrane loose laid over deck
PMA Advantages

• UV & temperature protection
• Low maintenance if properly installed
• Good use for high rise buildings
• Tolerant of wet conditions

PMA Disadvantages

• Higher Initial Cost
• Difficult to locate membrane defects
• Difficult to repair

Spray Polyurethane Foam (SPF)

SPF Defects

“If knowledge can create problems, it is not through ignorance that we can solve them.”

Isaac Asimov