Background

What Separation Roles?

- Water control layer
  - A.k.a. “drainage plane,” “water resistive barrier,” “weather resistive barrier,” WRB
  - Housewraps, tar paper… more modern options

- Air control layer
  - A.k.a. “air barrier”
  - Drywall, sheathing, spray foam… and continuity

- Vapor control layer
  - A.k.a. “vapor barrier”—poly, Kraft paper, latex paint

- Thermal control layer
  - Insulation (fluffy in stud bays, continuous on outside)
Climate Zone Map (BSC)

Climate Zone Map (DOE)

Water Control Layer

Housewrap (Residential)
Housewrap (Commercial)

Billowing Housewrap
- Is it really an air barrier (network airflow)?
- Potential damage from cyclic loading

Vapor-Impermeable Adhered Membrane
- Cold climate + no exterior insulation = danger

Vapor-Permeable Adhered Membrane
Self-Adhered Membranes

- Self-sealing
- Air leakage improvement; no blow-off/billowing
- No ‘hidden path’ water leakage/bypass
- Reverse laps not as critical

Taped Sheathings (WRB Surface)

- Fast dry-in
- Airtightness
- Reliance on adhesive vs. laps? Surface prep
- Rigid foam insulation too

Taped Joints (Foam Sheathing)

- Membrane-type flashing tape at joints
- Horizontals more important than verticals

Fluid-Applied WRBs

- “Housewrap in a can” (GBA Column)
- Continuous water control
- Airtightness
- Can be applied with air gun (paint sub)
- Issues: surface prep, application temperature, substrate condition, etc.
Reverse Lap Termination

- “Termination mastic” at reverse lap condition
Water Control and Drainage Gaps

- Water control layer
- Key is control of hydrostatic pressure
- All about “the gap”

- See “Mind the Gap” and “Hockey Pucks and Hydrostatic Pressure”
Wind Speed vs. Pressures

- ½” of “perched” water ≈ 35 mph wind force

Water Control Layers and Spaces

Strapped Cavities/“Rainscreen Wall”
**Why Rainscreen/Air Gap**

- "Sandwiched" water (surface tension) hangs up
- Staying wet or wet/dry cycling
  - Paint blow off
  - Damage over time

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**Cladding Ventilation**

- Airflow behind cladding dries out both cladding & backup wall
- Brick veneer example
- Why vinyl siding and metal panel cladding work in cold climates

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**Drainage from Lap Sidings**

- Added water between siding & housewrap
- Lap sidings “self draining”
- Window head flashings!

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**Commercial Rainscreen Options**
Shingle Wall Rainscreen/Air Gap

- Mesh style
  (Home Slicker, Keene Building Products)
Windows Flashings
EI\$S & Windows - Oops

Sill Pan Flashings

Backdams and Sloped Sills

Formable Sub-sill Flashing
Window Failure Repair

- Stripped shingles and housewrap
- Windows pulled, re-flashed (fluid-applied window ‘wrap’), and reinstalled
- Fluid-applied WRB
- Added rainscreen mat under shingles

Stucco & Adhered Stone
Stucco on Wood Frame Walls

Stucco Failures (MN, PA)

Stucco-to-Paper Bond
Adhered Stone Veneer
Stone Veneer Rainscreen Options

Wood Moisture Movement

Room for Expansion

Wood.. and Other Things Move...

- Wood will move—let it expand
  - For every 4" width of dry Certi-label Western Cedar shingle material, the product will expand 1/8"
- Wood floors indoors similar
**Wood Framing Shrinkage**

**Expanded PVC Trim**
- PVC trim, painted black, and facing due south
- Fasten like crazy, or add movement joints

**Airflow Control: Why**
- Moisture control
  - air leakage condensation
- Comfort and Health
  - Drafts
  - Odors, particles, gases
- Energy
  - Heat transferred with air
- Sound
- Required by some codes

*If you can’t enclose air, you can’t condition it*
Driving Forces

- 1. Wind Pressures
- 2. Buoyancy (or stack effect)
- 3. HVAC

Wind Flow Patterns

Wind speed increases with height

2. Stack Effect: Cold Weather

- Hot air rises
- Tall Building in Winter = Heavy Balloon
Stack Effect: Cold Weather
- “Perfect” Building equally leaky everywhere
- Neutral Pressure Plane at mid-height

Stack Effect: Warm Weather
- “Perfect” Building equally leaky everywhere
- Neutral Pressure Plane at mid-height

Air Barriers

Air Barrier Systems
- Function: to stop airflow through enclosure
- ABS can be placed anywhere in the enclosure
- Must be strong enough to take wind gusts (code requirement)
- Many materials are air impermeable, but most systems are not airtight
Air Barrier Systems: Requirements

- Continuous
  - primary need, common failure
- Strong
  - designed for full wind load
- Durable
  - critical component - repair, replacement
- Stiff
  - control billowing, pumping
- Air Impermeable
  - (may be vapour permeable)

Poly can be (?) an air and vapour barrier
But
BEWARE when Air Conditioning
Definitely not in South
Air sealing around components: e.g., windows and walls other Openings and penetrations

Typical Air Leakage Points

Air Leakage Testing

- 2009 IECC (Maine) does not have testing requirement; 2012 IECC onward requires 5 ACH 50
Air Leakage Testing

Problem:

Solution: Seal

If you can see daylight it is not sealed

Big holes

Problem: Filter

Solution: Seal

Spray Foam as an Air Barrier

- Spray foam doesn’t air seal where it isn’t there!
- Wood-to-wood connections
Cold Weather Condensation in Walls

Vapor Diffusion vs. Air Leakage

- **Vapor Diffusion**
  - more to less vapor
  - no air flow
  - flow through tiny pores

- **Air Convection**
  - more to less air pressure
  - flow through visible cracks and holes
  - vapor is just along for the ride
Wall w/o Insulated Sheathing

- Air leakage
- Cold = Condensation
- Vapor Diffusion

Wall with Insulated Sheathing

- Air leakage
- Warm = no condensation
- Vapor Diffusion

Frosting on Sheathing

Vapor Barriers and the Code

- Class I: 0.1 perm or less (polyethylene)
- Class II: 0.1 < perm ≤ 1.0 perm (Kraft facing, vapor retarder paint)
- Class III: 1.0 < perm ≤ 10 perm (Latex paint)
- Polyethylene = no inward drying
- More open vapor control allows greater drying—more “forgiveness” in wall
**Vapor Barriers and the Code**

<table>
<thead>
<tr>
<th>Zone</th>
<th>Class II vapor retarders permitted for:</th>
</tr>
</thead>
</table>
| Marine 4 | Vented cladding over OSB  
Vented cladding over plywood  
Vented cladding over fiberboard  
Insulated sheathing with R-value ≥ 2.5 over 2x4 wall  
Insulated sheathing with R-value ≥ 3.75 over 2x6 wall |
| 5      | Vented cladding over OSB  
Vented cladding over plywood  
Vented cladding over fiberboard  
Insulated sheathing with R-value ≥ 5 over 2x4 wall  
Insulated sheathing with R-value ≥ 7.5 over 2x6 wall |
| 6      | Vented cladding over fiberboard  
Insulated sheathing with R-value ≥ 7.5 over 2x4 wall  
Insulated sheathing with R-value ≥ 11.75 over 2x6 wall  
Insulated sheathing with R-value ≥ 15 over 2x8 wall |
| 7 and 8 | Insulated sheathing with R-value ≥ 15 over 2x8 wall  
Insulated sheathing with R-value ≥ 19 over 2x10 wall  
Insulated sheathing with R-value ≥ 23 over 2x12 wall |

Can just use latex paint (no vapor barrier) if you add enough insulation outside of the stud bay insulation. Safer -> controls diffusion and air leakage moisture. Zone 6A = ~40%/60% R-value ratio

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**Thermal Bridging at Framing**

Steel is 400 times more conductive than wood

Steel studs are about 40 times thinner

A 2x6 steel stud wall 16" OC with R-19 Fiberglass Batt = effective R-9 wall assembly.
Thermal Bridging at Steel Framing

- Summertime/AC example
- Sun is hitting the wall (southeast orientation)

Exterior Continuous Insulation

Exterior Rigid Foam (Taped Seams)

4" Polyisocyanurate Foam Retrofit
Mineral Fiber, Nailbase Panel

4” Polyisocyanurate Foam

Foam Sheathing Cladding

250 lbs/113 kg load (7.8 psf): <0.003” deflection
Wood siding ~2 psf
Fiber cement 2-3 psf
Stucco 8-10 psf

Foam Sheathing Cladding Attachment
BSC Cladding Attachment Research

- System Mechanics
  - Shear and rotational resistance provided by fastener to wood connections
  - Rotational resistance provided by tension in fastener and compression of the insulation
  - Vertical movement resistance provided by friction between layers

Full System Laboratory Tests

- Looked at initial response full system capacity as well as long term sustained loading
- Used full scale samples to limit variations in fastener installation

Recommendations

- Based on the results of the testing it is currently recommended to use a maximum load per fastener of no more than 10lbs for up to 4” of insulation

<table>
<thead>
<tr>
<th>Cladding weight (psf)</th>
<th>16” oc Furring</th>
<th>24” oc Furring</th>
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<tbody>
<tr>
<td>5</td>
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<td>2</td>
</tr>
</tbody>
</table>

The “Perfect Wall”
1. Air / Rain Barrier
2. Structural Support
3. Rain Shedding
4. Insulation

The Perfect Wall

Cladding
Control layers
Structure

Wall

Slab

Roof

Ballast
Filter fabric
Control layers
Roof structure

Cladding
Control layers
Structure

Slab
Control layers
Stones
Earth
The “Perfect” Wall: Higher Performance

- Very robust enclosure—“500 year building”
- Structural portion in “interior” conditions
- Institutional/long term buildings
- No risk of interstitial condensation
- Continuity of control layers
  - Continuous thermal insulation outside
  - Inspectable and simple air barrier “wrap”
  - Water control layer/WRB inspectable before insulation
- Any interior condition
- Any exterior condition

The Commercial Steel Frame Wall

- Inspectable and simple air barrier “wrap”
- Water control layer/WRB inspectable before insulation
- Any interior condition
- Any exterior condition
Building the “Perfect Wall”

Fluid-Applied Asphalt & Rock Wool
- Asphalt Drainage Plane Air Barrier
- Rock wool Insulation

Self-adhered membrane, XPS insulation

Exterior Closed Cell Spray Foam
- All Four Control Layers
- Transitions, Continuity, Penetrations
- Spray foam= air barrier & drainage plane & insulation & vapor control
Cladding Support (Z-Furring)

- Z-furring 16" o.c.,
- All this effort to cover up our thermal bridges with insulation… and then we punch steel through it…

Thermal Bridging at Cladding

- Thermal Performance of Building Envelope Details for Mid- and High-Rise Buildings (ASHRAE 1365-RP)

Thermally Broken Cladding Supports

- Cascadia Clip (pultruded fiberglass)
- Knight Wall (fasteners through foam)
- Engineered Assemblies
- T Clip

Questions?

Kohta Ueno
kohta (at sign) buildingscience dot com

This presentation will be available at http://buildingscience.com/past-events
Document Resources

- Building Science Digest 014: Air Flow Control in Buildings
- Building Science Digest 163: Controlling Cold-Weather Condensation Using Insulation
- Building Science Insight 001: The Perfect Wall
- Building Science Insight 005: A Bridge Too Far
- Building Science Insight 029: Stucco Woes—The Perfect Storm
- Building Science Insight 038: Mind the Gap, Eh!
- Building Science Insight 048: Exterior Spray Foam
- Building Science Insight 057: Hockey Pucks and Hydrostatic Pressure
- Building Science Insight 062: Thermal Bridges Redux