

Kohta Ueno

Building Science of Walls

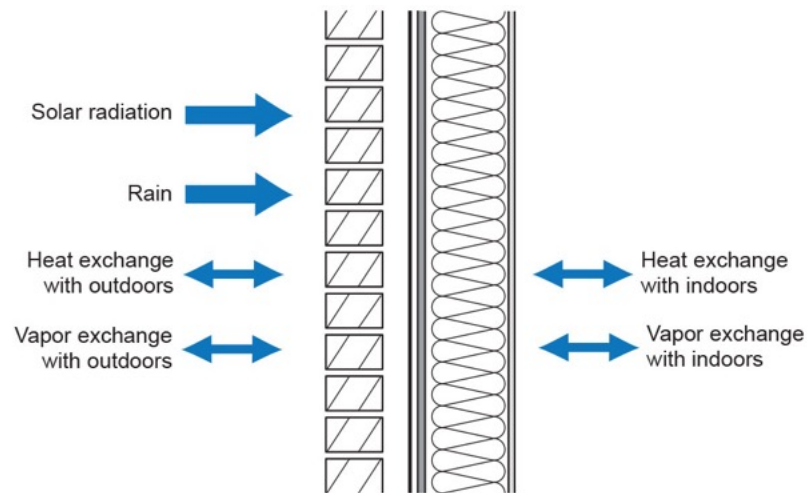
January 19, 2017



Background



Environmental Separator



What Separation Roles?

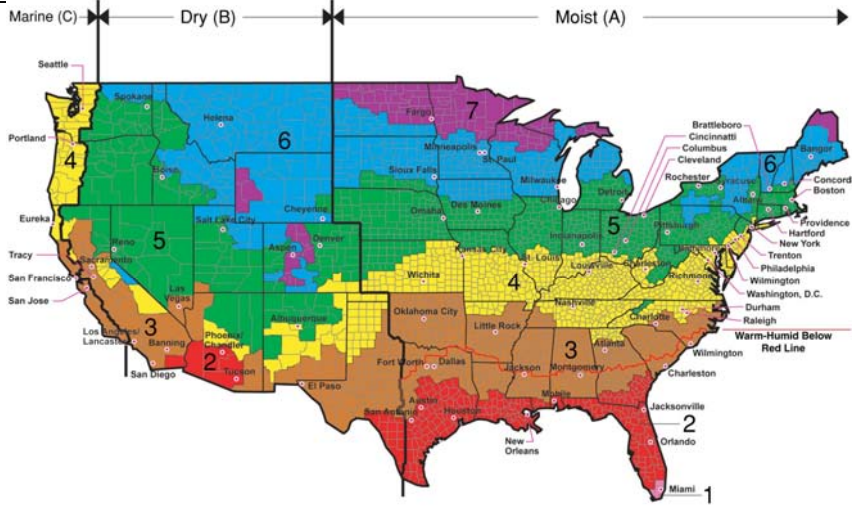
- Water control layer
 - A.k.a. “drainage plane,” “water resistive barrier,” “weather resistive barrier,” WRB
 - Housewraps, tar paper... more modern options
- Air control layer
 - A.k.a. “air barrier”
 - Drywall, sheathing, spray foam... and continuity
- Vapor control layer
 - A.k.a. “vapor barrier”—poly, Kraft paper, latex paint
- Thermal control layer
 - Insulation (fluffy in stud bays, continuous on outside)

Climate Zone Map (BSC)



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Climate Zone Map (DOE)



All of Alaska in Zone 7 except for the following Boroughs in Zone 8: Bethel, Dellingham, Fairbanks, N. Star, Nome North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, and Yukon-Koyukuk.



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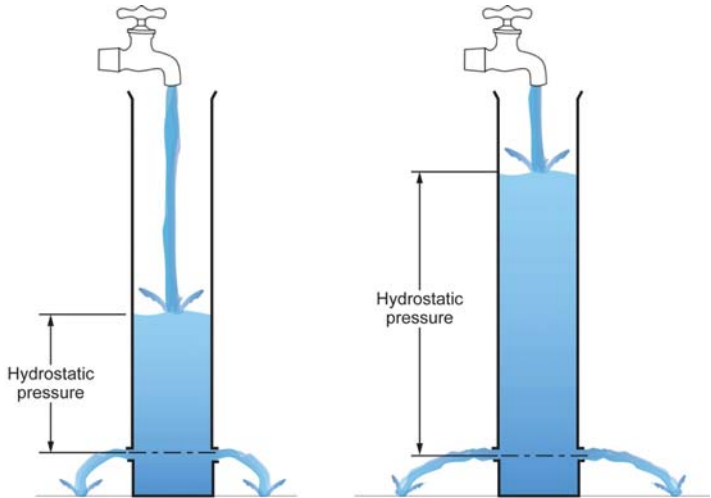
Water Control- Hydrostatic Pressure

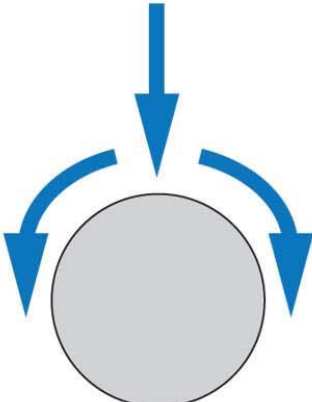
Water Control and Drainage Gaps

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

- See “Mind the Gap” and “Hockey Pucks and Hydrostatic Pressure”

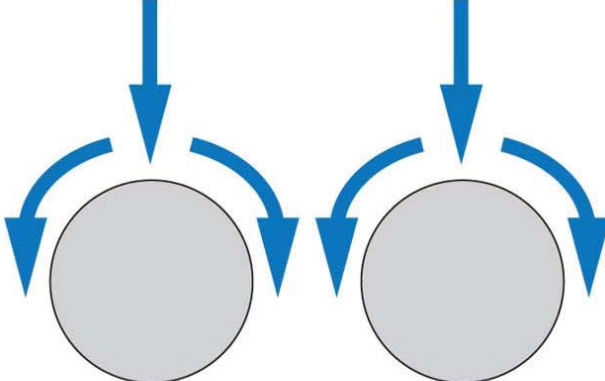
Hydrostatic Pressure





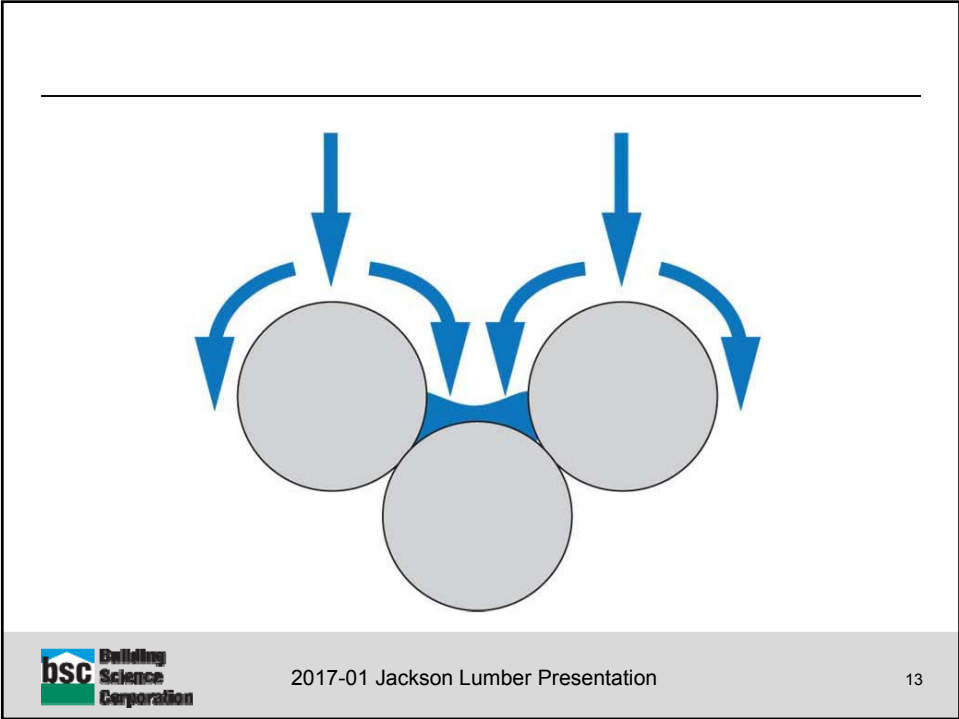
A diagram showing a single grey circular element. A solid blue arrow points vertically downwards towards the top of the circle. Two curved blue arrows originate from the top edge of the circle, one curving to the left and one to the right, with their heads pointing outwards.

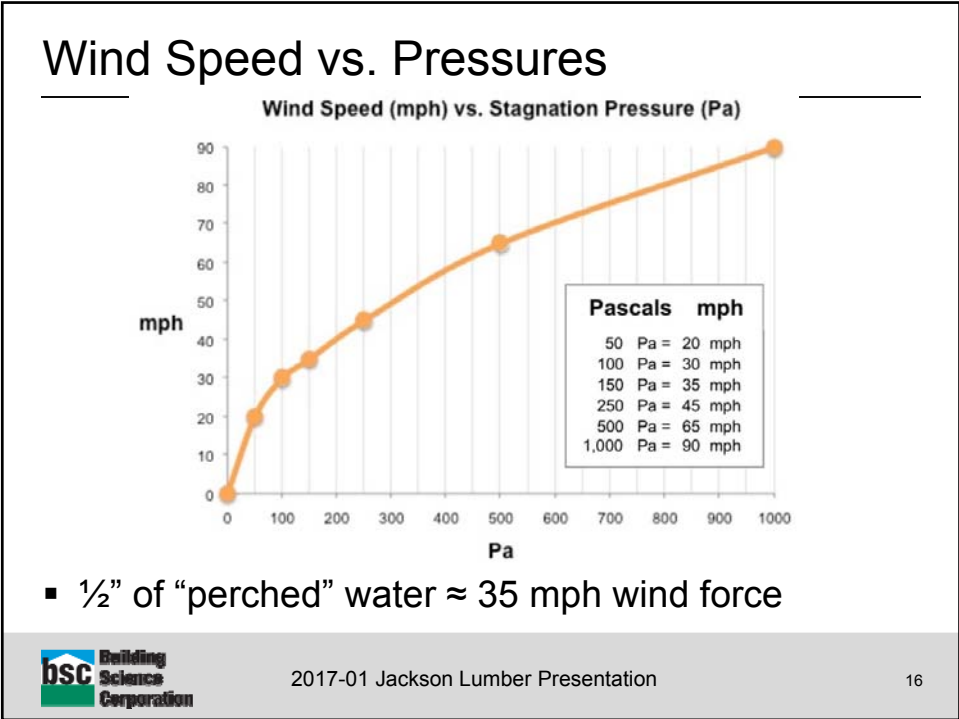
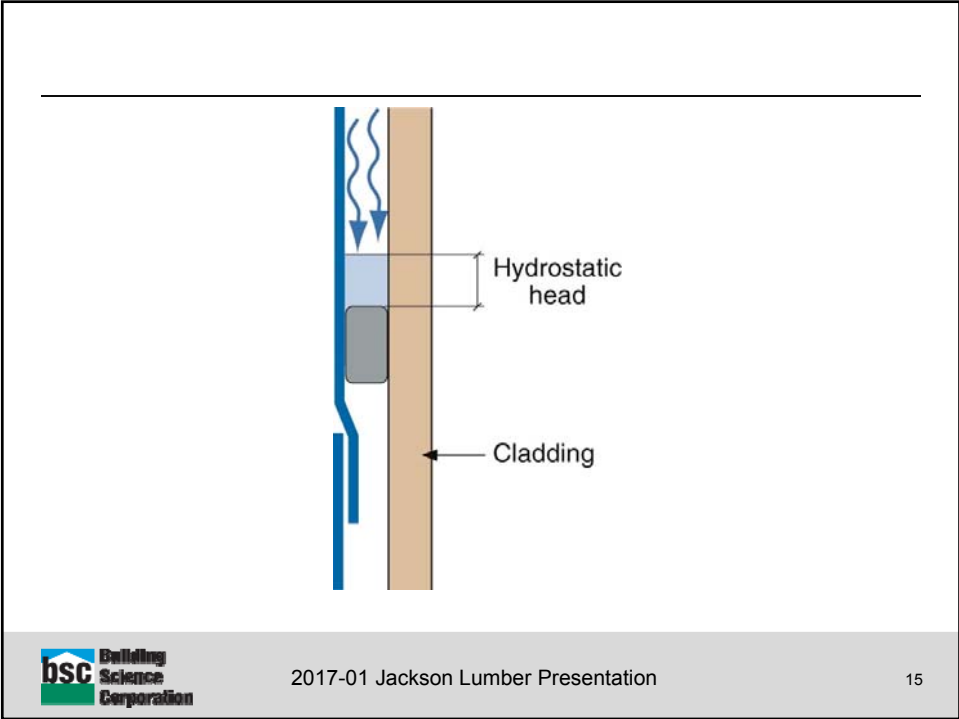
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A diagram showing two identical grey circular elements positioned side-by-side. Each circle has a solid blue arrow pointing vertically downwards towards its top. Each circle also has two curved blue arrows originating from its top edge, one curving to the left and one to the right, with their heads pointing outwards.

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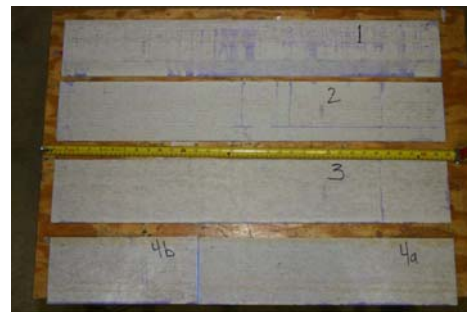
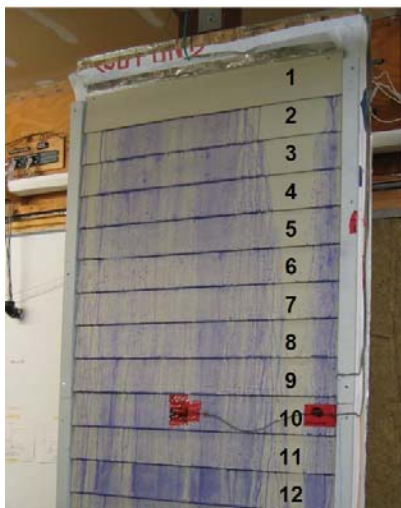


Why Rainscreen/Air Gap



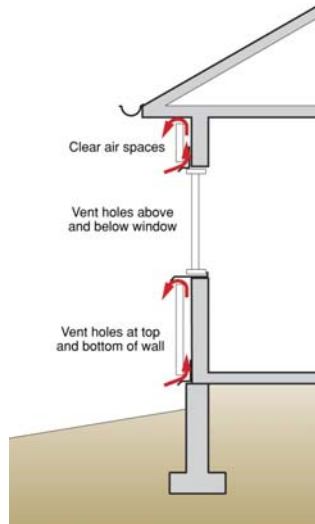
- “Sandwiched” water (surface tension) hangs up
- Staying wet or wet/dry cycling
 - Paint blow off
 - Damage over time

Drainage from Lap Sidings



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

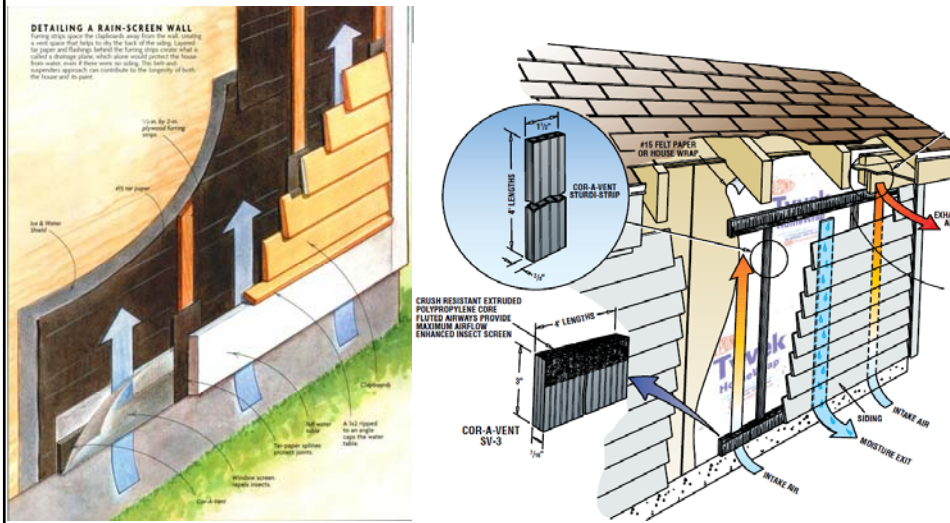
Cladding Ventilation



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

Water Control Layers and Spaces

Strapped Cavities/“Rainscreen Wall”

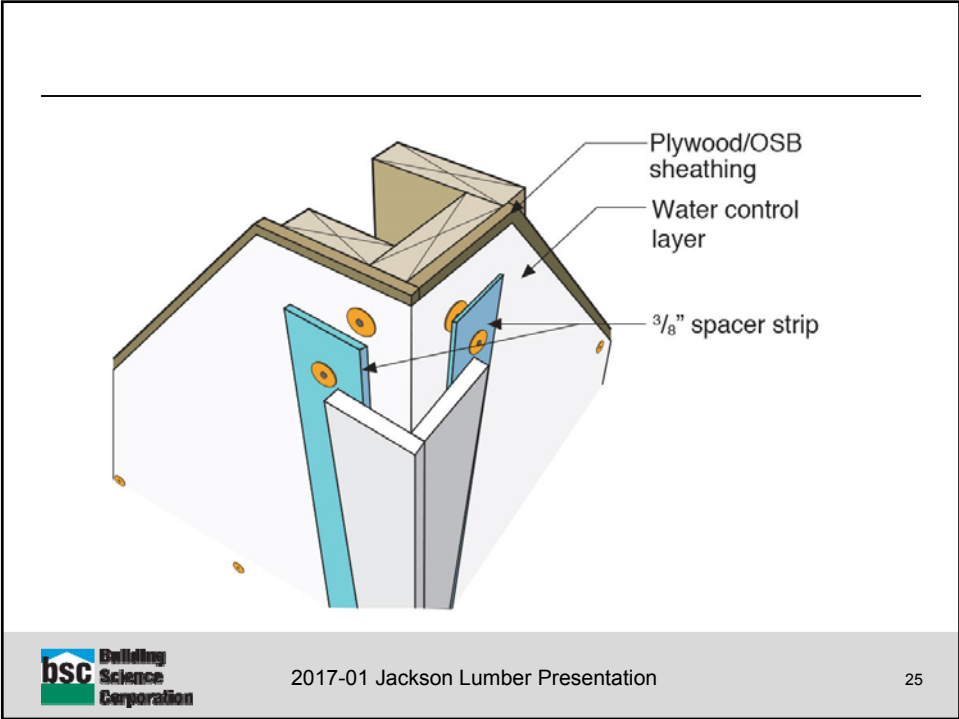


Shingle Wall Rainscreen/Air Gap



- Mesh style
(Home Slicker, Keene Building Products)







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Water Control Layer Options

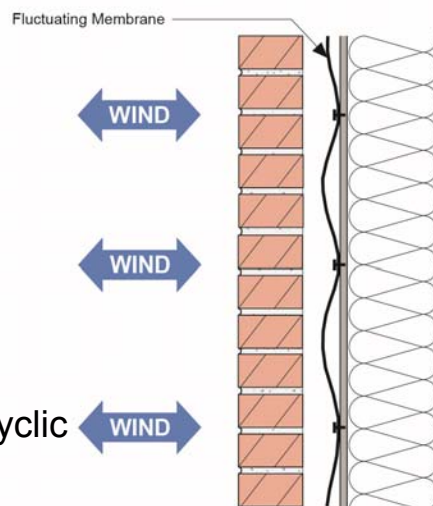
Housewrap (Residential)



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



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Vapor-Permeable Adhered Membrane



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Self-Adhered Membranes



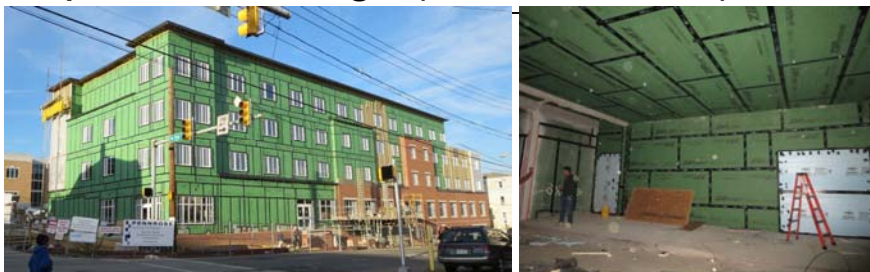
- Self-sealing
- Air leakage improvement; no blow-off/billowing
- No 'hidden path' water leakage/bypass
- Reverse laps not as critical



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Taped Sheathings (WRB Surface)



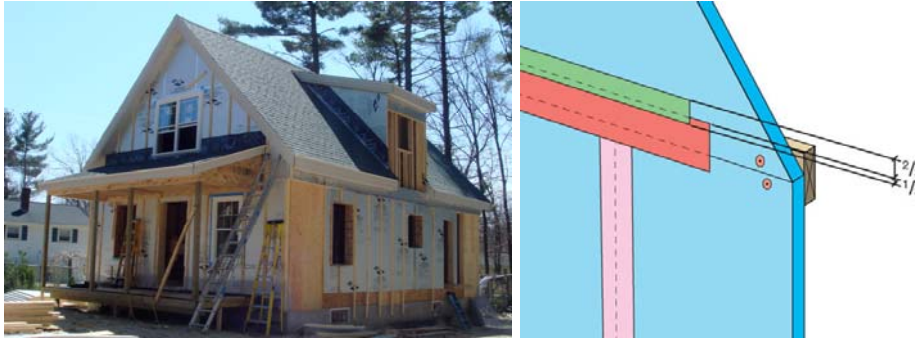
- Fast dry-in
- Airtightness
- Reliance on adhesive vs. laps? Surface prep
- Rigid foam insulation too



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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

Windows Flashings



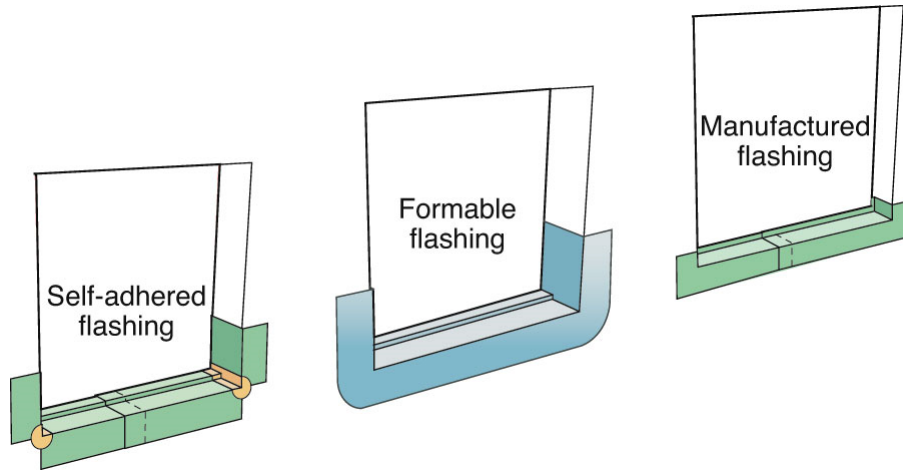
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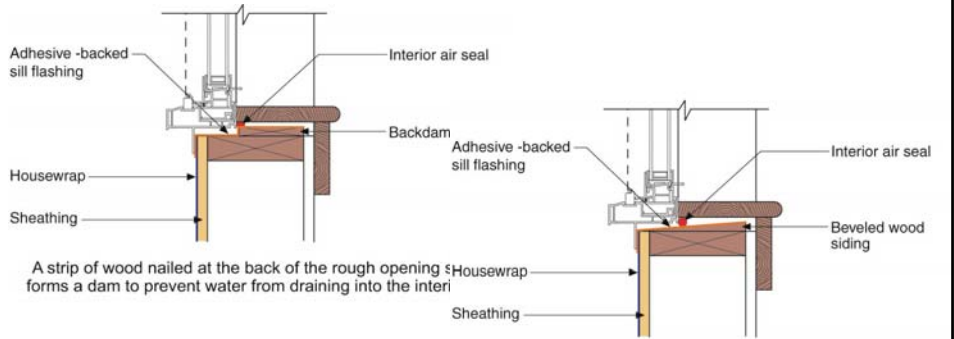
EIFS & Windows - Oops



Sill Pan Flashings



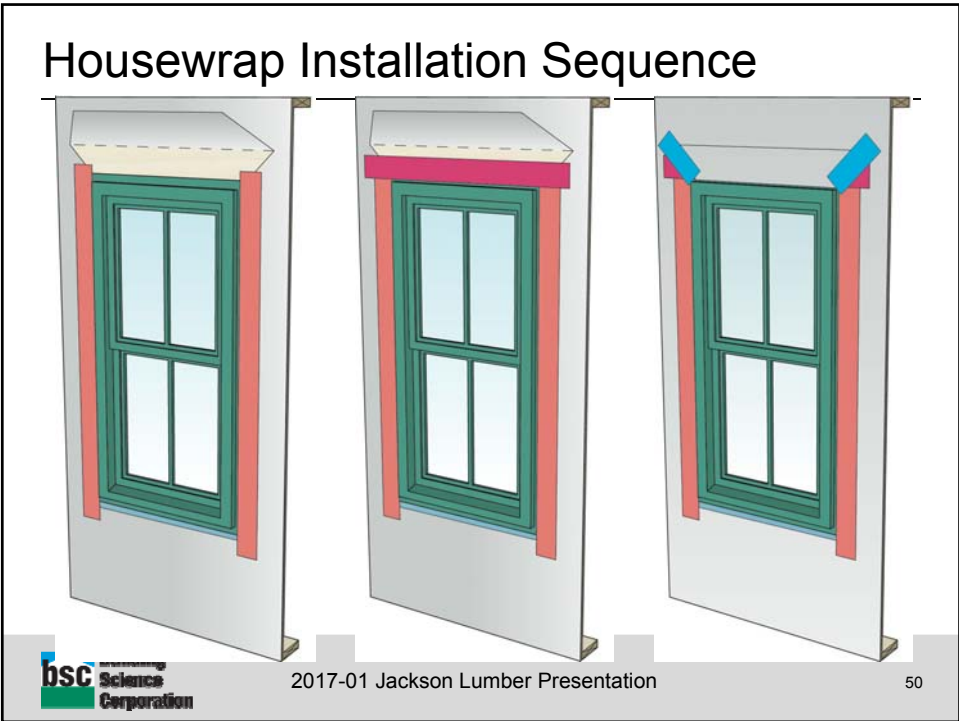
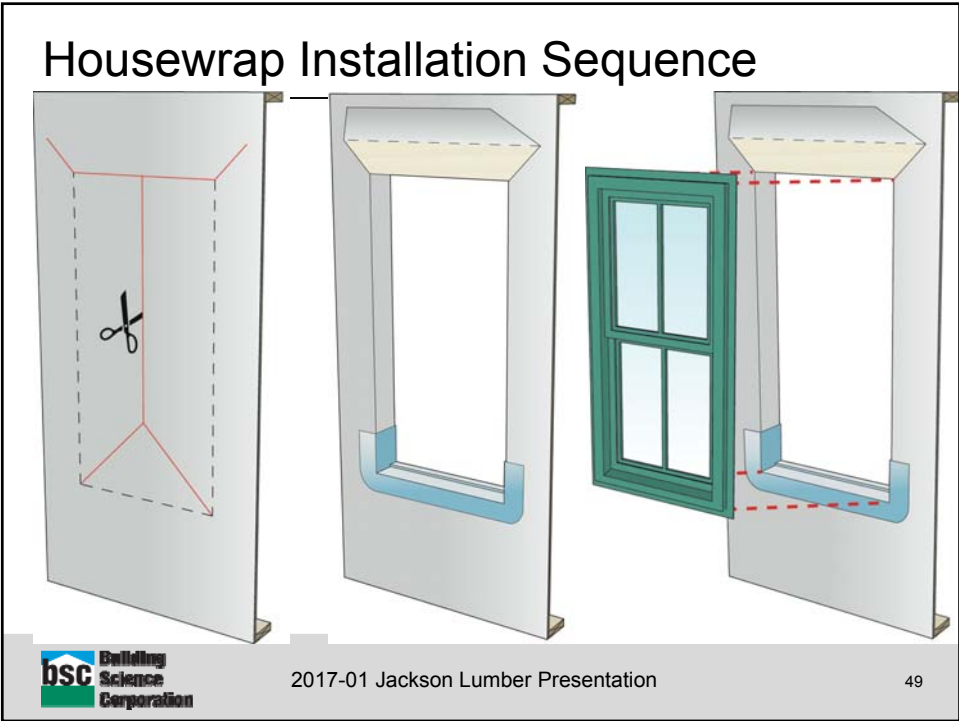
Backdams and Sloped Sills



A strip of wood nailed at the back of the rough opening forms a dam to prevent water from draining into the interior.

A piece of wood bevel siding nailed over the sill to create positive drainage toward the exterior is even better. Note that the rough opening needs to be enlarged to account for this and tapered shims in the opposite direction of the slope may be required.





Foam Sheathing Window Flashing



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Window Failure Examples



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Window Failure Examples



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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



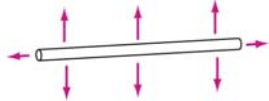
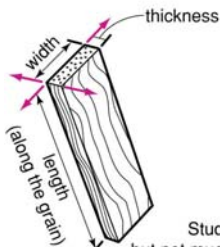
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Wood Moves...

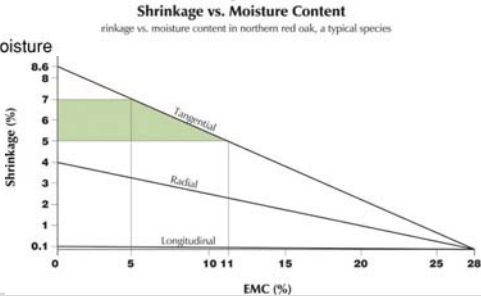


Wood Moisture Movement



Wood Fiber
Fibers get much thicker than longer when they pick up moisture

Studs get much wider and thicker, but not much longer, when they pick up moisture



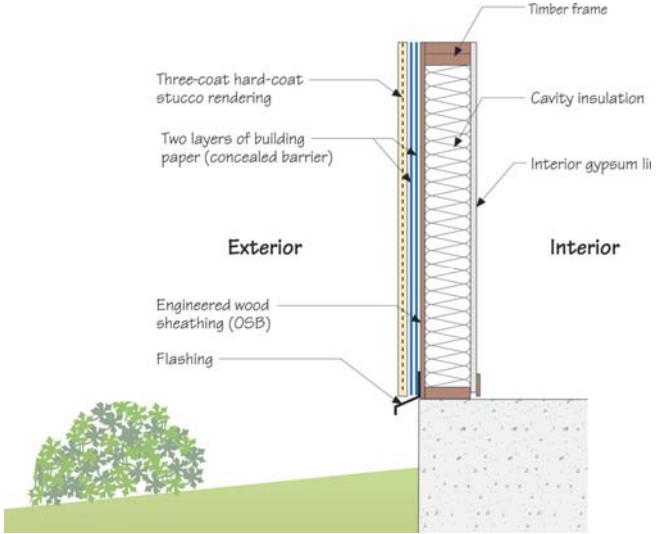
Room for Expansion



- 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

Stucco & Adhered Stone

Stucco on Wood Frame Walls



Stucco Failures (MN, PA)



Stucco-to-Paper Bond




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Adhered Stone Veneer



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Air Flow

Airflow Control: Why

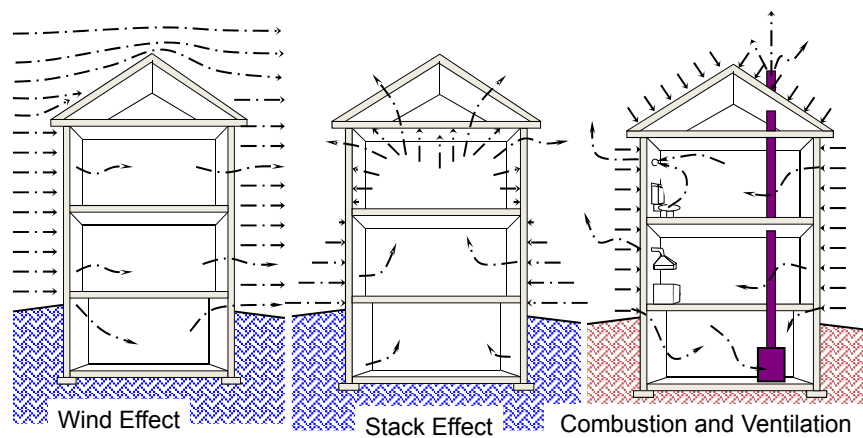
- Moisture control
 - air leakage condensation
- Comfort and Health
 - Drafts
 - Odors, particles, gases
- Energy
 - Heat transferred with air
- Sound
- Required by some codes

*If you can't enclose air,
you can't condition it*

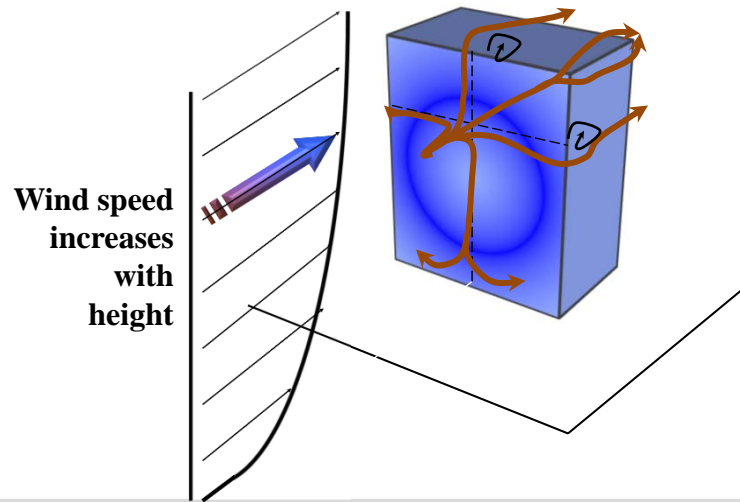
Driving Forces

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

Driving Forces

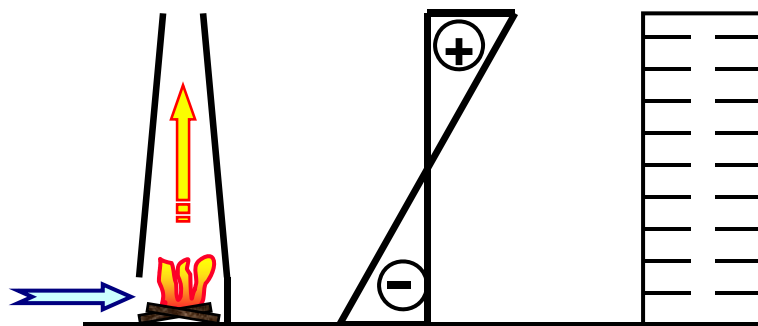


Wind Flow Patterns



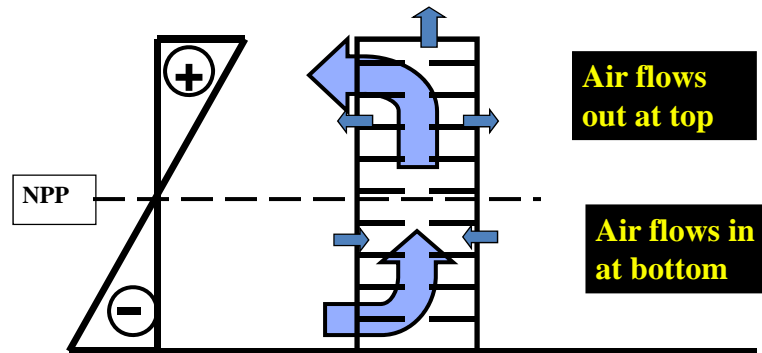
2. Stack Effect: Cold Weather

- Hot air rises
- Tall Building in Winter = Heavy Balloon



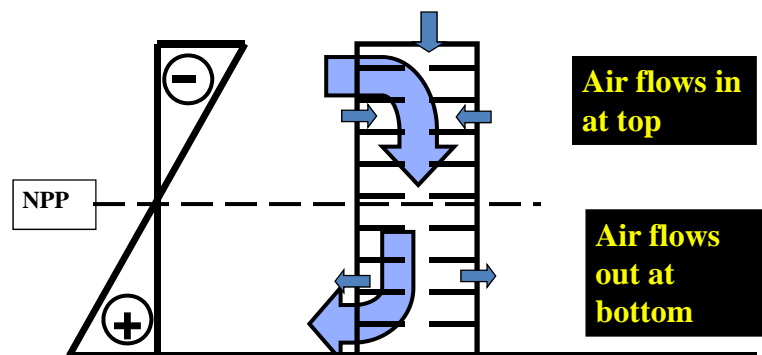
Stack Effect: Cold Weather

- “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

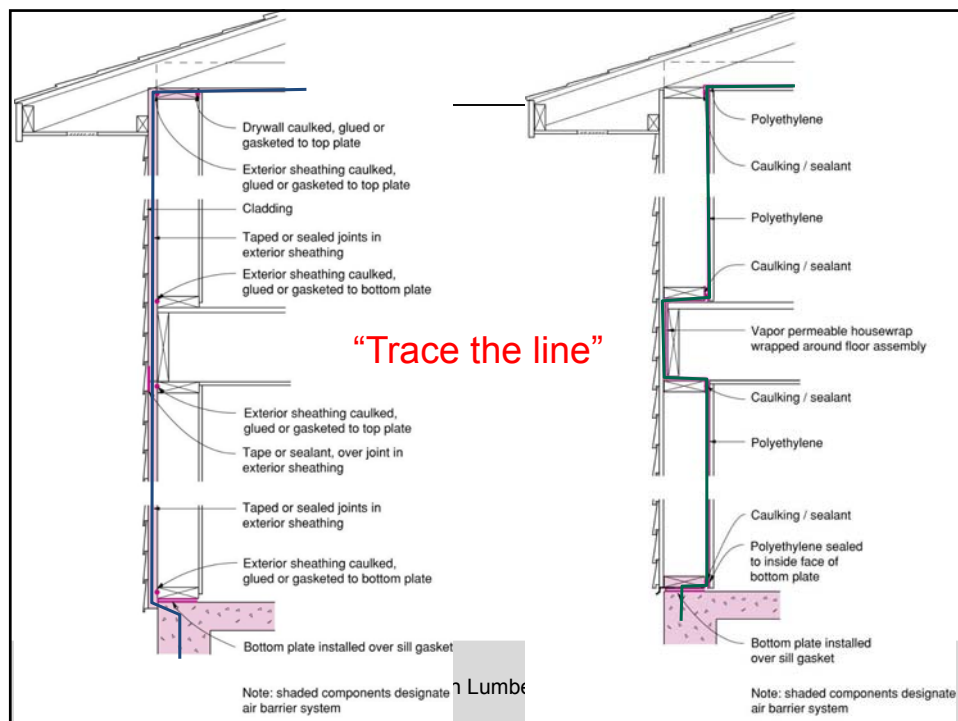
Air Barrier Systems: Requirements

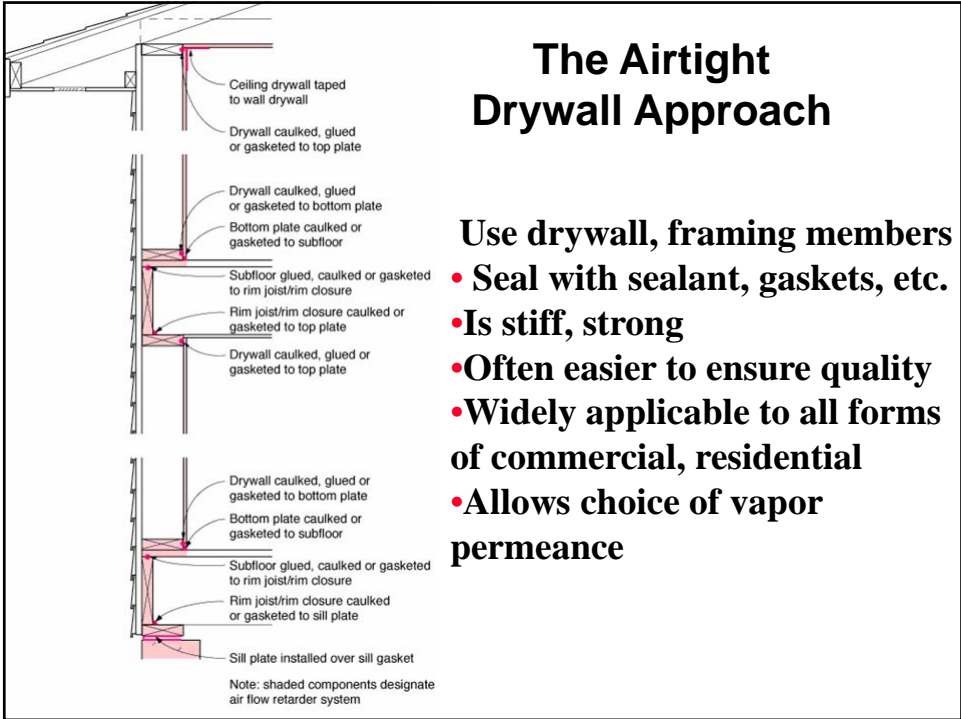
- Continuous
 - primary need, common failure
- Strong
 - designed for full wind load
- Durable
 - critical component - repair, replacement
- Stiff
 - control billowing, pumping
- Air Impermeable
 - (may be vapour permeable)



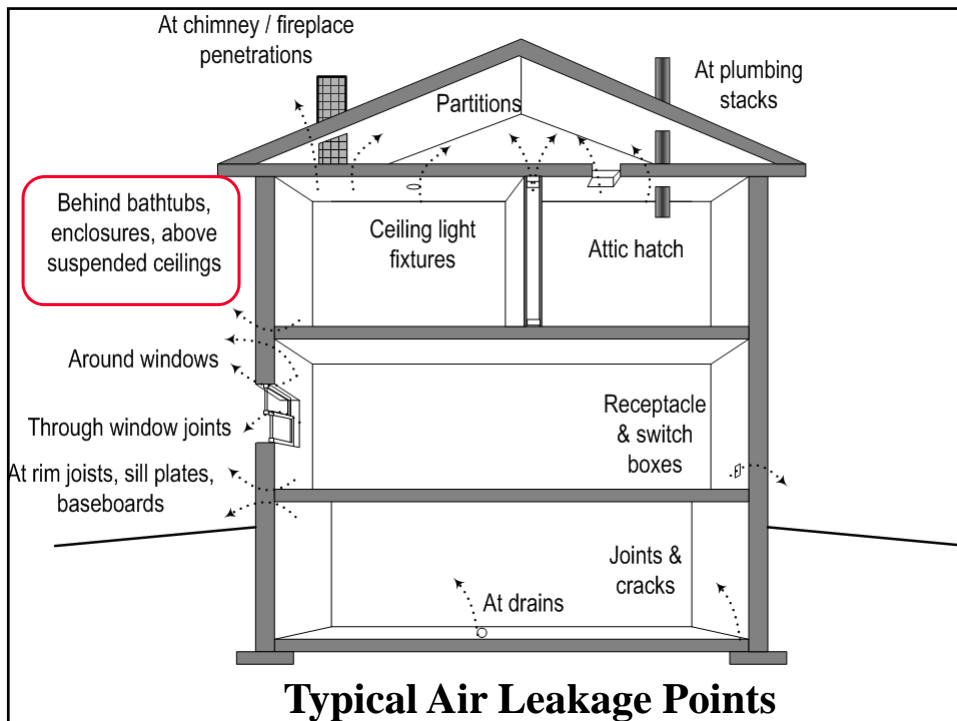
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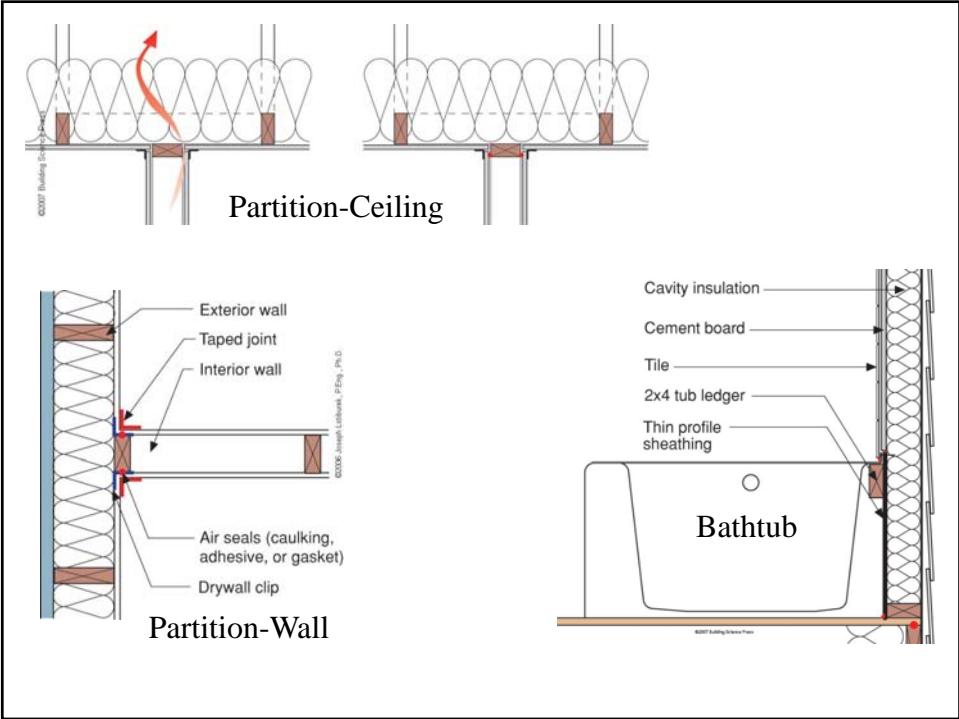
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**Air sealing
around
components:
e.g., windows
and walls
other
Openings and
penetrations**



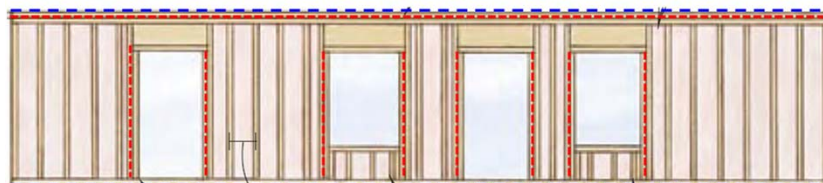


Big holes



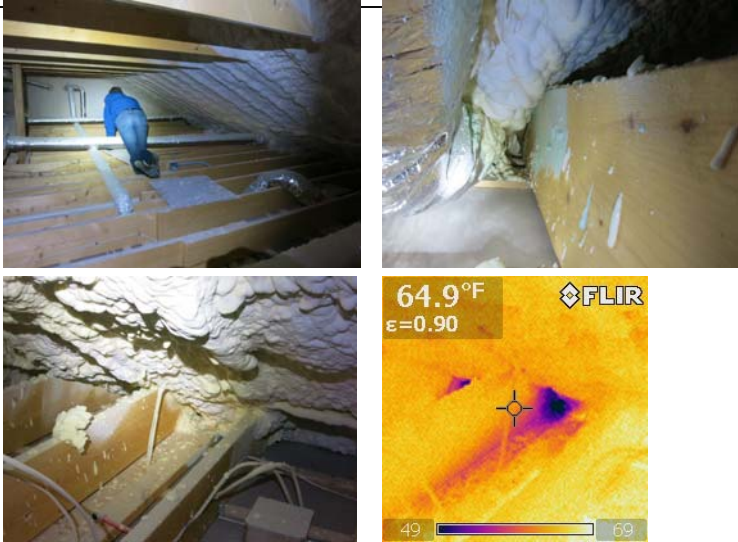


Spray Foam as an Air Barrier



- Spray foam doesn't air seal where it isn't there!
- Wood-to-wood connections

Spray Foam as an Air Barrier



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Spray Foam as an Air Barrier



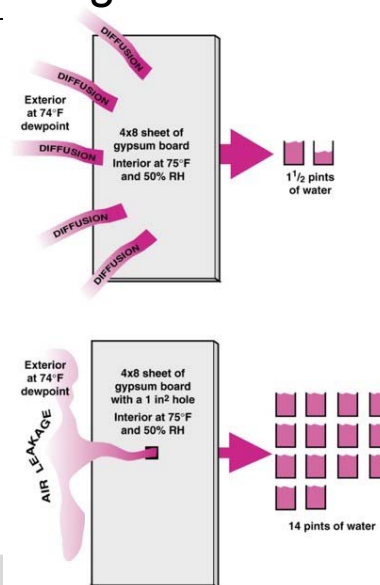
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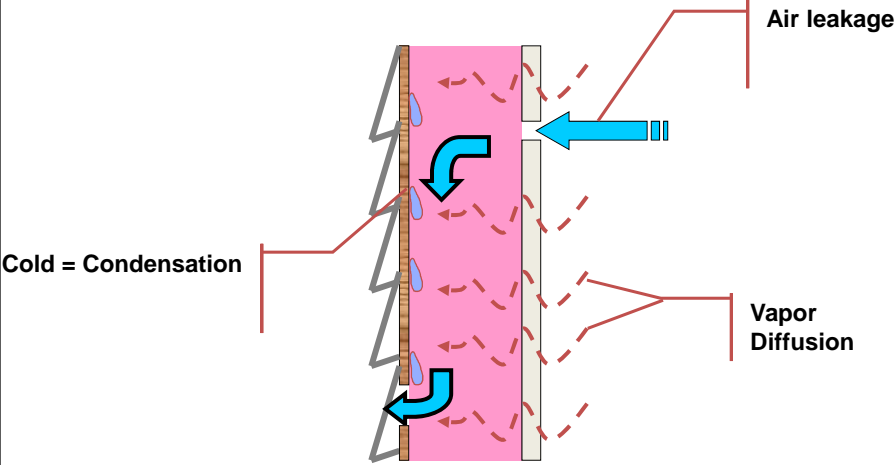
Cold Weather Condensation in Walls

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



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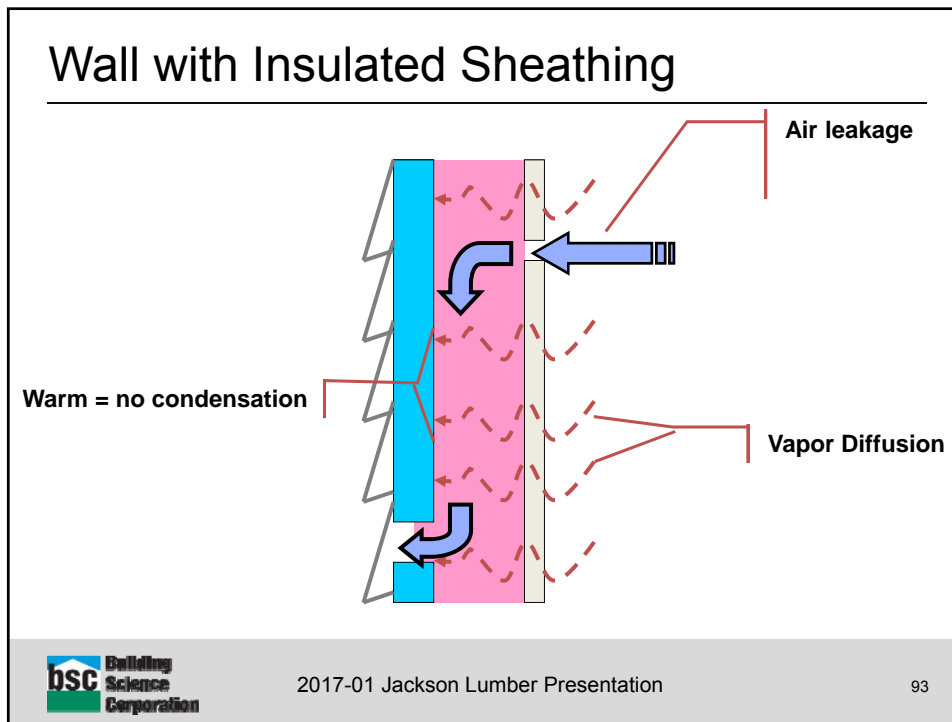
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Frosting on Sheathing



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Vapor Barriers and the Code

- Class I: 0.1 perm or less (polyethylene)
- Class II: $0.1 < \text{perm} \leq 1.0$ perm (Kraft facing, vapor retarder paint)
- Class III: $1.0 < \text{perm} \leq 10$ perm (Latex paint)
- Polyethylene = no inward drying
- More open vapor control allows greater drying—more “forgiveness” in wall

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Vapor Barriers and the Code

TABLE N1102.5.1
CLASS III VAPOR RETARDERS

| Zone | Class III vapor retarders permitted for: |
|----------|---|
| Marine 4 | Vented cladding over OSB Vented cladding over plywood Vented cladding over fiberboard Vented cladding over gypsum 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 Vented cladding over gypsum Insulated sheathing with R-value ≥ 5 over 2x4 wall Insulated sheathing with R-value ≥ 7.5 over 2x6 wall |
| 6 | Vented cladding over fiberboard Vented cladding over gypsum Insulated sheathing with R-value ≥ 7.5 over 2x4 wall Insulated sheathing with R-value ≥ 11.25 over 2x6 wall |
| 7 and 8 | Insulated sheathing with R-value ≥ 10 over 2x4 wall Insulated sheathing with R-value ≥ 15 over 2x6 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 5A = 30%/70% R-value ratio



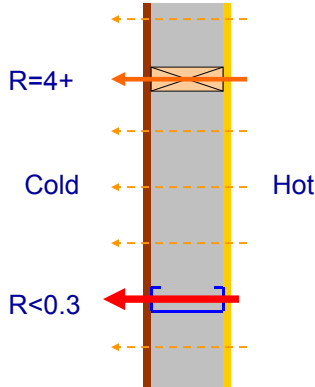
Thermal Bridging at Framing



Thermal Bridging at Steel Framing

Steel is 400 times more conductive than wood

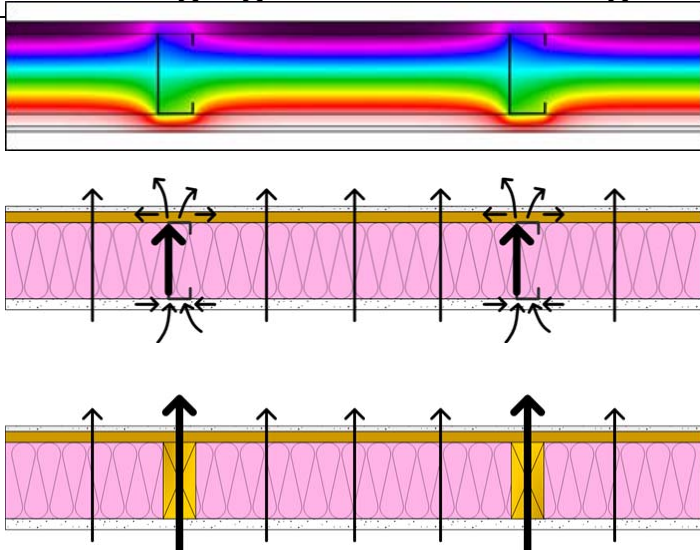
Steel studs are about 40 times thinner



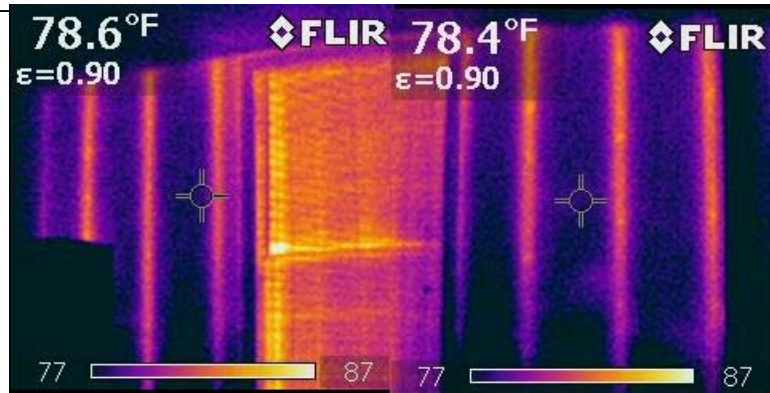
A 2x6 steel stud wall 16" OC with R-19 Fiberglass Batt = effective R-9 wall assembly.



Thermal Bridging at Steel Framing



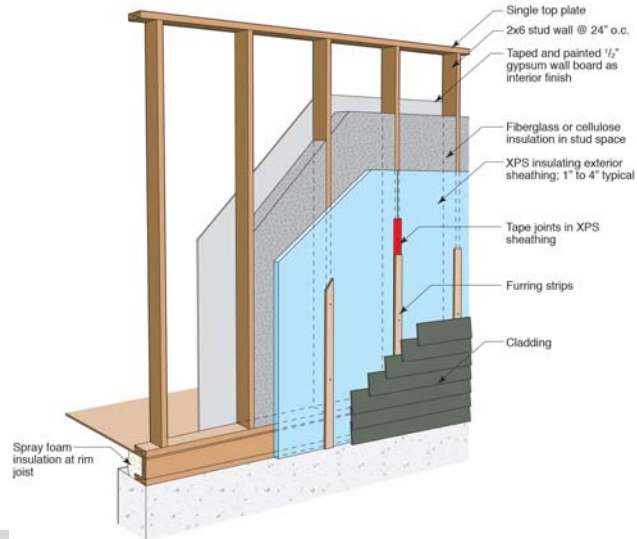
Thermal Bridging at Steel Framing



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

Exterior Rigid Foam

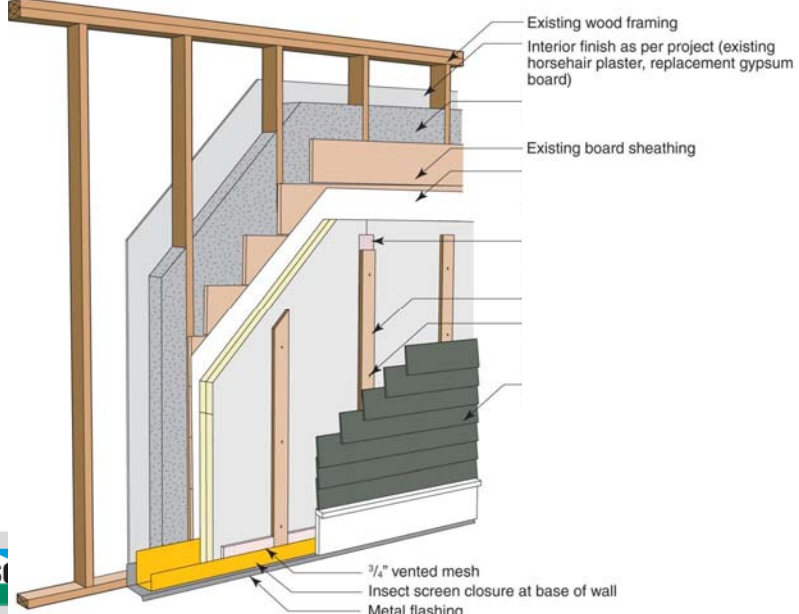
Exterior Rigid Foam (Taped Seams)



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4" Polyisocyanurate Foam Retrofit



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4" Polyisocyanurate Foam



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Foam Sheathing Cladding



250 lbs/113 kg load (7.8 psf): <0.003" deflection

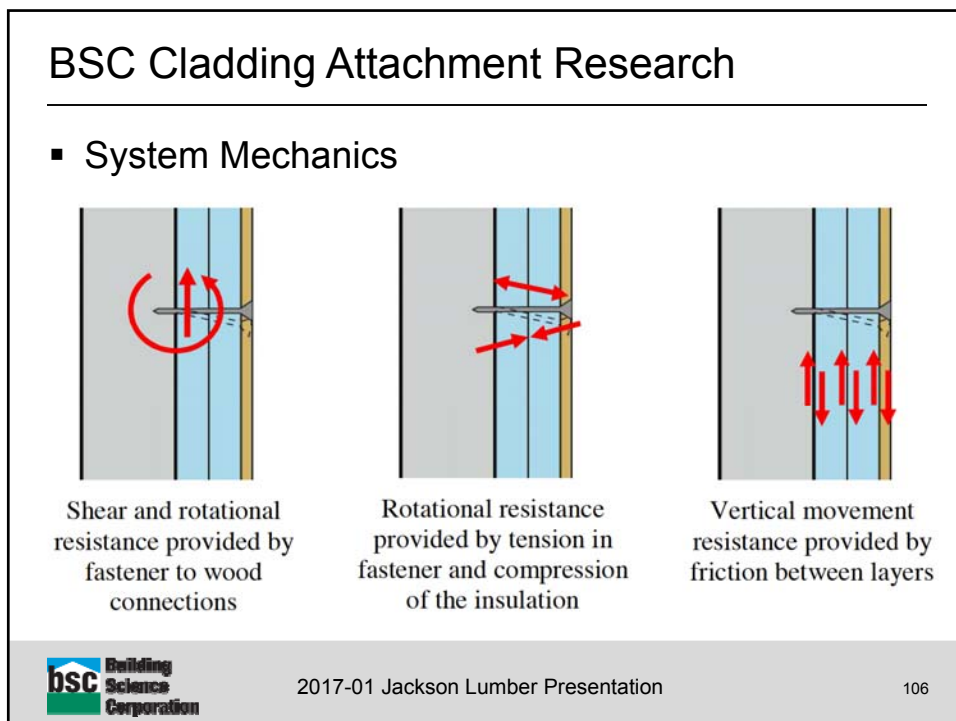
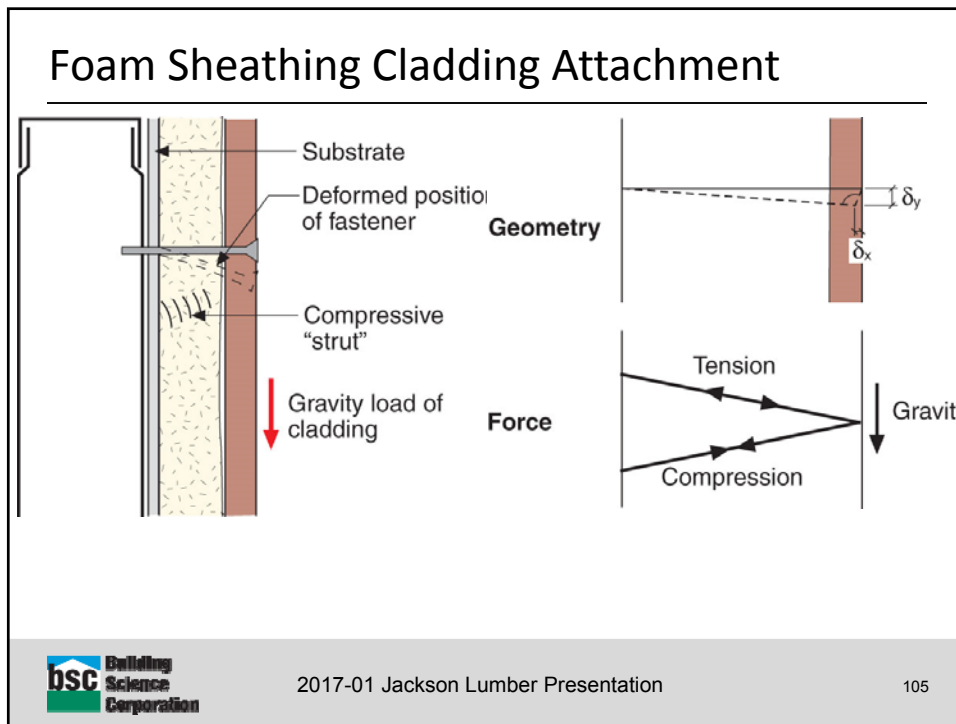
Wood siding ~2 psf
Fiber cement 2-3 psf
Stucco 8-10 psf

Image c/o Petersen Engineering



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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



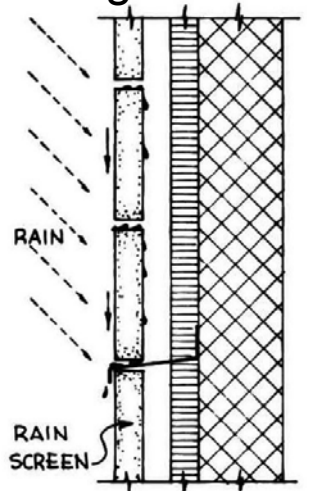
Recommendations

- 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

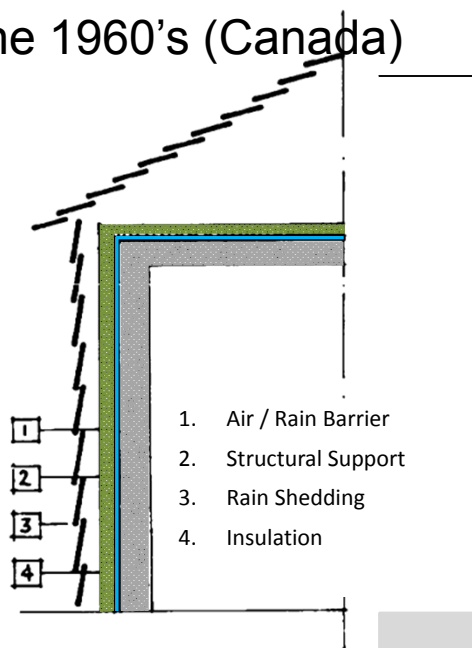
| Cladding weight (psf) | 16" oc Furring | 24" oc Furring |
|--------------------------|----------------|----------------|
| 5 | 18 | 12 |
| 10 | 9 | 6 |
| 15 | 6 | 4 |
| 20 | 4 | 3 |
| 25 | 3 | 2 |

The "Perfect Wall"

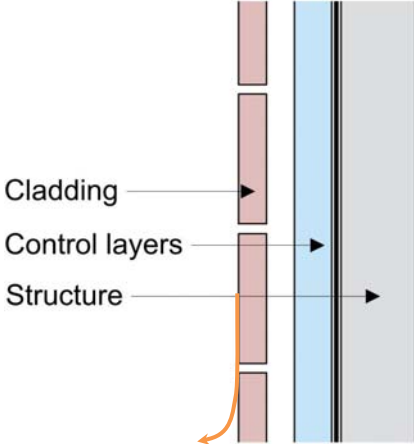
Design Info from the 1960's (Canada)



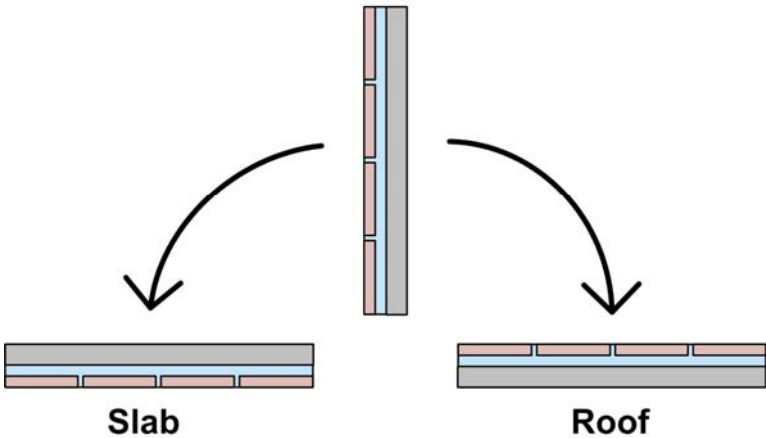
WATER THAT PENETRATES
IS DIVERTED OUTWARD
BY FLASHINGS

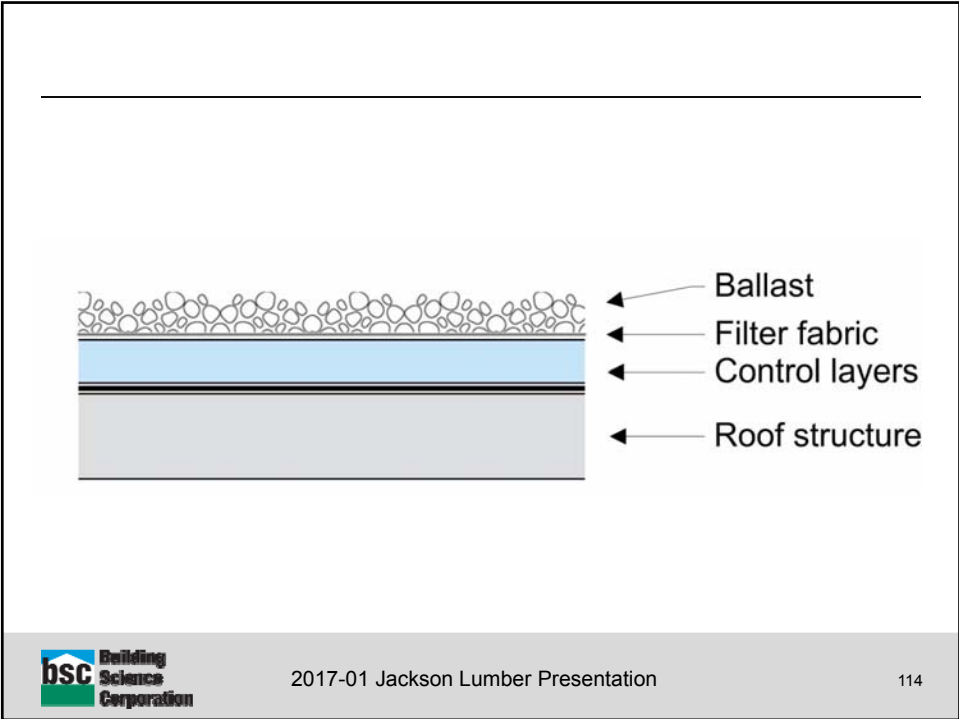
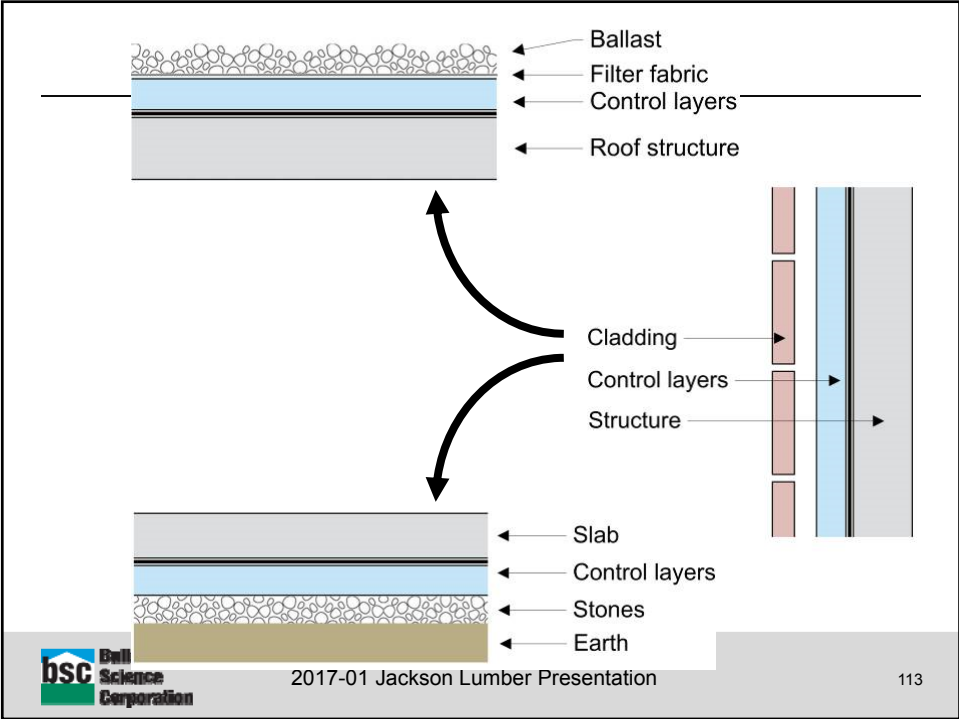


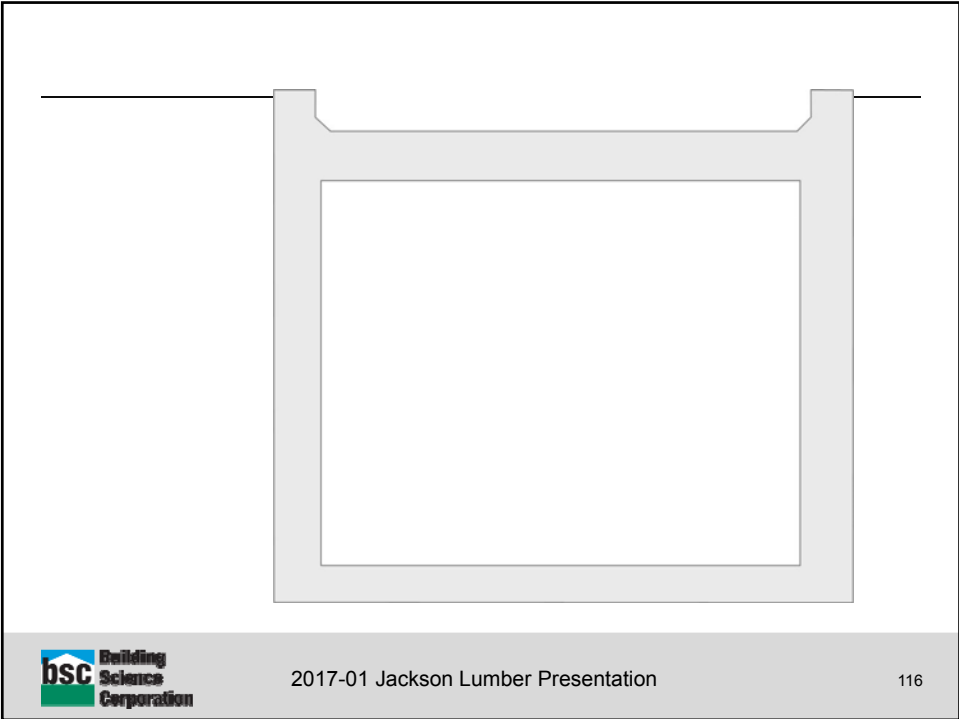
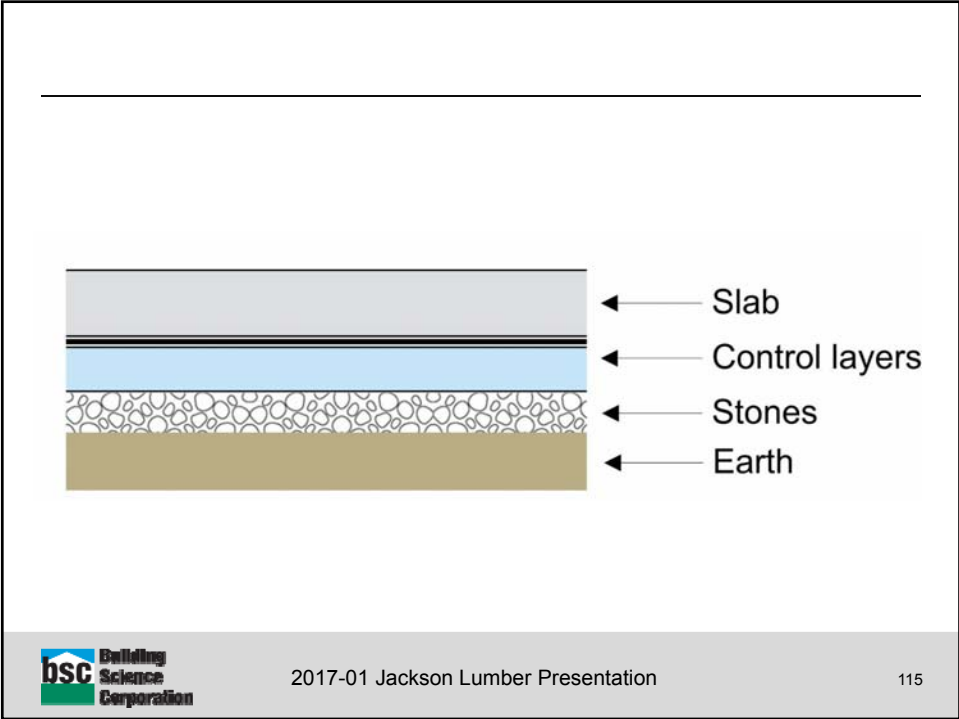
The Perfect Wall

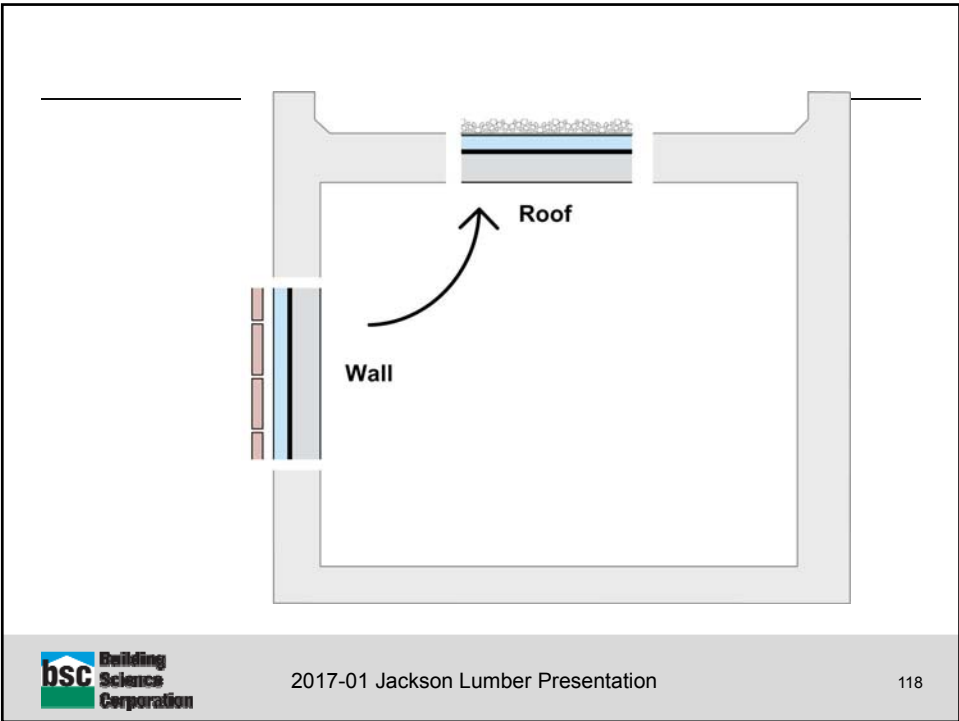
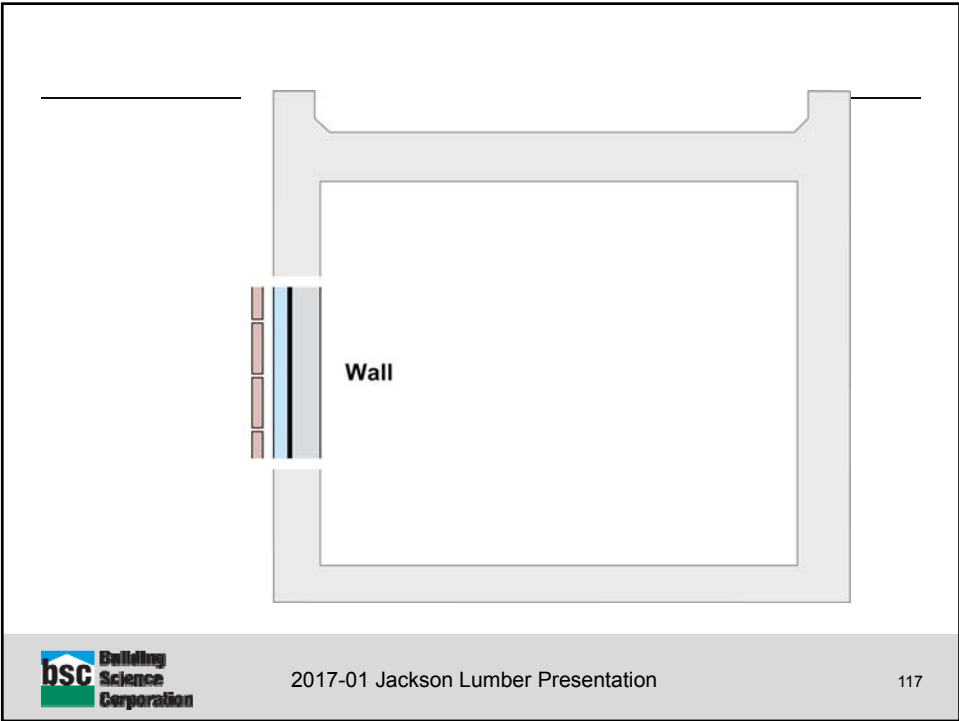


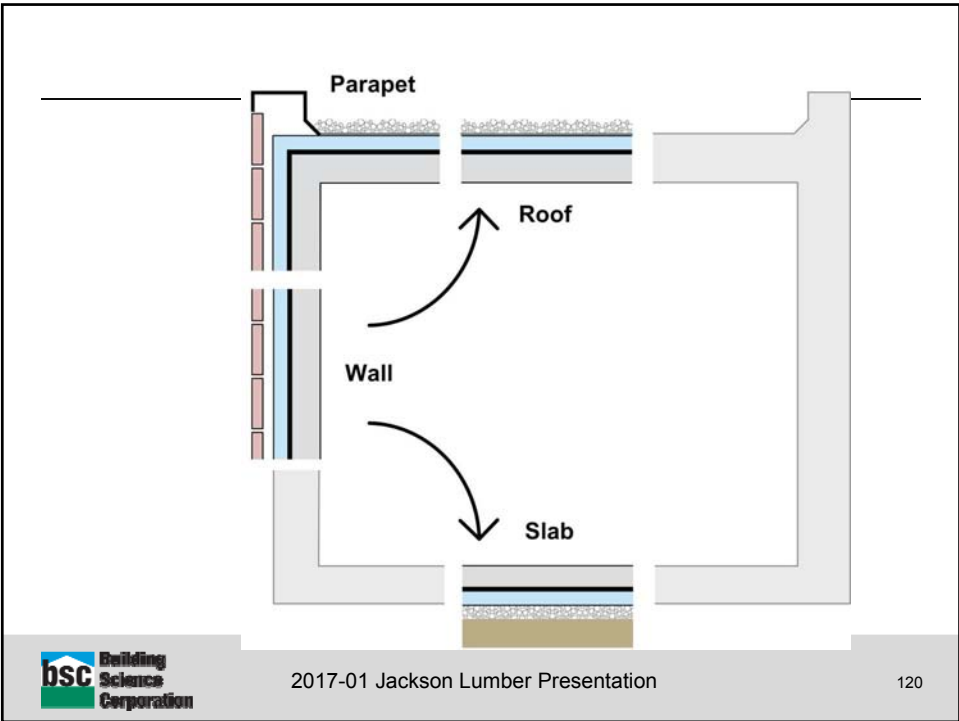
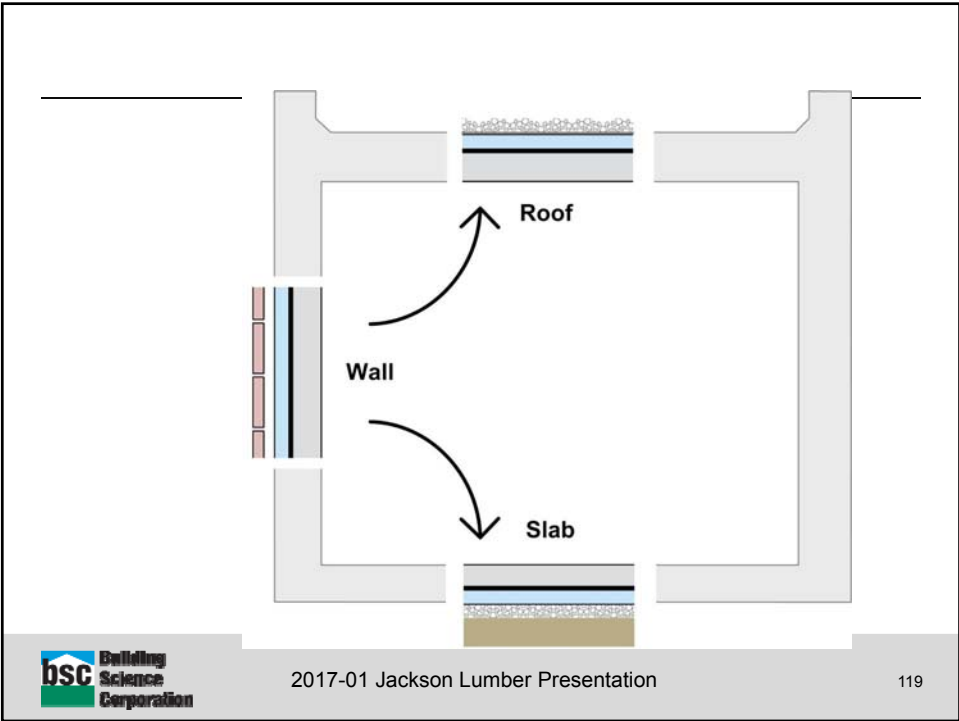
Wall

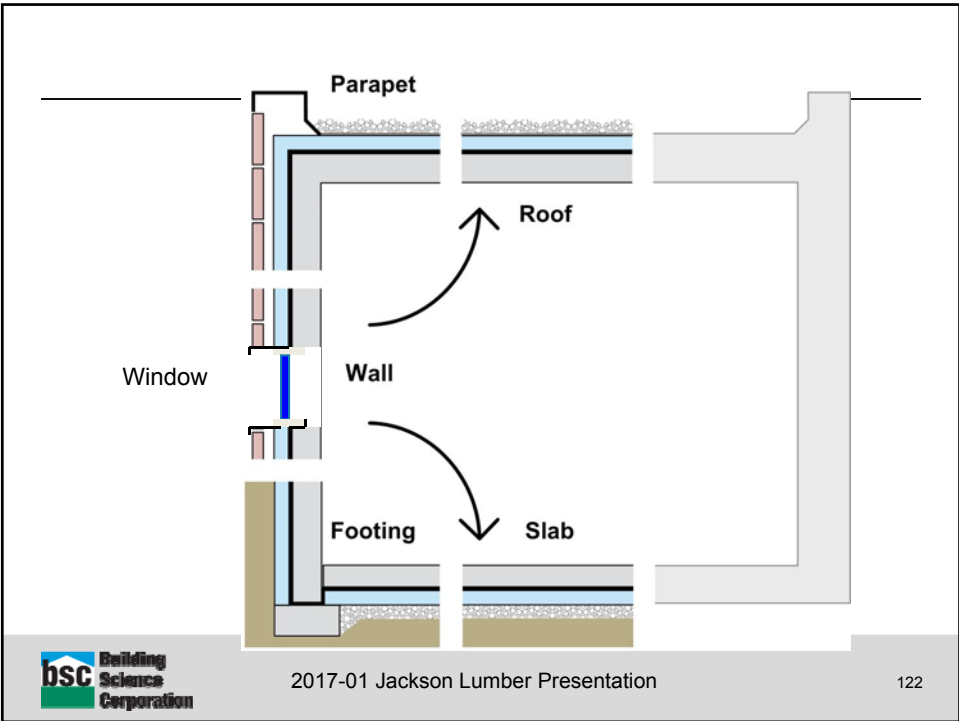
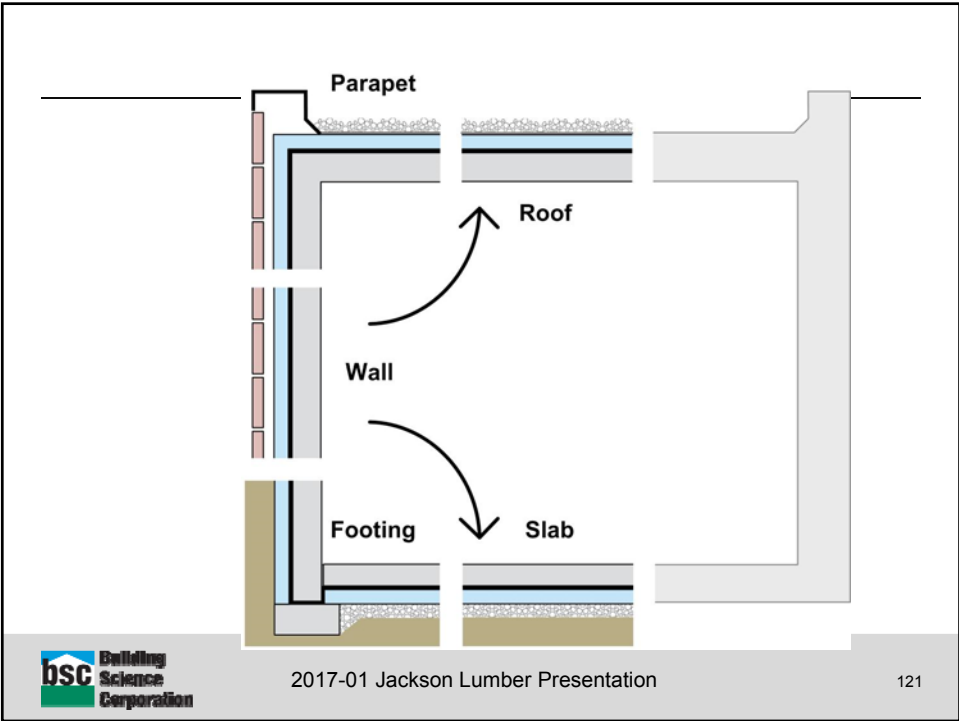




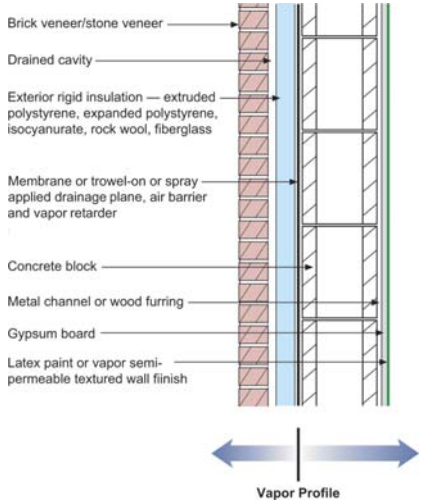




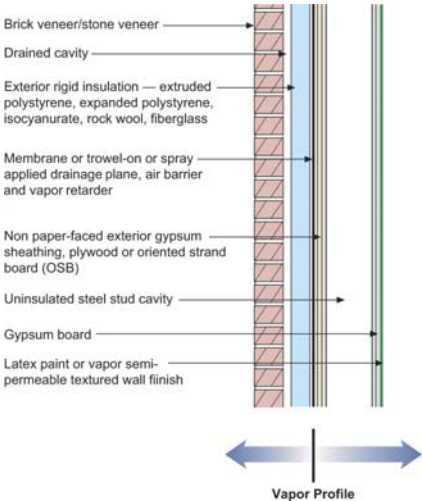




The "Perfect" Wall: Higher Performance



The Commercial Steel Frame Wall



“Perfect Wall” Advantages

- 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

Questions?

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This presentation will be available at <http://buildingscience.com/past-events>

Document Resources

- Building Science Digest 014: Air Flow Control in Buildings
<http://www.buildingscience.com/documents/digests/bsd-014-air-flow-control-in-buildings>
- Building Science Digest 163: Controlling Cold-Weather Condensation Using Insulation
<https://buildingscience.com/documents/digests/bsd-controlling-cold-weather-condensation-using-insulation>
- Building Science Insight 001: The Perfect Wall
<http://www.buildingscience.com/documents/insights/bsi-001-the-perfect-wall/>
- Building Science Insight 005: A Bridge Too Far
<http://www.buildingscience.com/documents/insights/bsi-005-a-bridge-too-far/>
- Building Science Insight 029: Stucco Woes—The Perfect Storm
<http://buildingscience.com/documents/insights/bsi-029-stucco-woes-the-perfect-storm>
- Building Science Insight 038: Mind the Gap, Eh!
<http://www.buildingscience.com/documents/insights/bsi-038-mind-the-gap-eh/>
- Building Science Insight 048: Exterior Spray Foam
<http://www.buildingscience.com/documents/insights/bsi-048-exterior-spray-foam/>
- Building Science Insight 057: Hockey Pucks and Hydrostatic Pressure
<http://buildingscience.com/documents/insights/bsi-057-hockey-pucks-and-hydrostatic-pressure>
- Building Science Insight 062: Thermal Bridges Redux
<http://www.buildingscience.com/documents/insights/bsi062-thermal-bridges-redux>

