

Joseph Lstiburek, Ph.D., P.Eng, ASHRAE Fellow

Building Science

Adventures In Building Science

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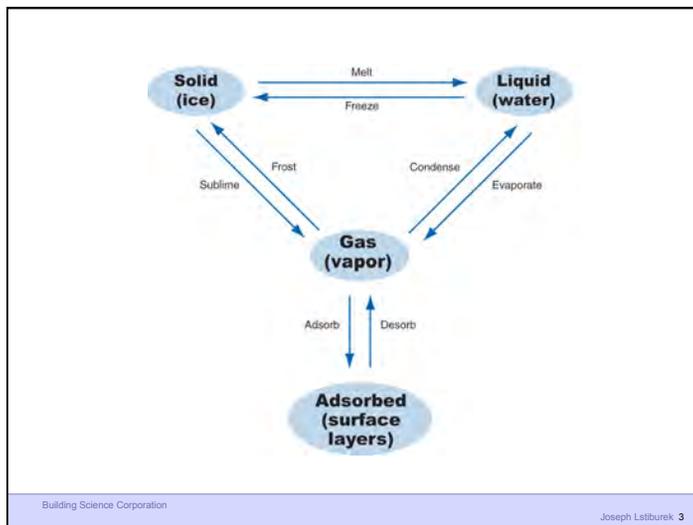
"It isn't what we don't know that gives us trouble, it's what we know that ain't so"

Will Rogers

"There are known knowns. These are things we know. There are known unknowns. There are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know."

Donald Rumsfeld

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Moisture transport processes in building materials and components

Transport Process	Phase	Potential (Difference)
Gas diffusion	Vapor	Vapor pressure
Liquid diffusion	Liquid	Concentration
Surface diffusion	Adsorbate	Concentration
Thermal diffusion	Vapor and liquid	Temperature
Capillary flow	Liquid	Suction pressure
Convective flow	Vapor	Air pressure
Gravitational flow	Liquid	Height
Poiseuille flow	Liquid	Liquid pressure

From Kumaran, M. K.; Chapter 1, Moisture in Buildings, ASTM, 1994

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Water

- Vapor is a single molecule
- Liquid is molecular clumps, 75 or more

Vapor **Liquid**

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The Water Molecule

- Asymmetrical = polar
- Small: one billion = one foot

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"Polar Molecule"

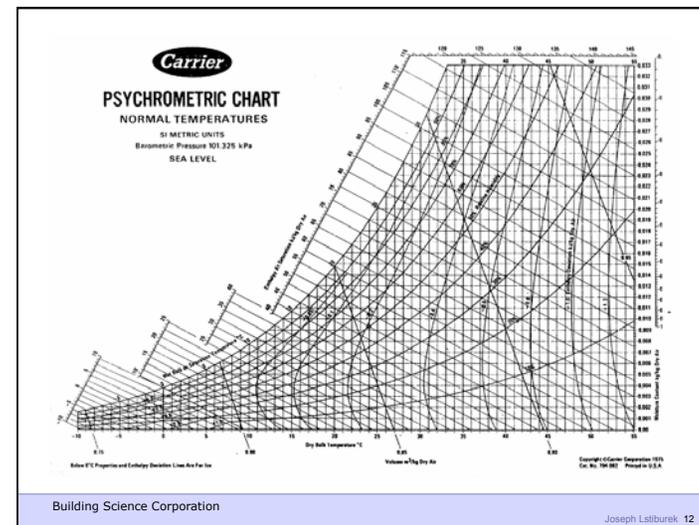
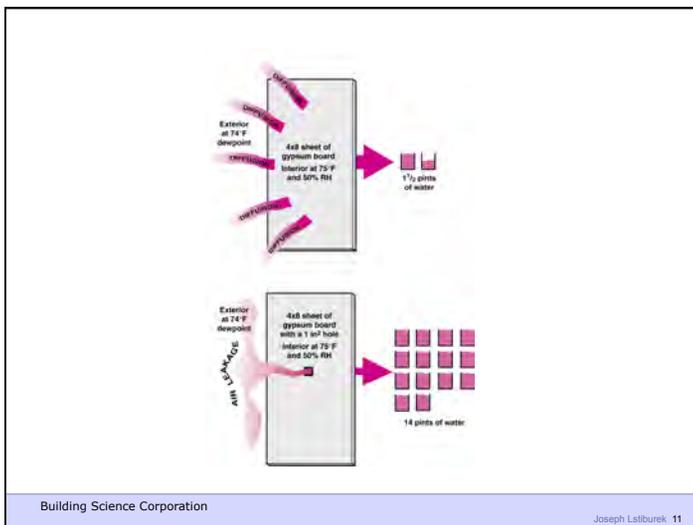
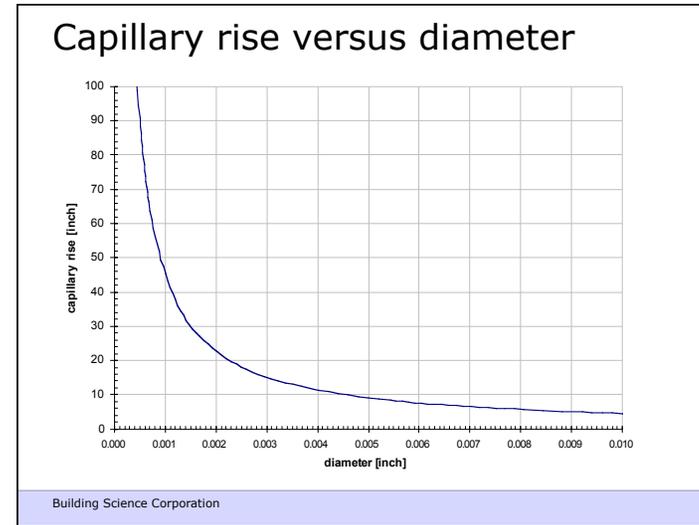
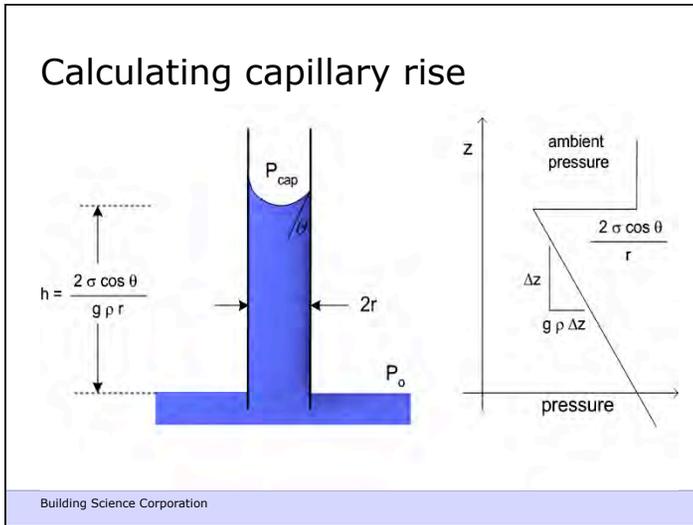
- Hydrogen end is "more" positive
- Oxygen end is "more" negative

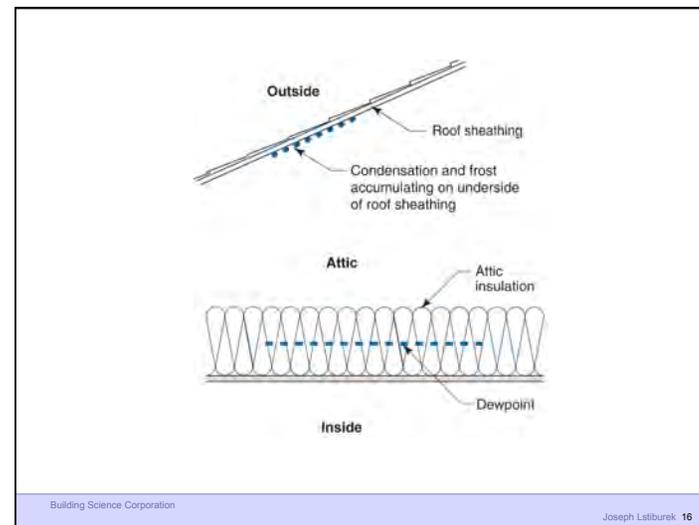
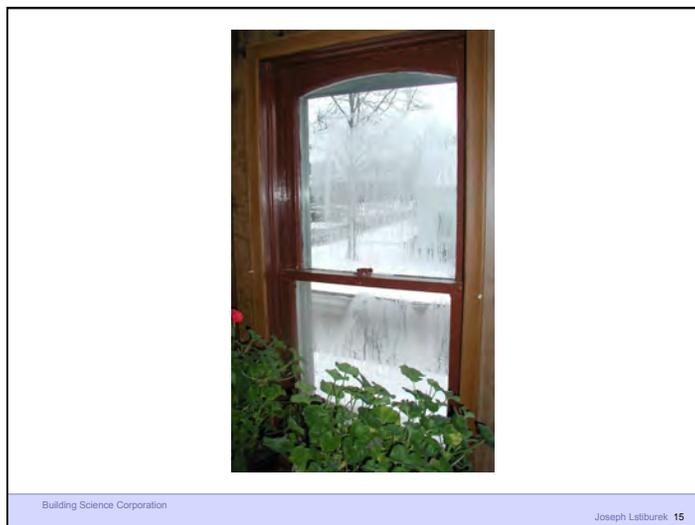
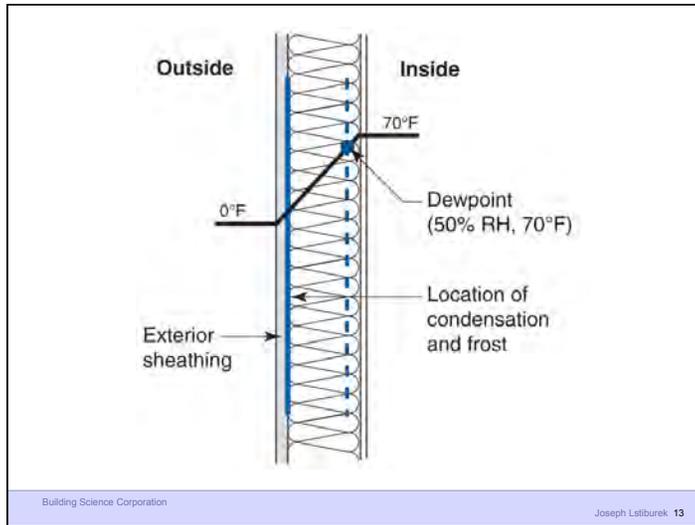
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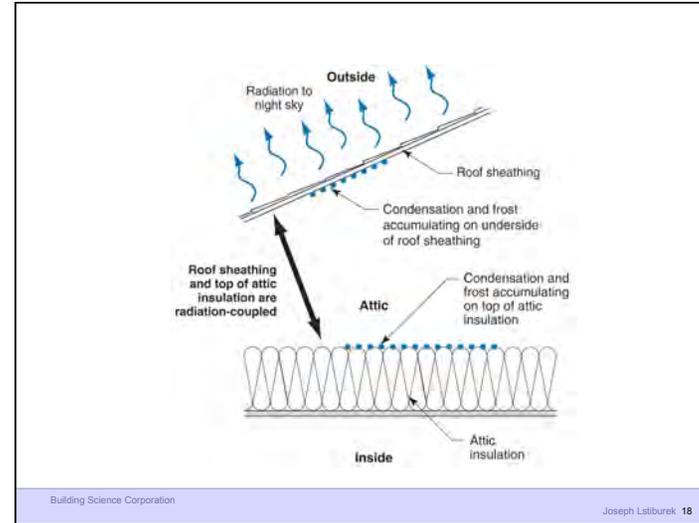
Surface Tension/Surface Energy

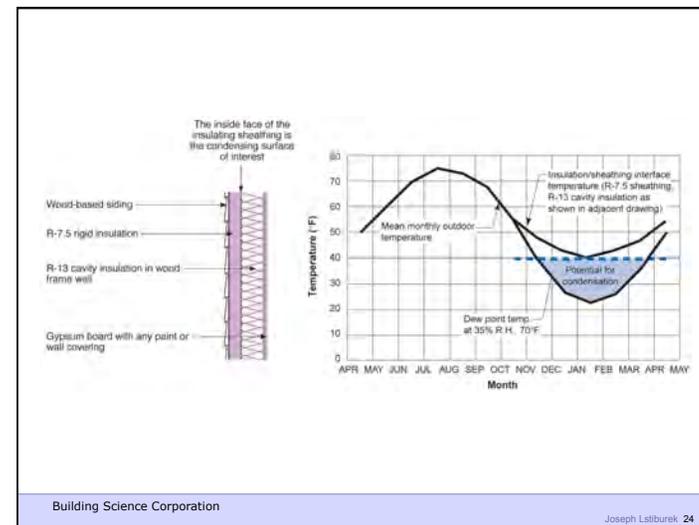
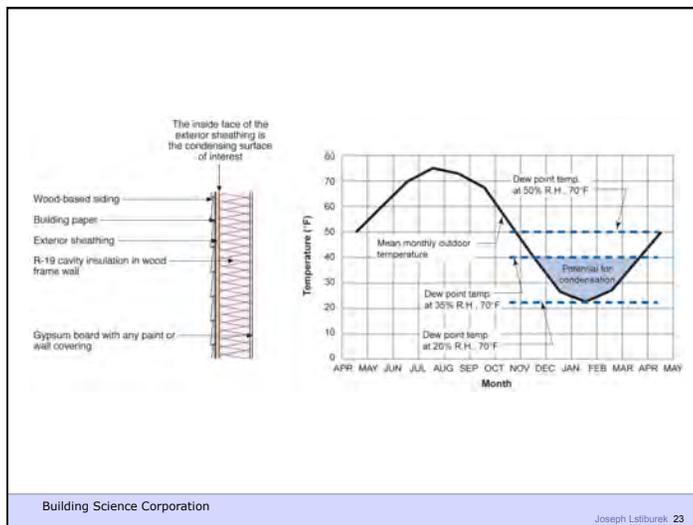
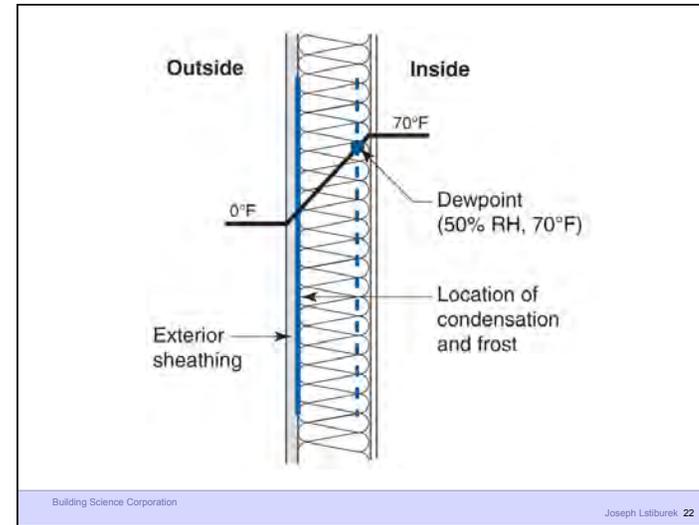
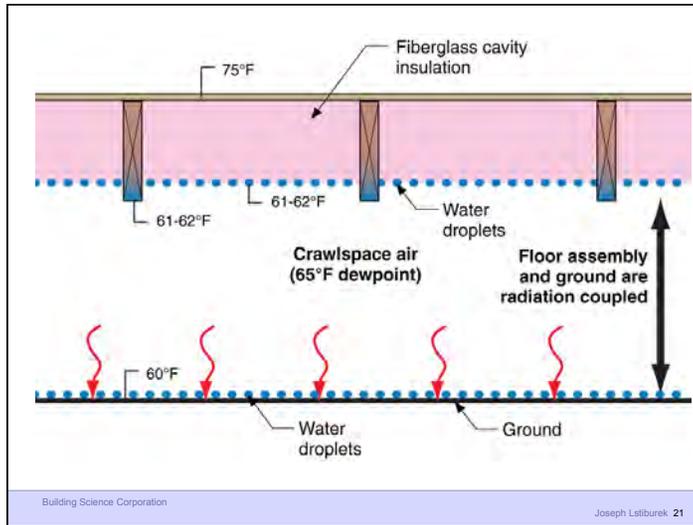
normal material: "wetable" hydrophobically treated: "non-wetable"

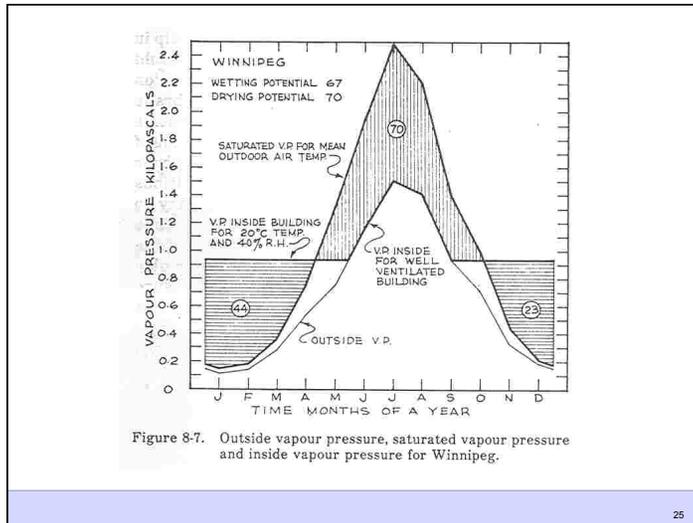
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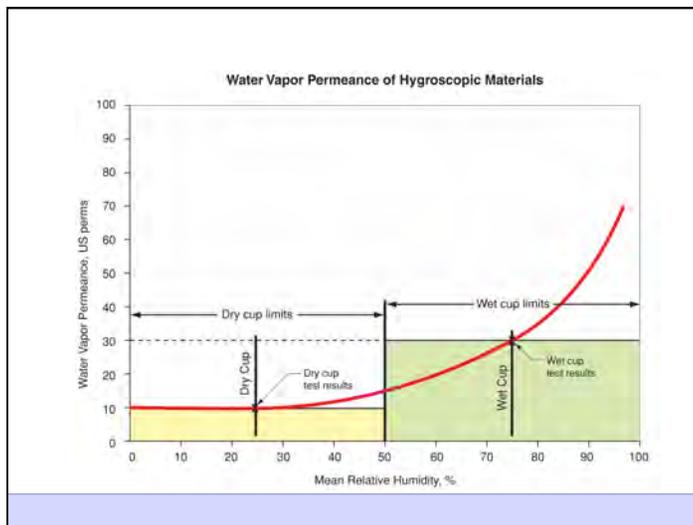
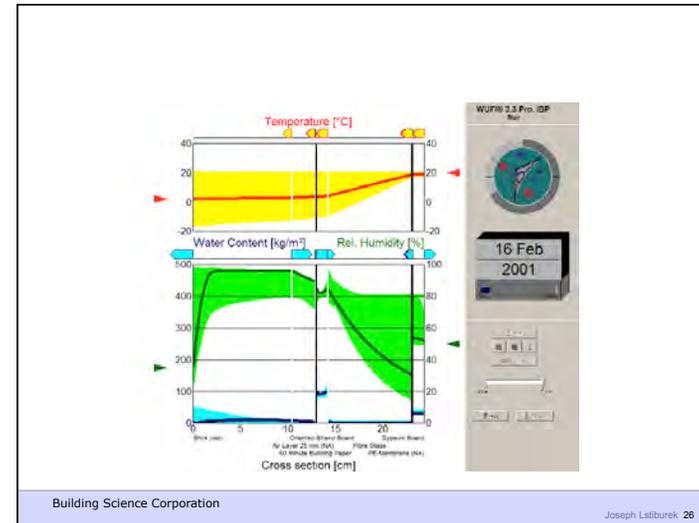


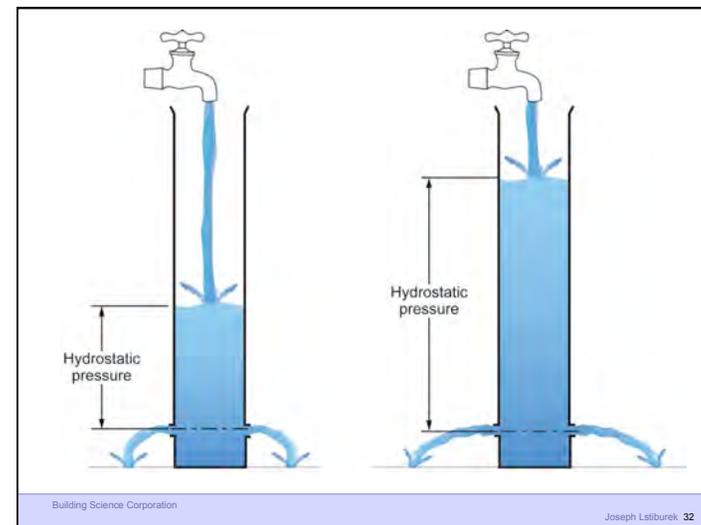
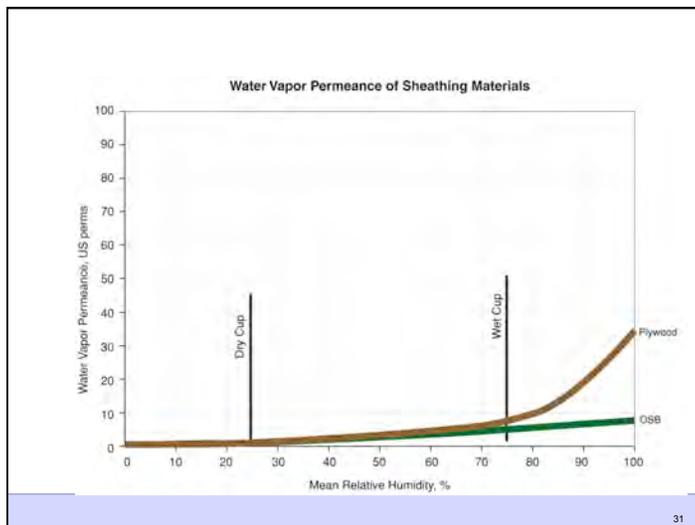
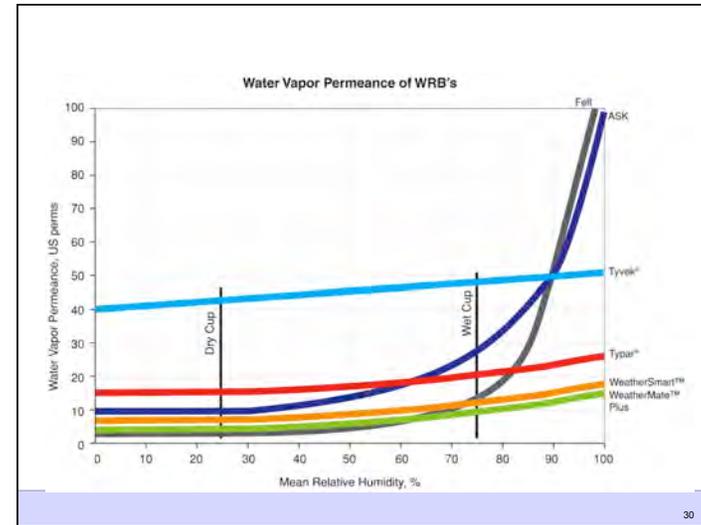
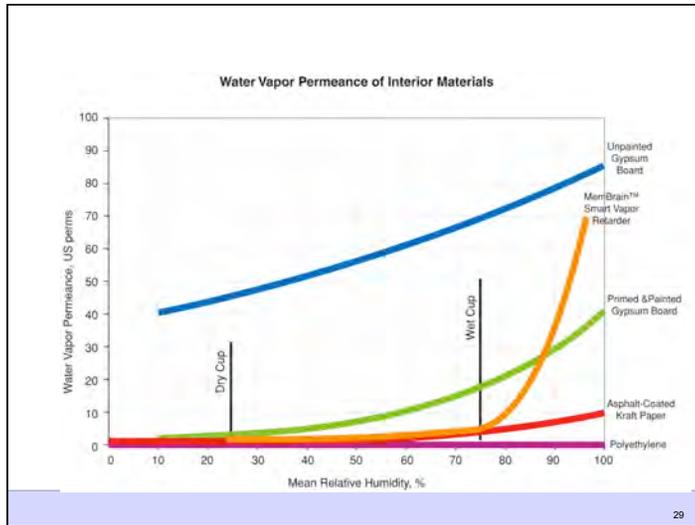


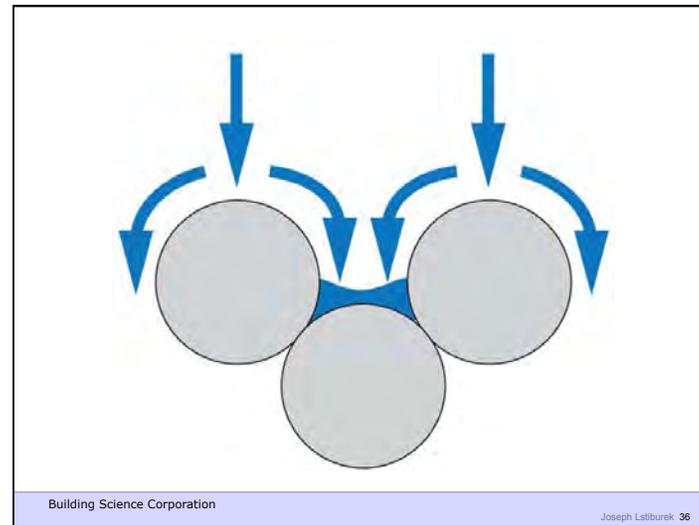
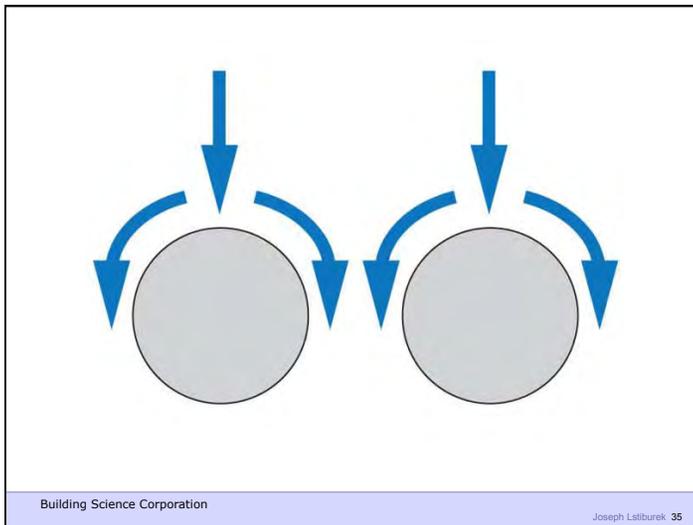
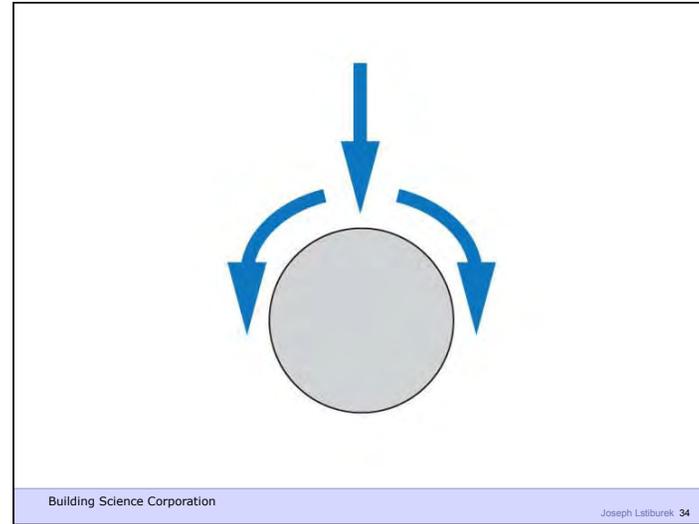


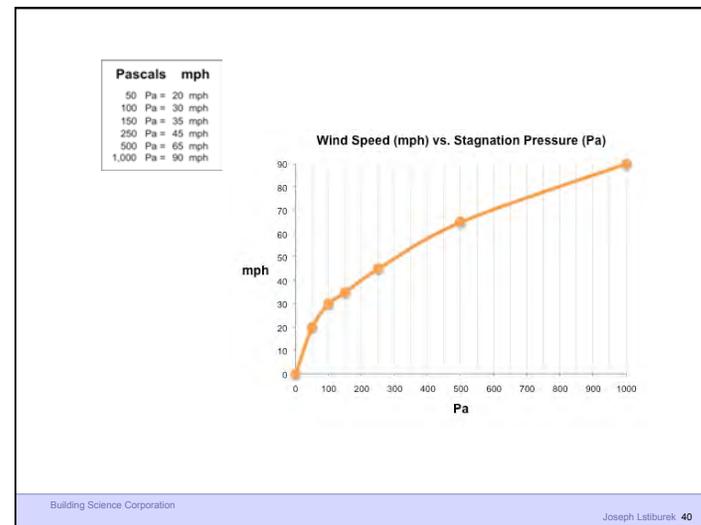
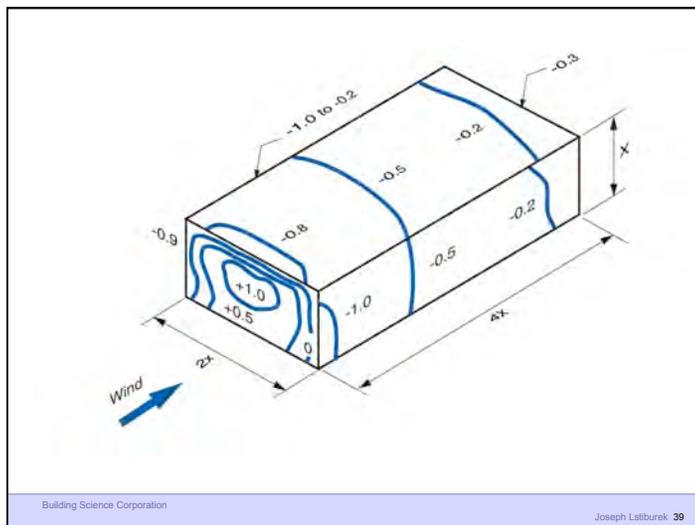
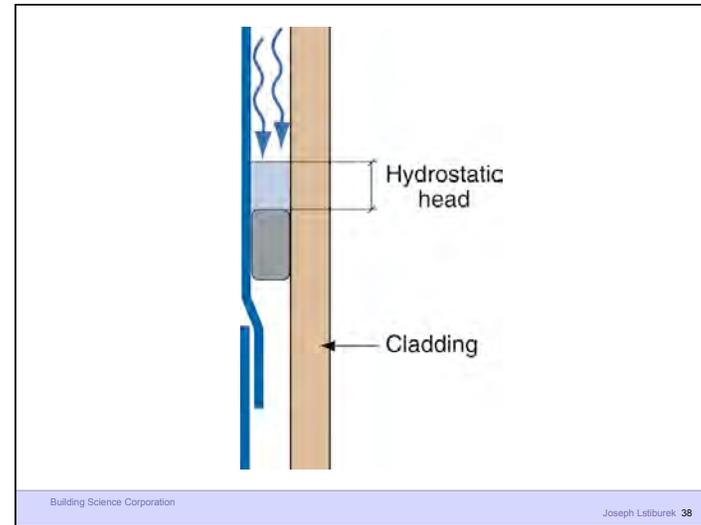
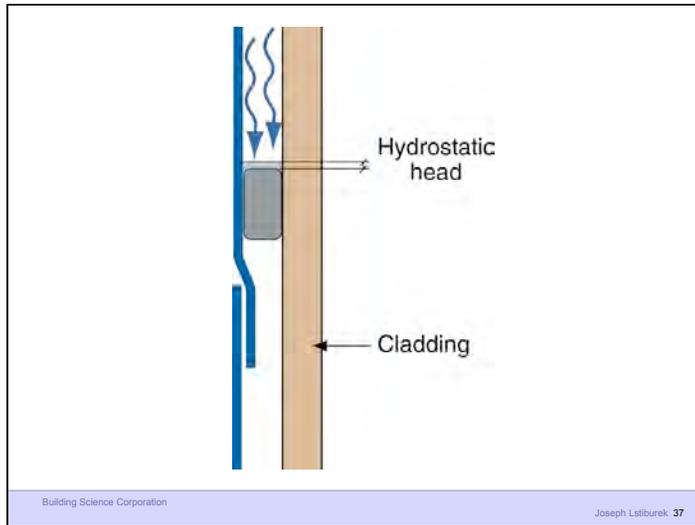


25

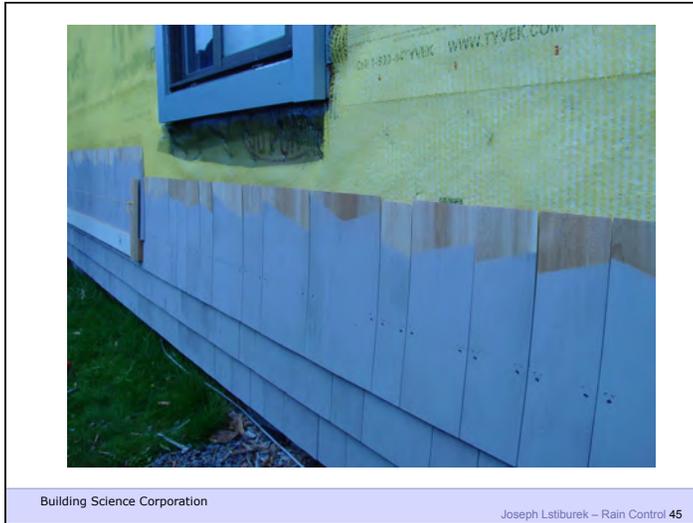














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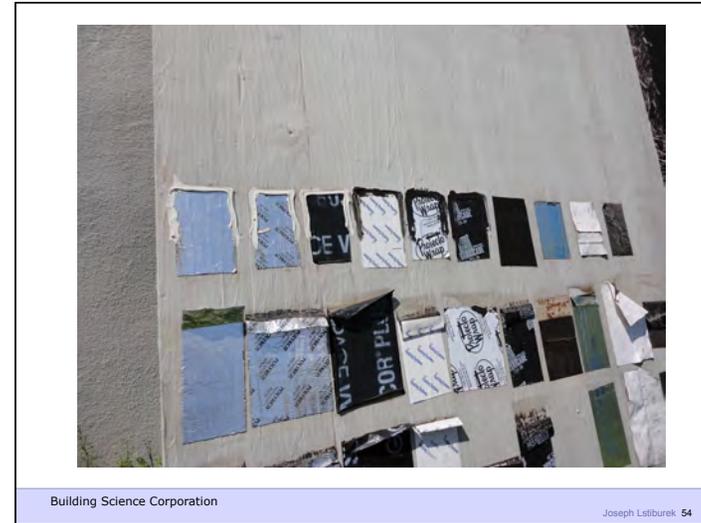
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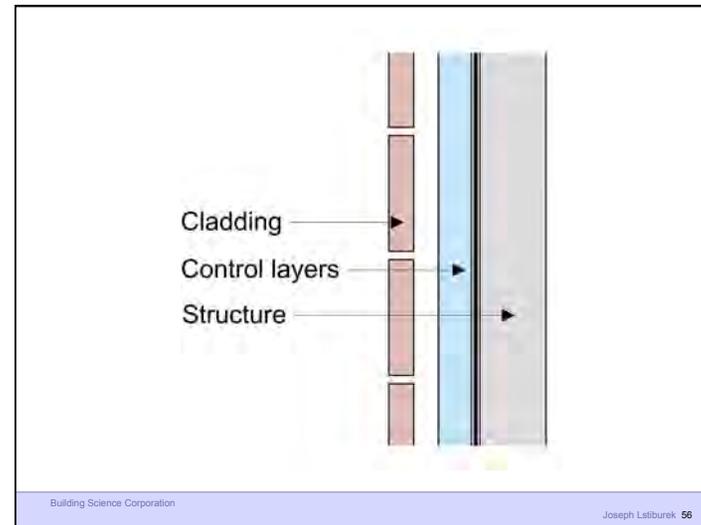
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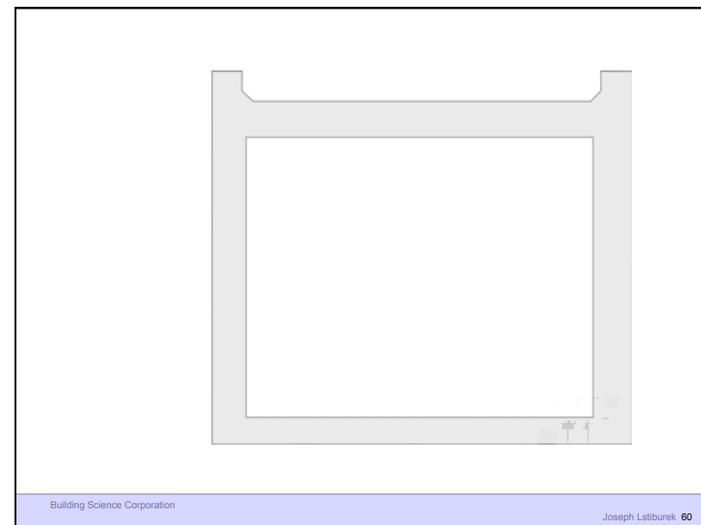
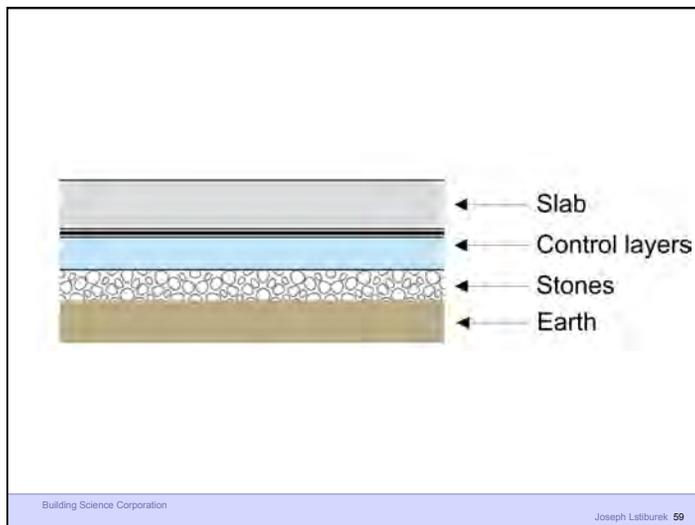
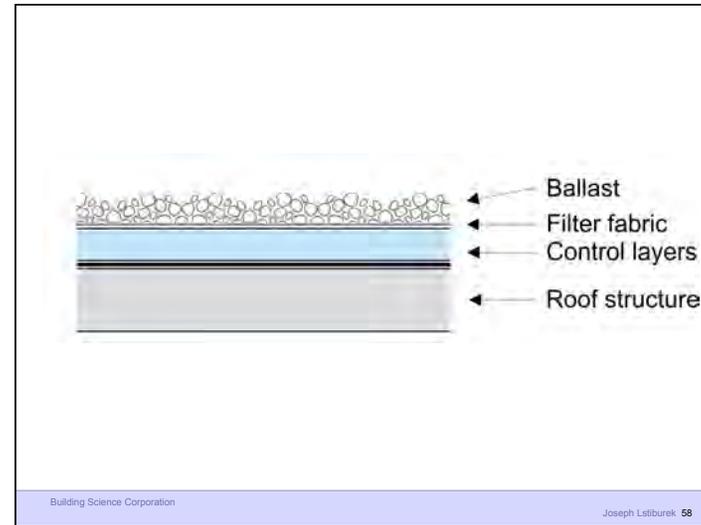
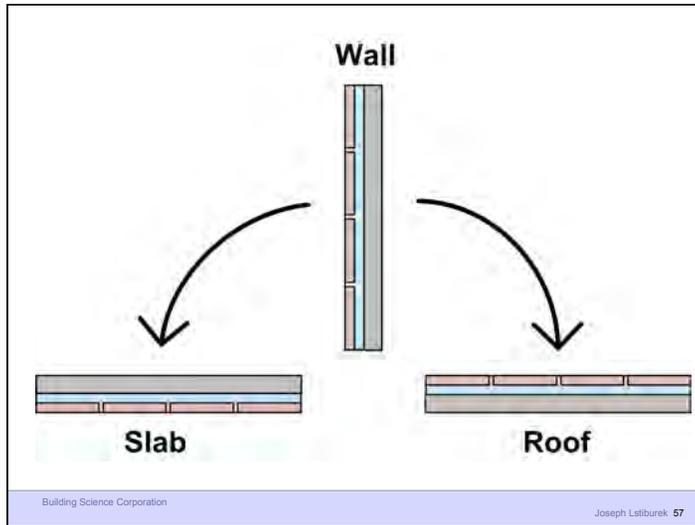
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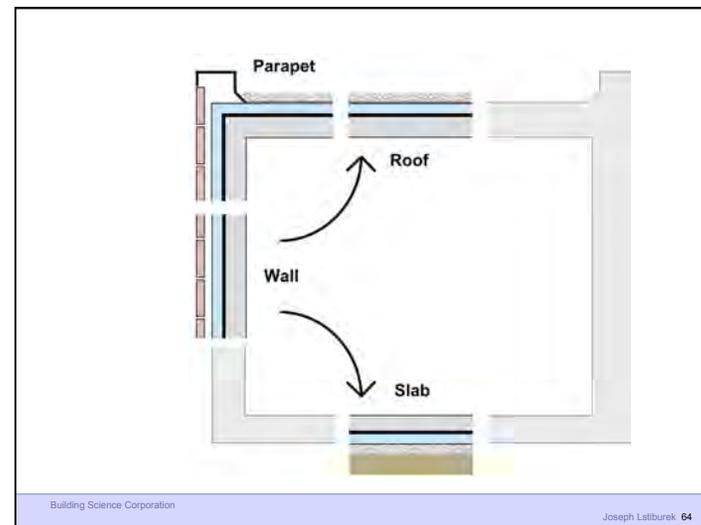
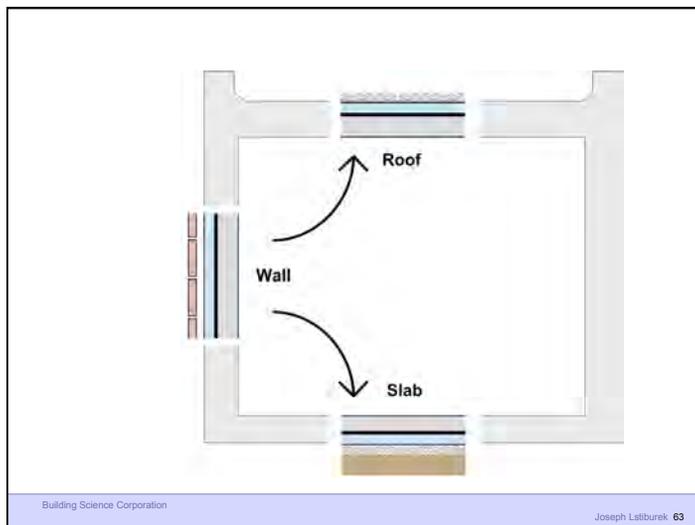
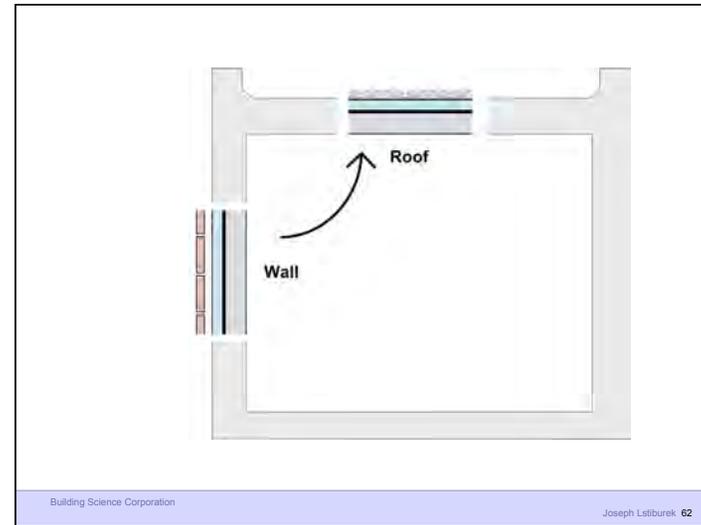
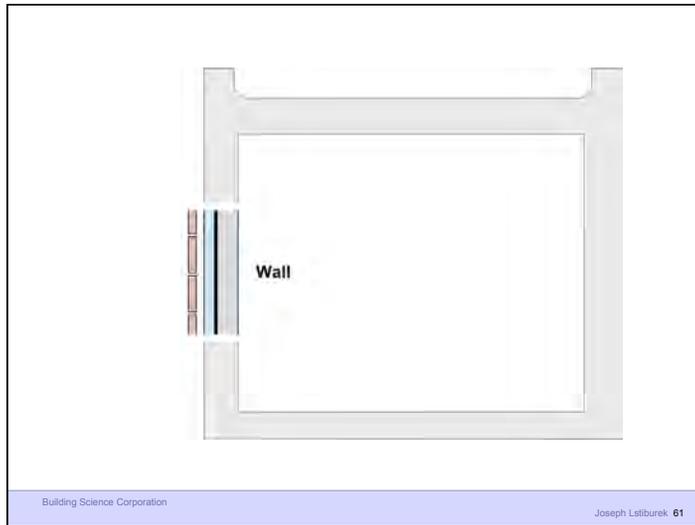


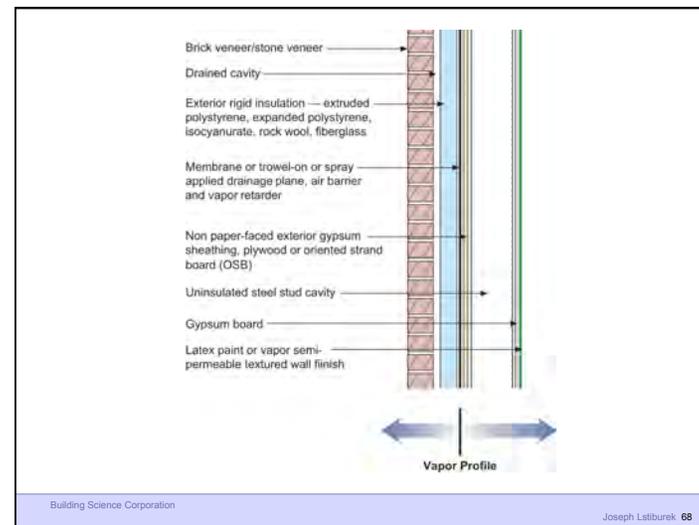
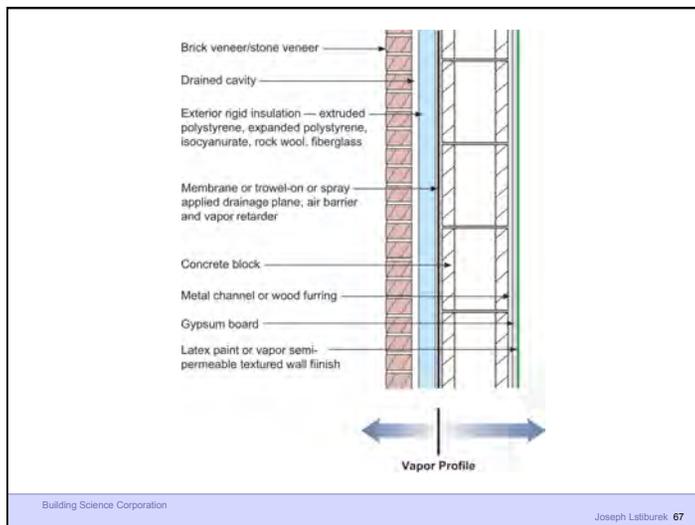
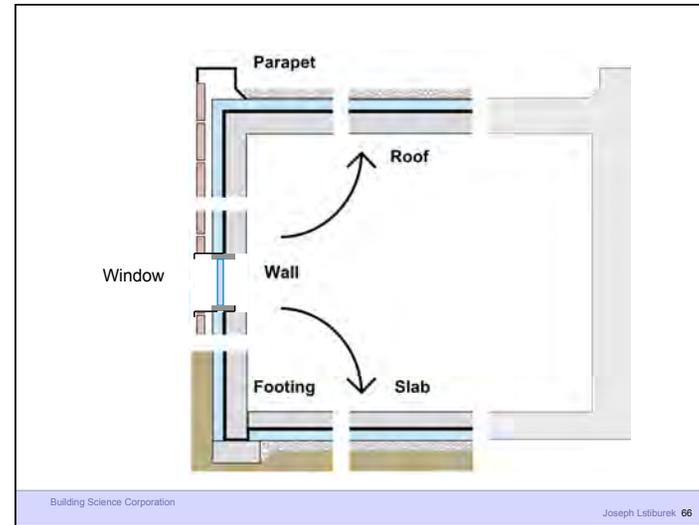
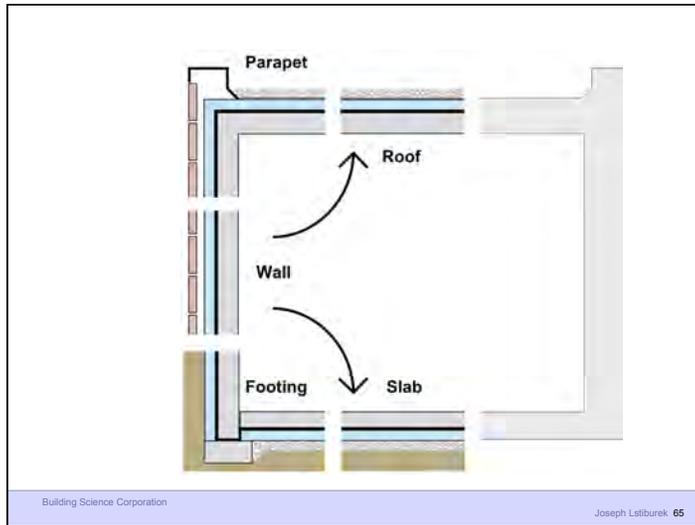
Water Control Layer
Air Control Layer
Vapor Control Layer
Thermal Control Layer

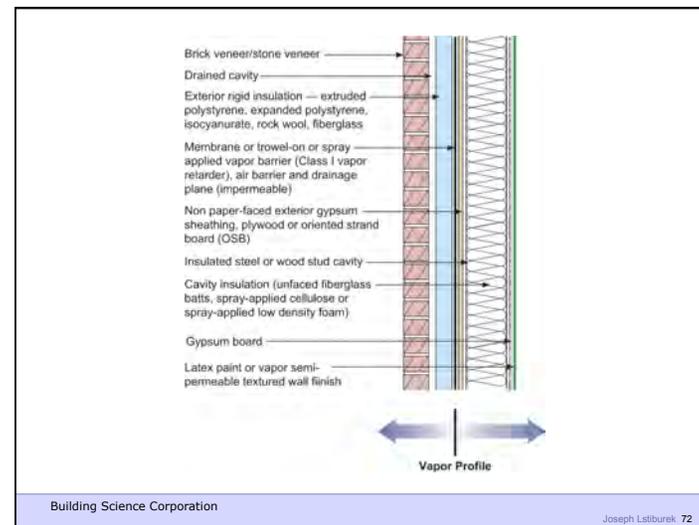
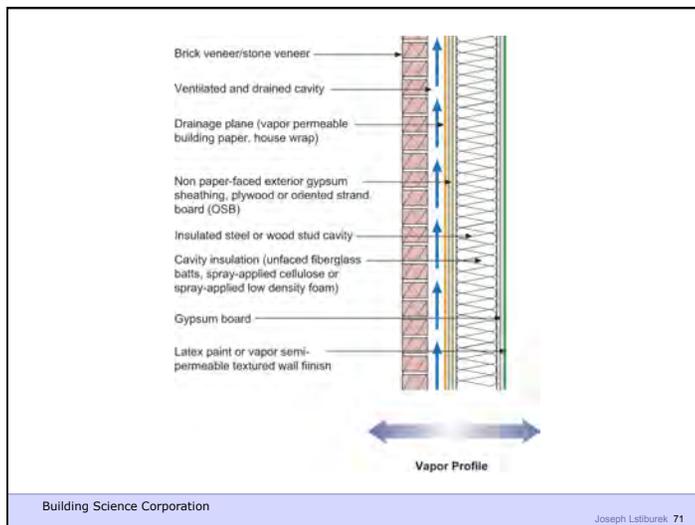
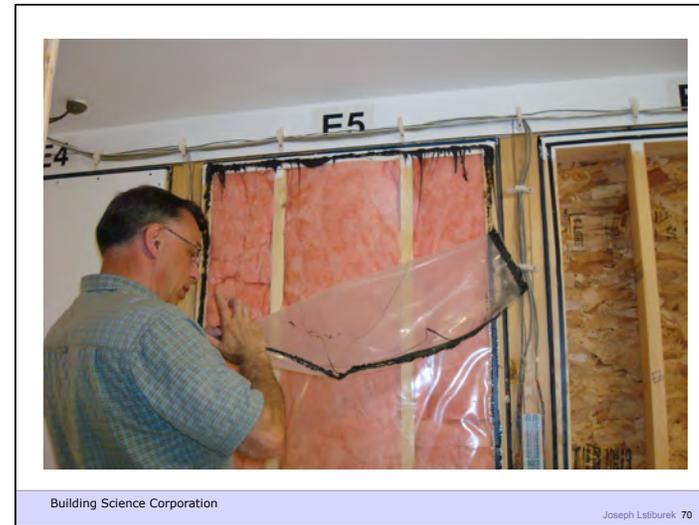
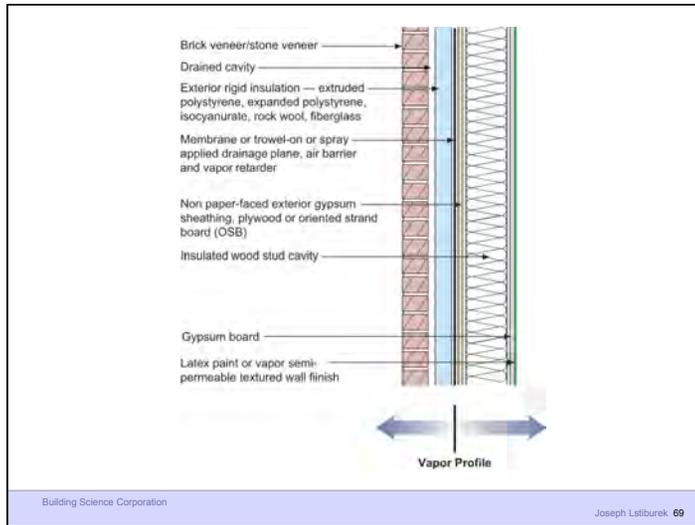
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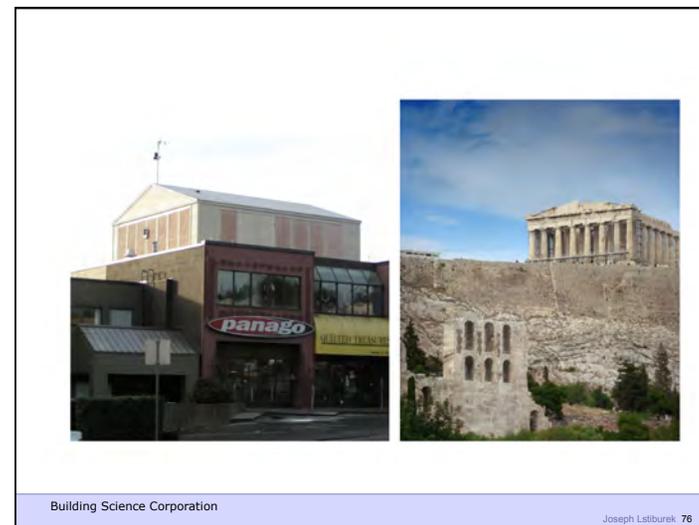
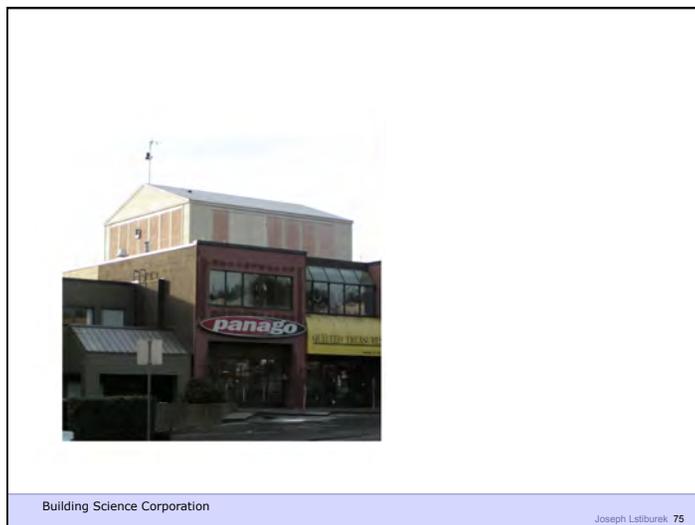
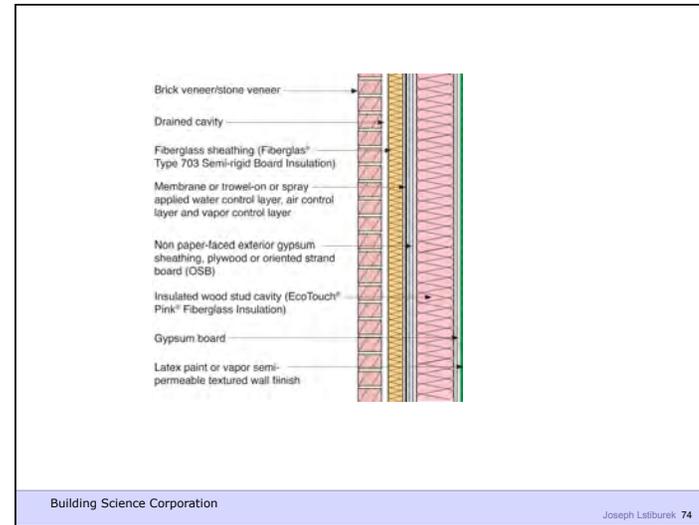
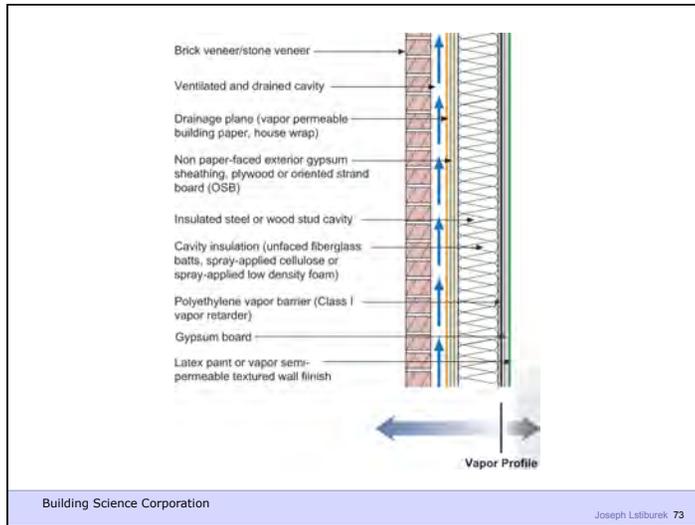


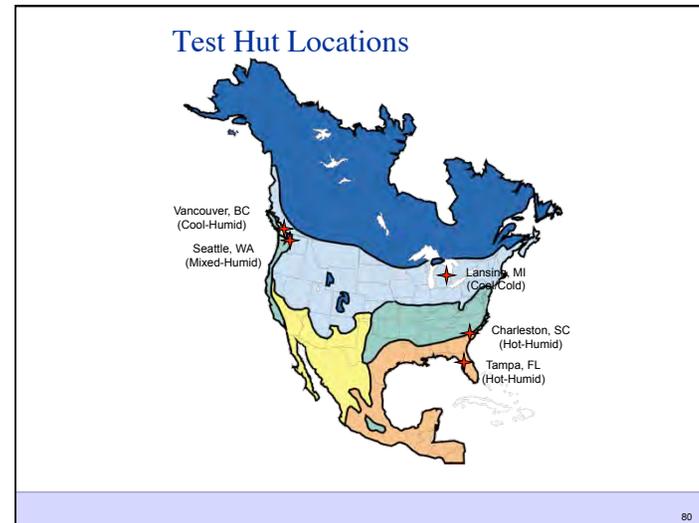
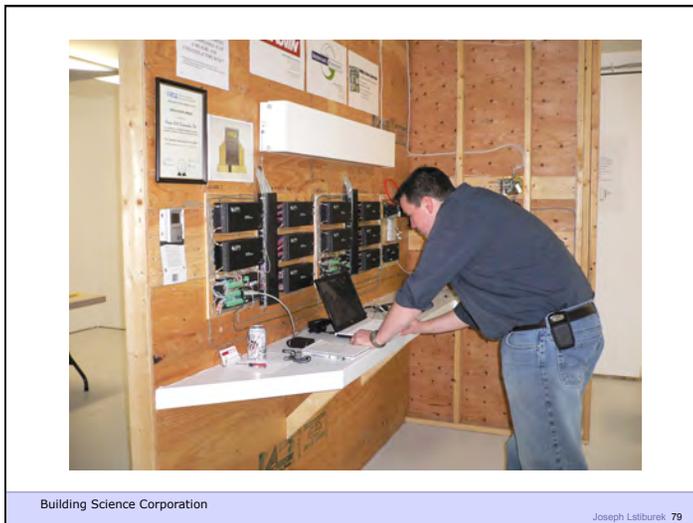


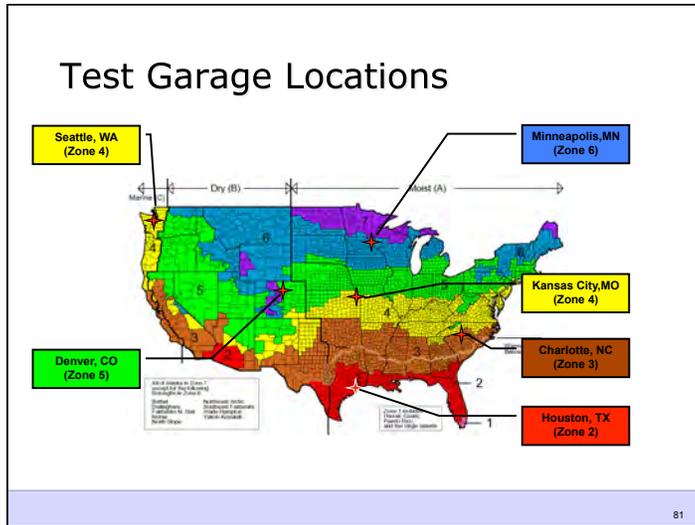












Monitoring

- Measure every 5 minutes, save every hour
- Stored locally with battery back up
- Ethernet connection allows data to be collected from any Internet connection

85

Experimental Approach

- Run for 12 months
 - A. How do perfect walls behave under normal conditions?
- Run for 12 months
 - B. Introduce calibrated “leaks”
 - Different times of year
 - Different quantities

86

A calibrated leak

- Known quantity
- Known location
- Known time
- Avoid draining

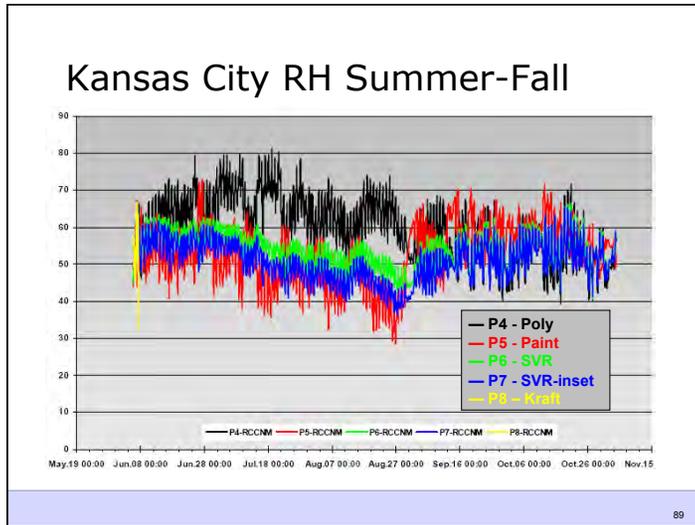


87

Methodology

- Model homes in Cold, Mixed-Humid, and Hot-Humid climate zones.
- Logged wall conditions, and indoor & outdoor temperature, relative humidity; physical condition of assembly periodically checked
- Comparison to hygrothermal models
- Tune hygrothermal models based on experimental results
- Comparison to proposed code language
- Adjust code proposed code language
- Iterate as often as necessary – politics driven but physics constrained

88



402.2.2 Material vapor retarder class. The vapor retarder class shall be based on the manufacturer's certified rating as a rated assembly. The following shall be deemed to meet the class specified:

- Class 1: One polyethylene, non-perforated membrane foil.
- Class 2: Kraft-faced fiberglass wool.
- Class 3: Low-permeability foam.

402.2.3 Water retarders, Class 1 or 2. Water retarders are treated as the pressure plane of a wall, except as follows: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100.

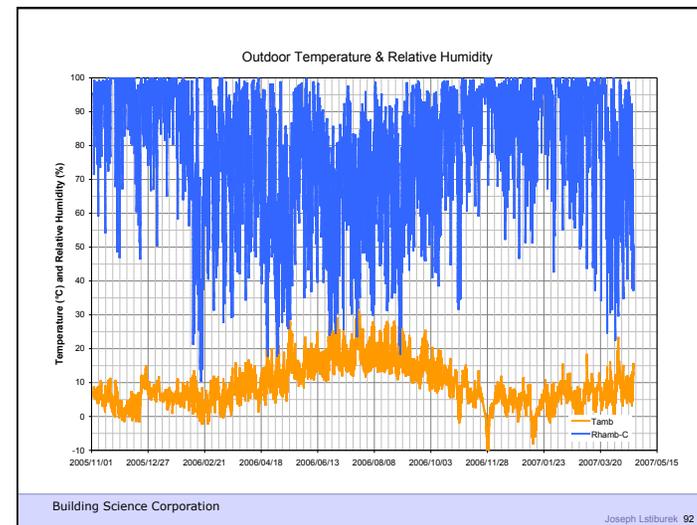
Class	Material	Permeance (perms)
1	One polyethylene, non-perforated membrane foil	≤ 0.01
2	Kraft-faced fiberglass wool	≤ 0.01
3	Low-permeability foam	≤ 0.01

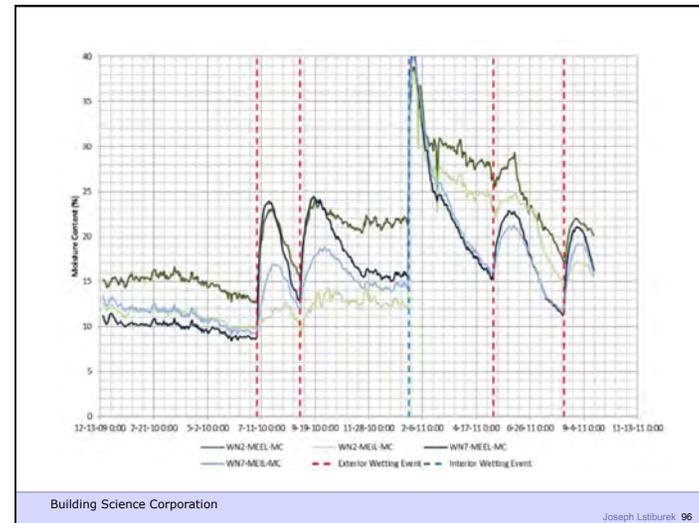
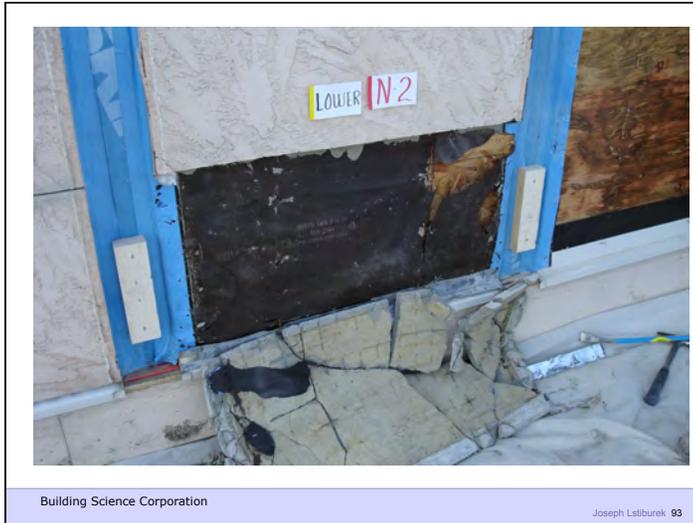
402.2.4 Material vapor retarder class. The vapor retarder class shall be based on the manufacturer's certified rating as a rated assembly. The following shall be deemed to meet the class specified:

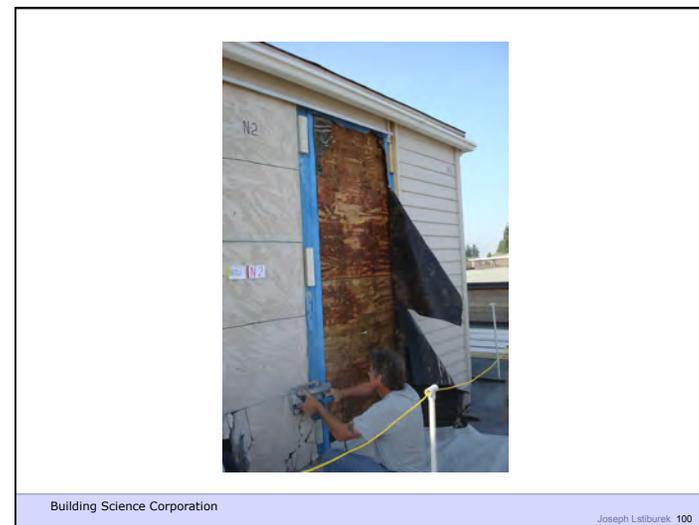
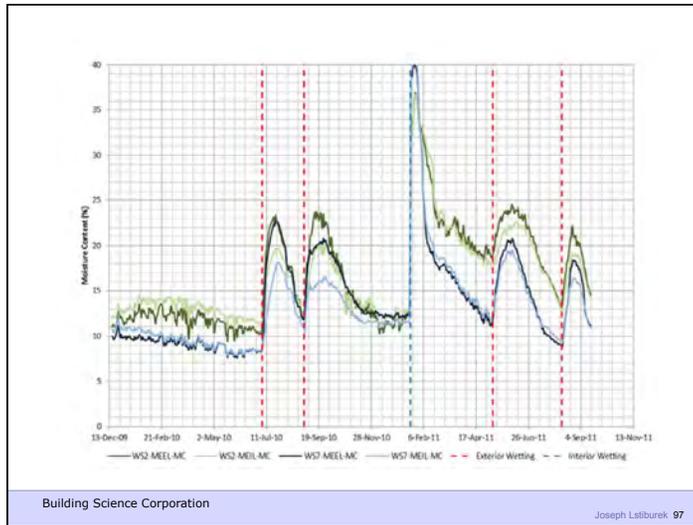
- Class 1: One polyethylene, non-perforated membrane foil.
- Class 2: Kraft-faced fiberglass wool.
- Class 3: Low-permeability foam.

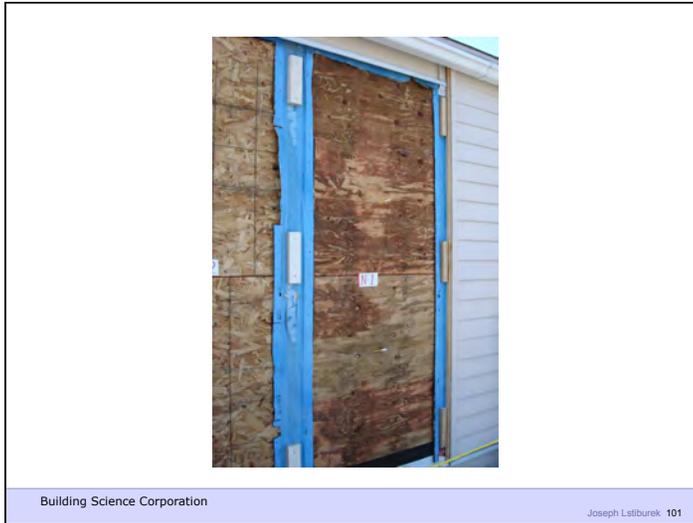
402.2.5 Water retarders, Class 1 or 2. Water retarders are treated as the pressure plane of a wall, except as follows: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100.

90

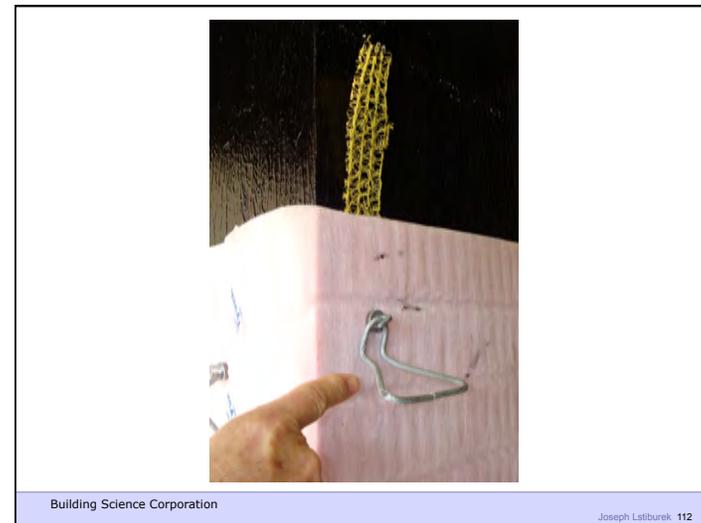


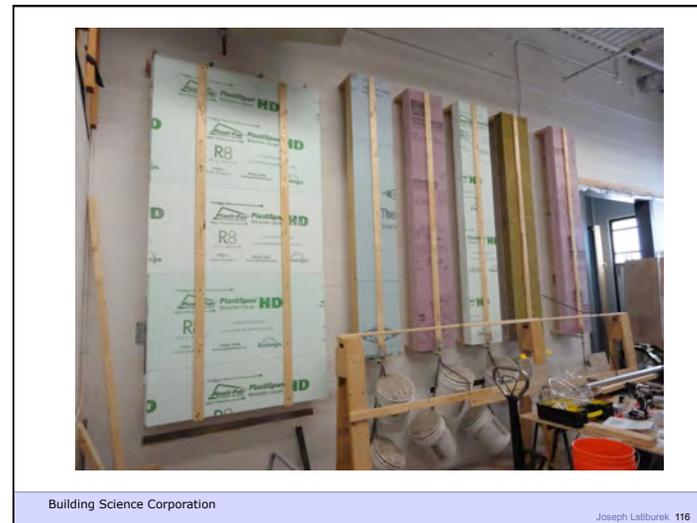
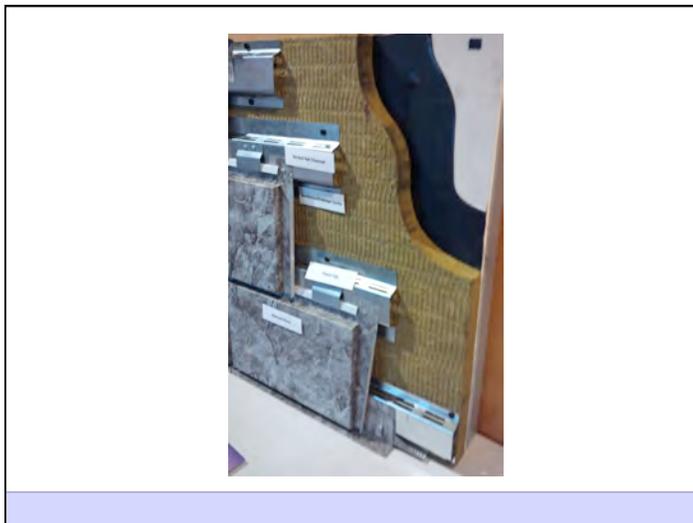


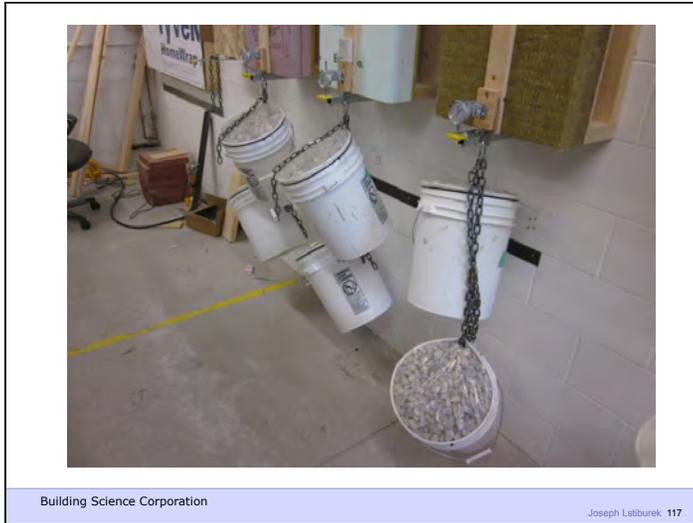












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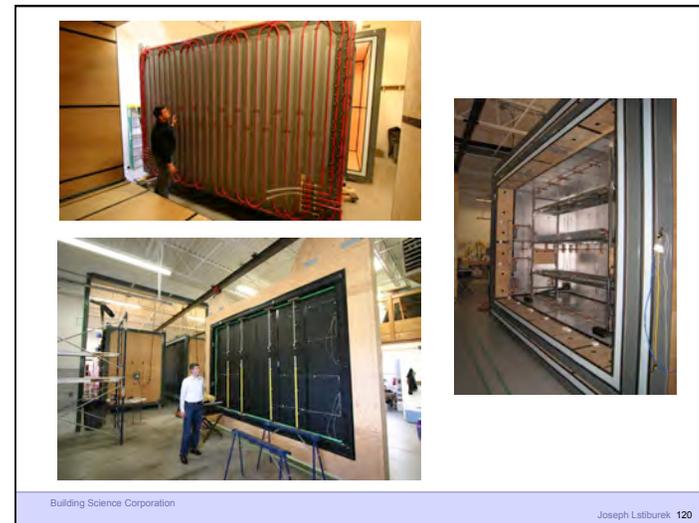
Rockwool

1x3 furring @ 24" o.c.
#10 screws @ 16" o.c. vertically
Result: 20 psf cladding weight
with < 2/100" deflection

Energy Impact of Gaps?

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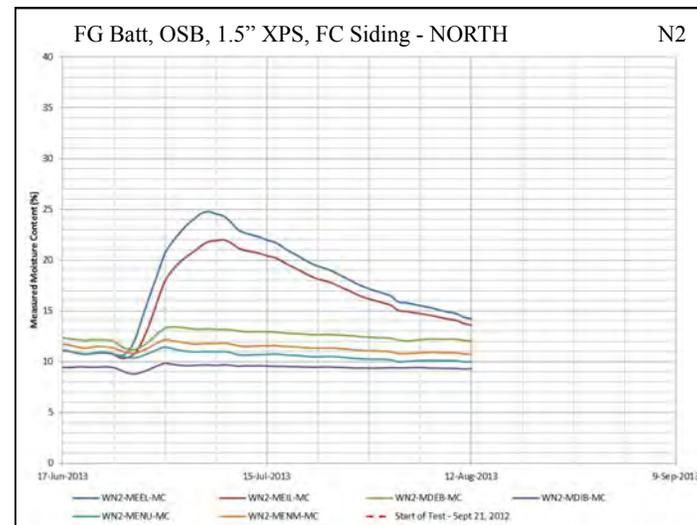
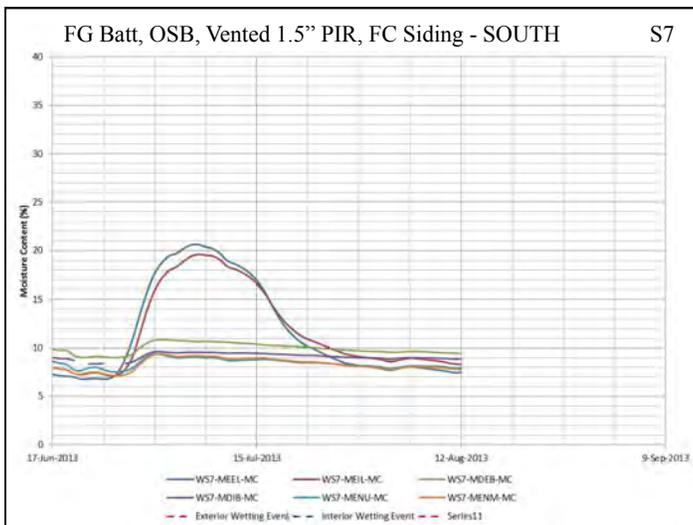
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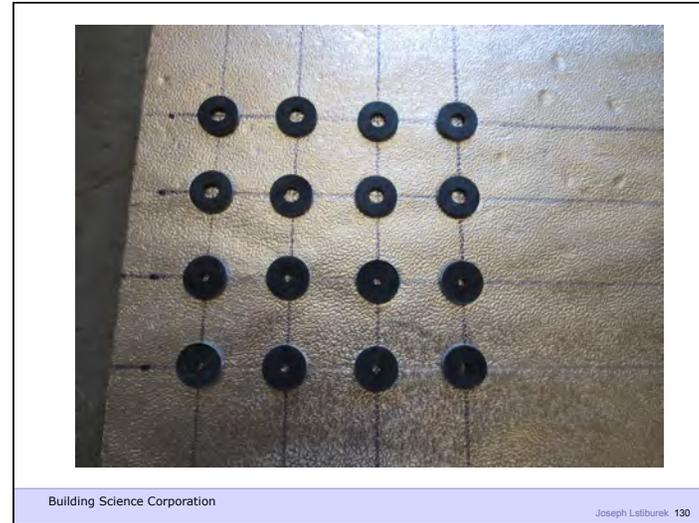




Rain Screen

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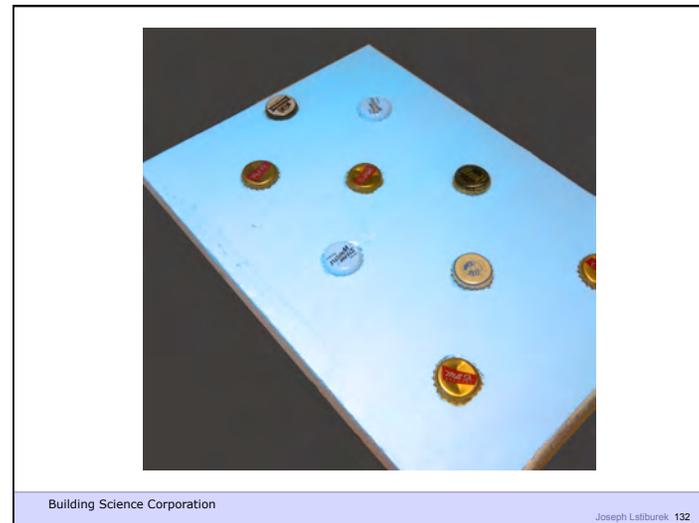
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Beer Screen?

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Research ongoing

Building Science Labs paper
(CCBST 2014)(Smegal & Straube)

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