Membranes

Manitoba Building Envelope Council
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Mom's Rules of Building Science

- →Close the window / door / fridge
  - →Airtightness matters
- →Wear a hat
  - →Sunshade, rain shelter
- →Don't tuck pants into boots
  - →Drainage and shingling
- →Wear your jacket, sweater, mittens
  - › Insulate on the outside

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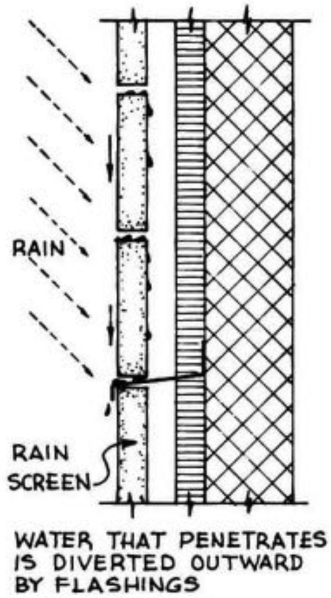
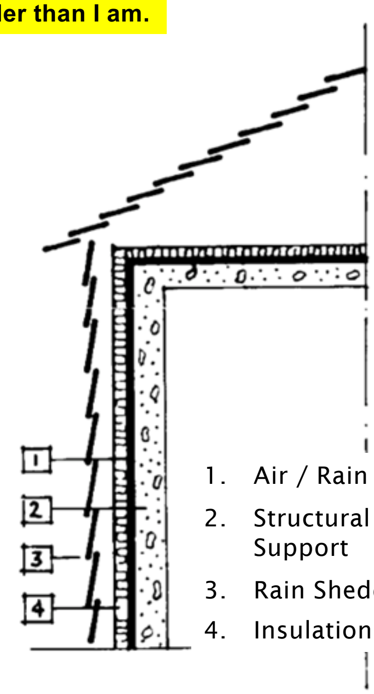
2

Design Information older than I am.





1. Air / Rain Barrier
2. Structural Support
3. Rain Shedding
4. Insulation

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3

Functions of the Building Enclosure
→Review

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The Enclosure: An Environmental Separator

→The part of the building that physically ***separates*** the ***interior*** and ***exterior*** environments.

→Includes all parts that make up the wall, window, roof, floor, caulked joint etc.

→Sometimes, interior partitions also are environmental separators (pools, rinks, etc.)

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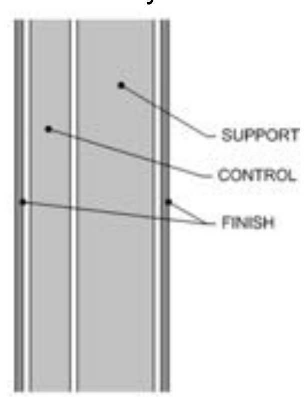
Basic Functions of the Building Enclosure

1. **Support**
   → Resist and transfer physical forces from inside and out
2. **Control**
   → Control mass and energy flows
3. **Finish**
   → Interior and exterior surfaces for people

Functional Layers



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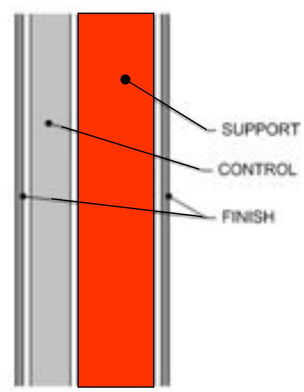
Basic Functions: Support

1. **Support**
   → Resist and transfer physical forces from inside and out
   - Lateral (wind, earthquake)
   - Gravity (snow, dead, use)
   - Rheological (shrink, swell)
   - Impact, wear, abrasion
2. **Control**
   → Control mass and energy flows
3. **Finish**
   → Interior and exterior surfaces for people

Functional Layers



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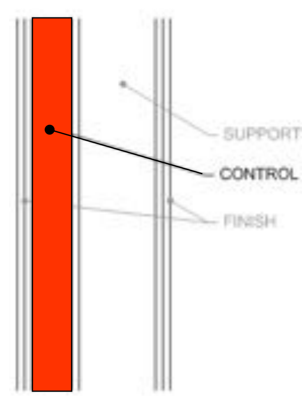
Basic Functions: Control

1. **Support**
   → Resist and transfer physical forces from inside and out
2. **Control**
   → Control mass and energy flows
   - Rain (and soil moisture)
   - Air
   - Heat
   - Vapor
3. **Finish**
   → Interior and exterior surfaces for people

Functional Layers



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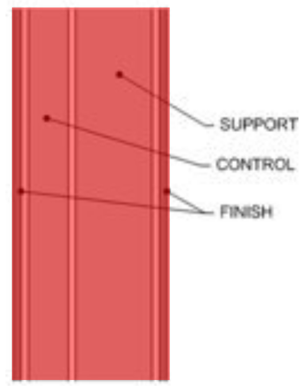
Other Control . . .

1. **Support**
2. **Control**
   - → Fire
     - › Penetration
     - › Propagation
   - → Sound
     - › Penetration
     - › Reflection
   - → Light
     - › Diffuse/glare
     - › View
3. **Finish**

Functional Layers



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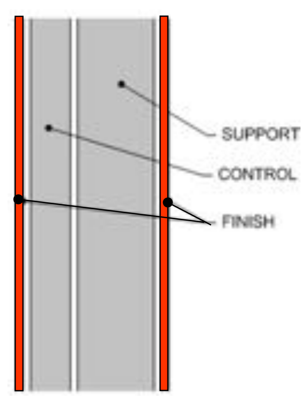
9

Basic Functions: Finish

1. **Support**
   - → Resist and transfer physical forces from inside and out
2. **Control**
   - → Control mass and energy flows
3. **Finish**
   - → Interior & exterior surfaces
     - › for people
     - › Color, speculance
     - › Pattern, texture

Functional Layers



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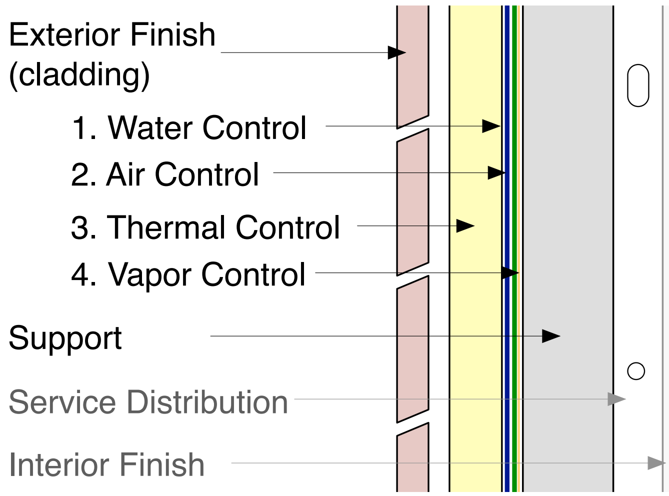
Perfect Wall: Layers = Functions



Clarity of Function
Ideal Arrangement of Materials

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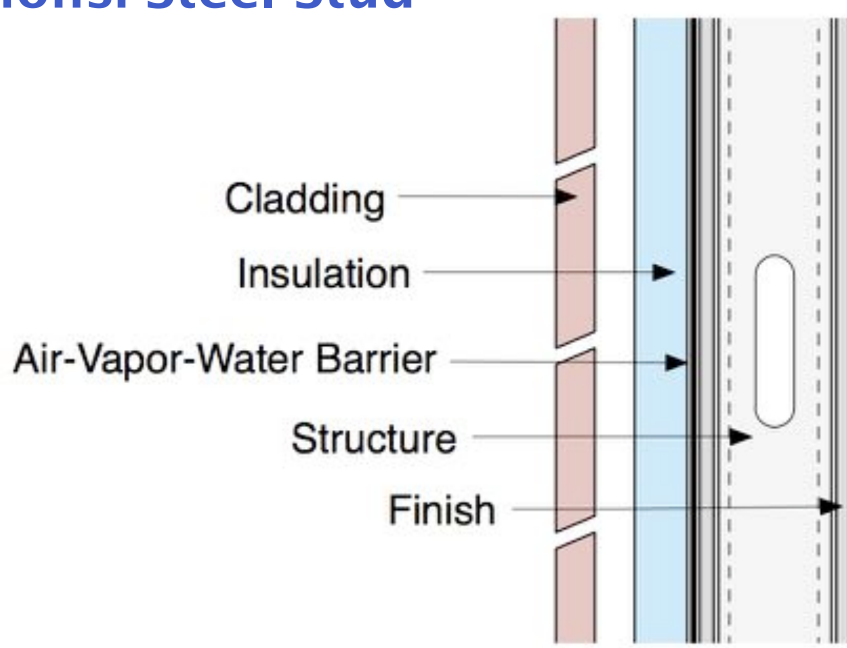
11

Variations: Steel Stud



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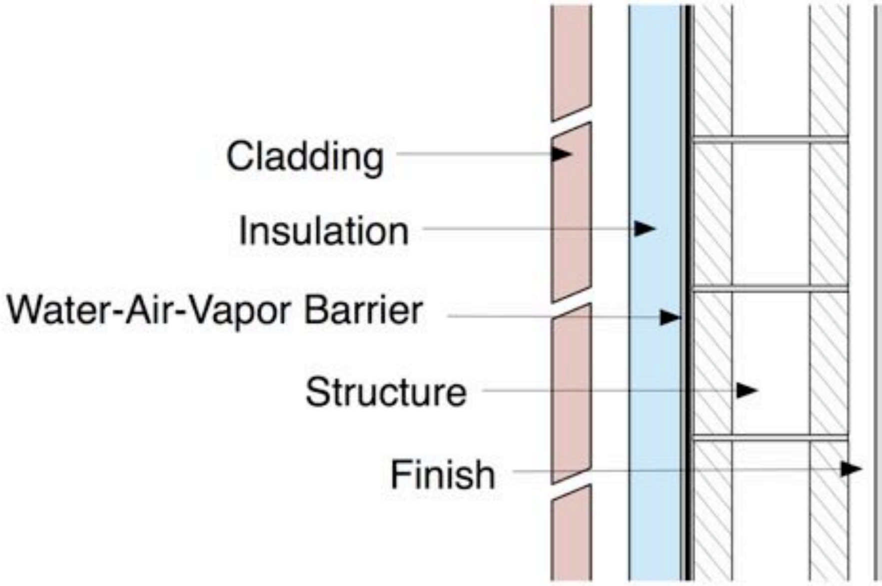
Variations: CMU Backup



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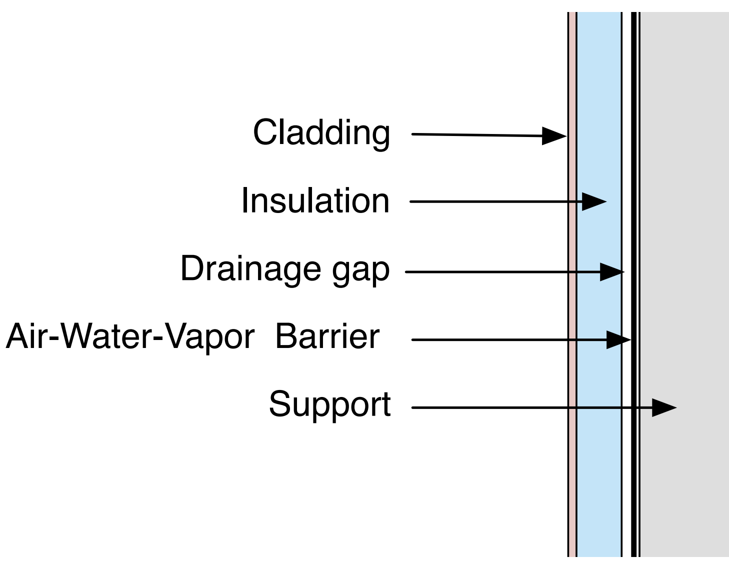
Variations: Drained EIFS

→Almost perfect retrofit



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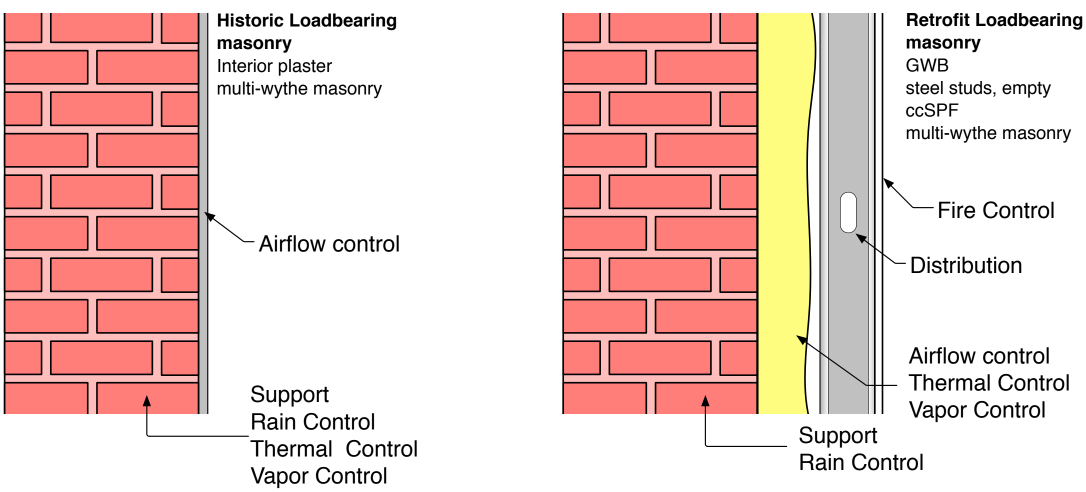
Control Layers in Mass Masonry



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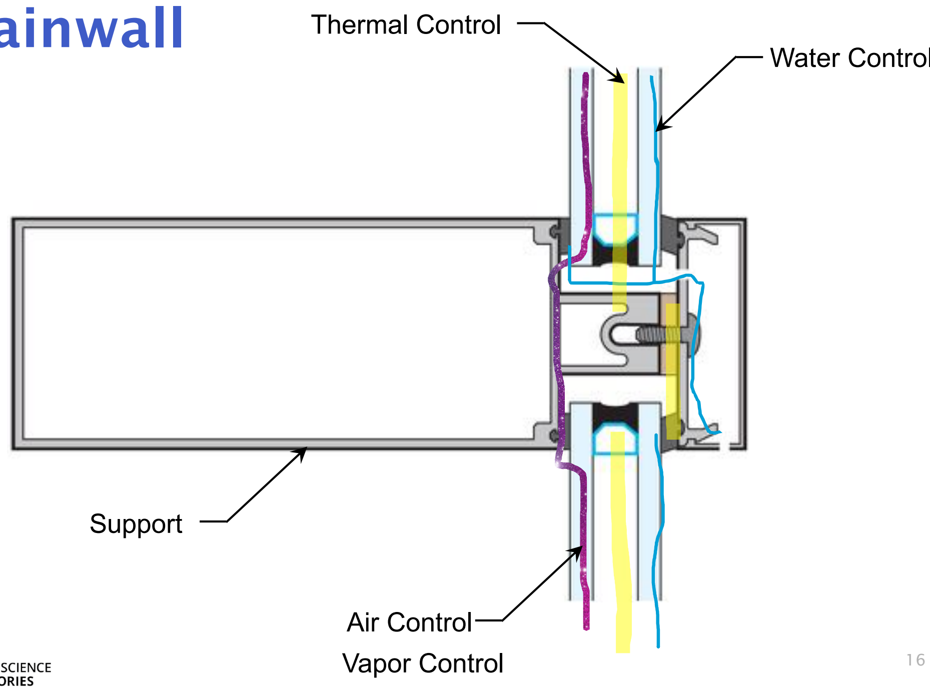
15

15

Curtainwall



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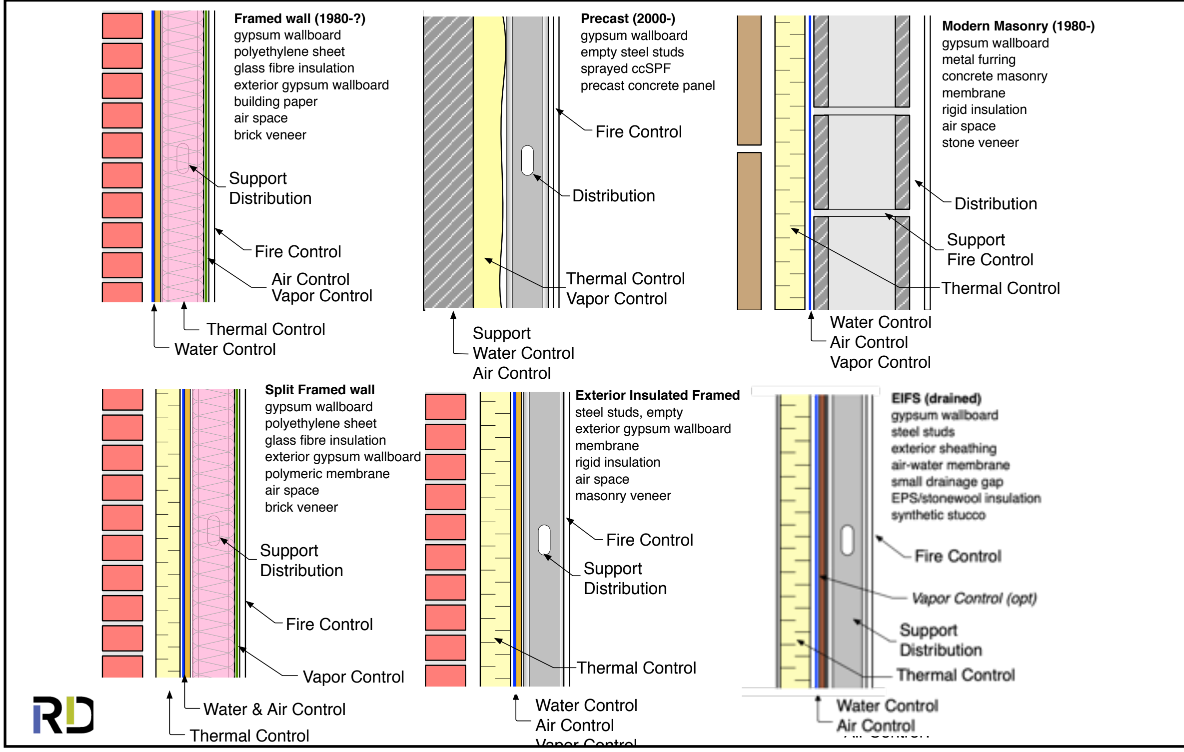
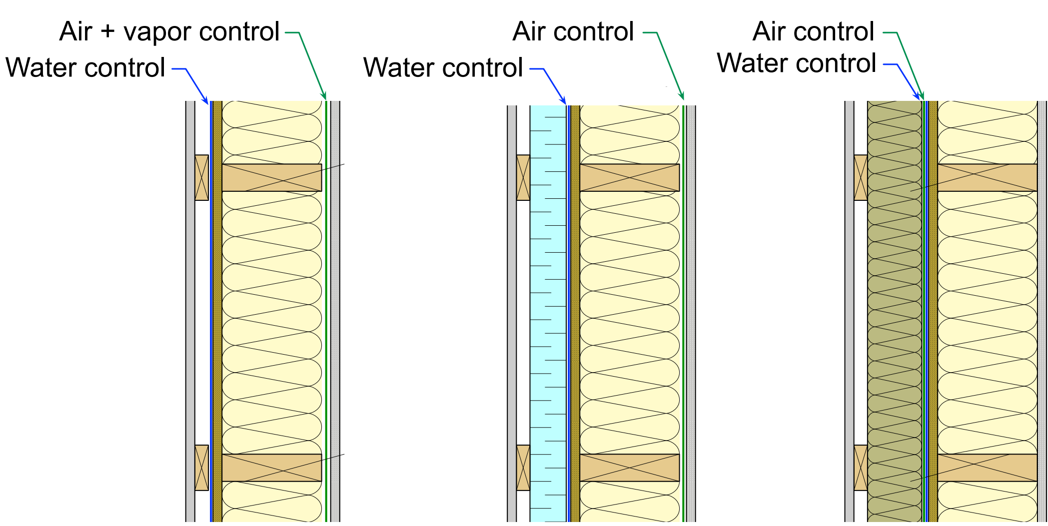
16

16



17

What are these layers? Were do they go?



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18

18

Water, Air, and Vapor Control: Layers and Products

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Code Requirements

→ Water control
→ Air Control
→ Vapor Control

3.2.4. Air Leakage

3.2.4.1. General

1) The *building envelope* shall be designed and constructed with a continuous air barrier system comprised of *air barrier assemblies* to control air leakage into and out of the *conditioned space.*

3.2.4.2. Opaque Building Assemblies

1) All *opaque building assemblies* that act as environmental separators shall include an *air barrier assembly.*

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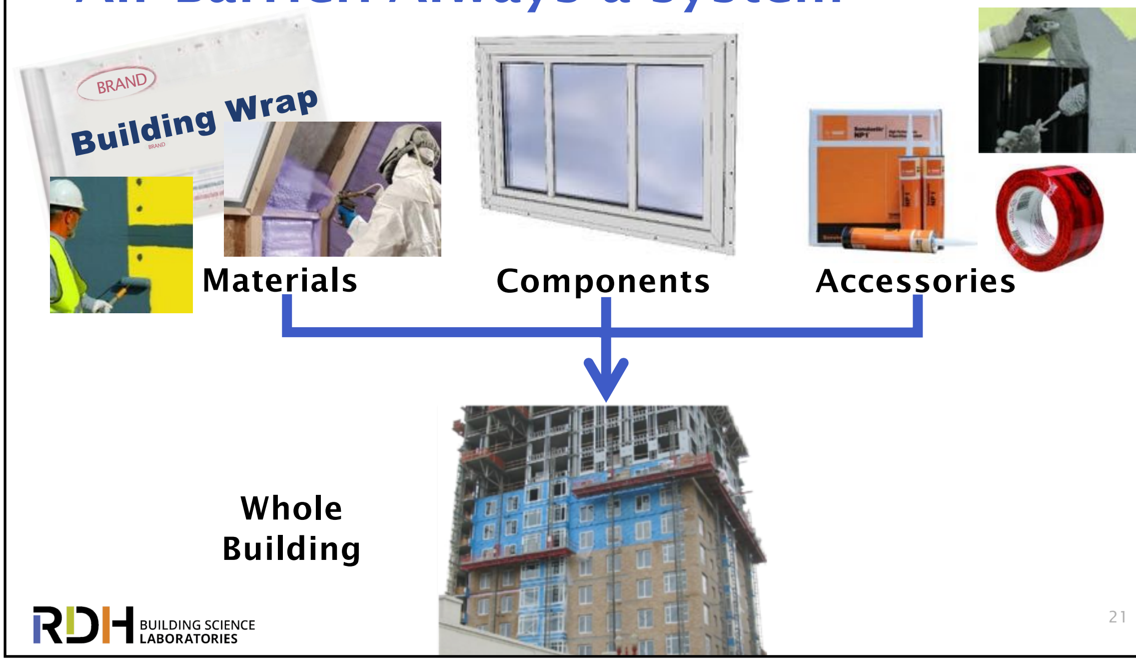
20

Air Barrier: Always a system



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21

More than just an Air Barrier?

→Modern assemblies often use materials and systems that serve more than one control function

→Thin control layers common

→Can be

1. Water control (vapor permeable, not airtight), or
2. Air & water control (vapor permeable), or
3. Air, water & vapor (vapor impermeable).

→Examples:
Building paper, untaped housewrap, sealed and supported housewrap, fluid applied (LAM), peel and stick (SAM)

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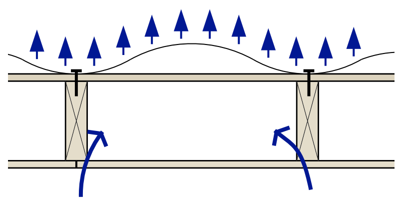
22

Fully-adhered vs. Mechanically Fastened

→ Bellows action: airtight but moves air!

→ Fully-adhered: uses substrate as support and increases airtightness



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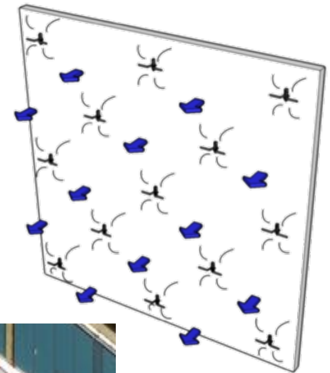
Fully-adhered preferred

→



25

25

Water, Air, and Vapor Control Products

Product Label	Water Barrier (WRB)	Air Barrier	Vapor Barrier
Primary Characteristics	Liquid Water Resistance	Air Permeance	Vapor Permeance
Secondary Characteristics	Attachment	UV Resistance Durability (oxidation)	Strength (XD/MD/ pull thru/ fatigue, temperature)

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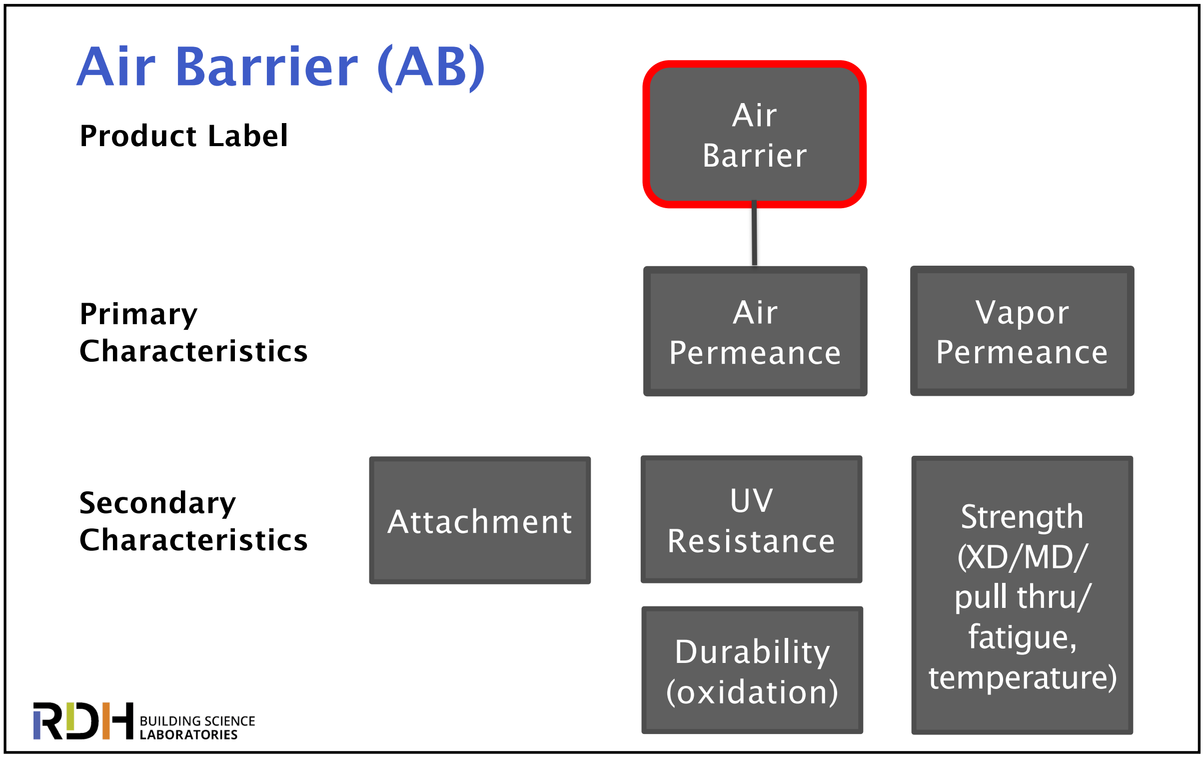
26


Air Barrier (AB)
Product Label
Air Barrier
Primary Characteristics
Air Permeance
Vapor Permeance
Secondary Characteristics
Attachment
UV Resistance
Durability (oxidation)
Strength (XD/MD/ pull thru/ fatigue, temperature)
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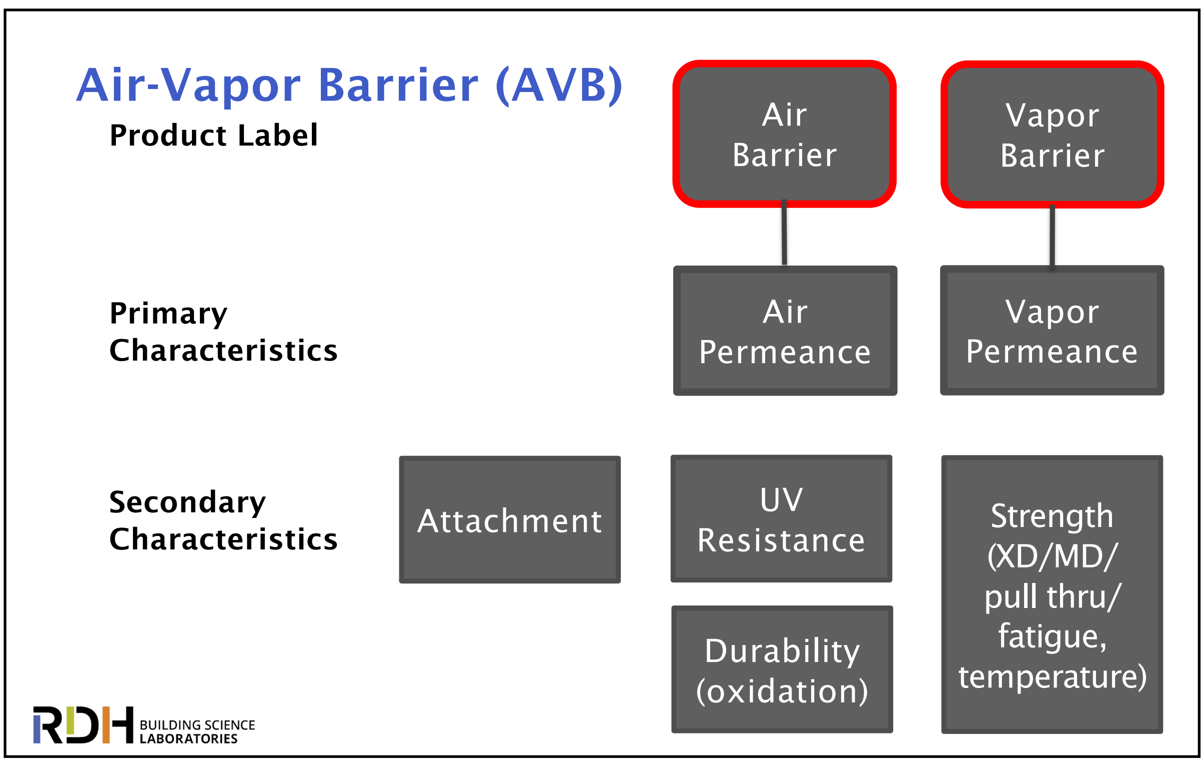
27


Air-Vapor Barrier (AVB)
Product Label
Air Barrier
Vapor Barrier
Primary Characteristics
Air Permeance
Vapor Permeance
Secondary Characteristics
Attachment
UV Resistance
Durability (oxidation)
Strength (XD/MD/ pull thru/ fatigue, temperature)
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28

Vapor Barrier (VB)

Product Label

Vapor Barrier

Primary Characteristics

Vapor Permeance

Secondary Characteristics

Attachment

UV Resistance

Durability (oxidation)

Strength (XD/MD/ pull thru/ fatigue, temperature)

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29

Water-Resistive Barrier (WRB)

Product Label

Water Barrier (WRB)

Primary Characteristics

Liquid Water Resistance

Secondary Characteristics

Attachment

UV Resistance

Durability (oxidation)

Strength (XD/MD/ pull thru/ fatigue, temperature)

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30

Water-Vapor Barrier (WVB)

Product Label
- Water Barrier (WRB)
- Vapor Barrier

Primary Characteristics
- Liquid Water Resistance
- Vapor Permeance

Secondary Characteristics
- Attachment
- UV Resistance
- Durability (oxidation)
- Strength (XD/MD/ pull thru/ fatigue, temperature)

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Which are air? Water? barriers?

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Classes of Air Barrier Products

→ Based on material, format, attachment, etc.

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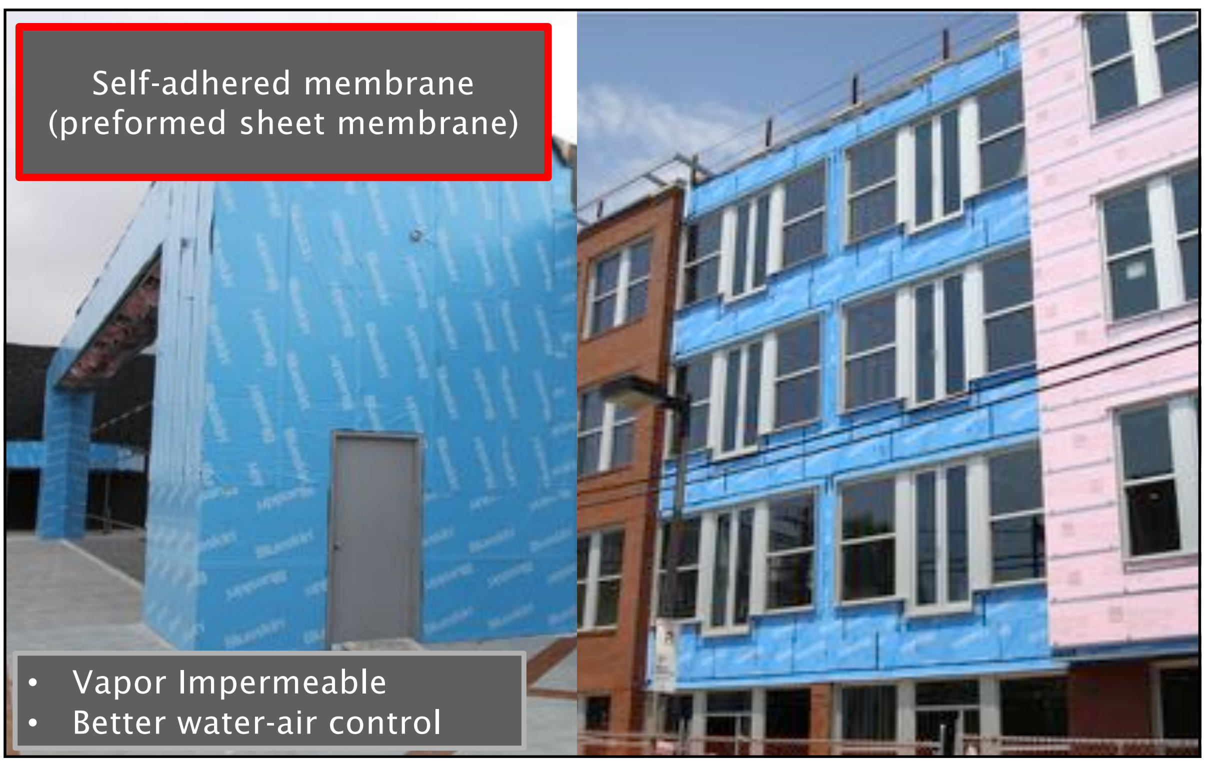
Mechanically attached "housewraps" (preformed sheet membrane)

- Vapor Permeable
- Should be fully supported
- Moderate water-air control

34


Self-adhered membrane
(preformed sheet membrane)
• Vapor Impermeable
• Better water-air control

35


Self-adhered membrane
(preformed sheet membrane)
• Vapor Impermeable
• Better water-air control

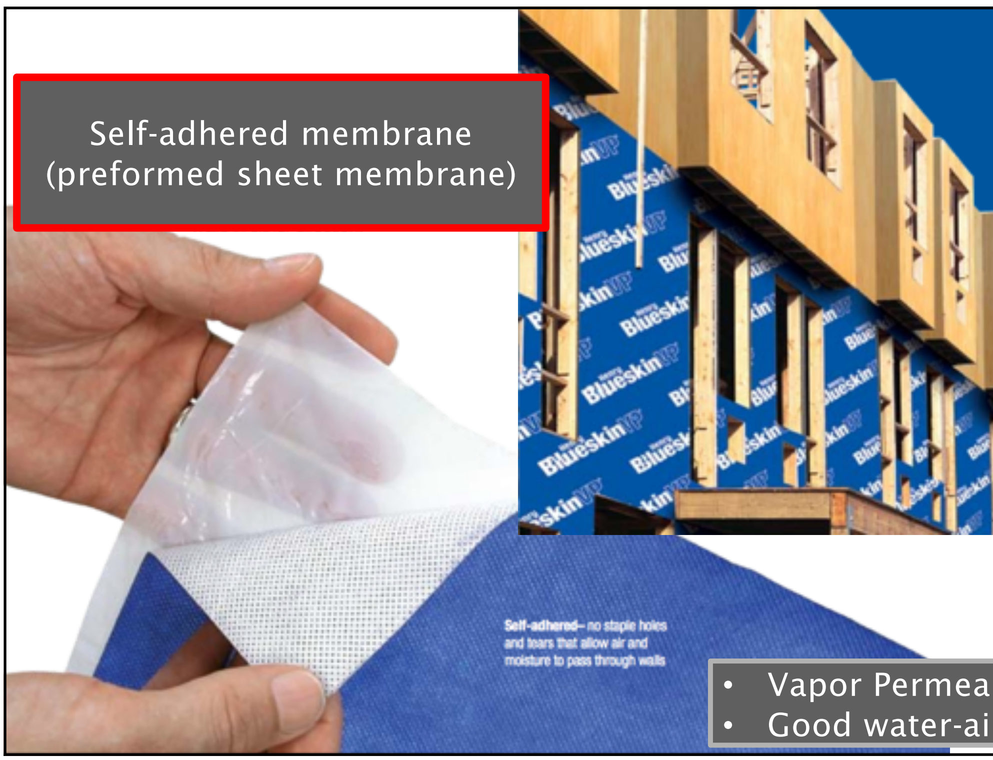
36

Self-adhered membrane
(preformed sheet membrane)

- Vapor Impermeable
- Sloped and complex surfaces demand very high water control performance
- Lapping important despite fully-adhered installation
- Some thicker membranes offer “self sealing” benefits at fastener penetrations

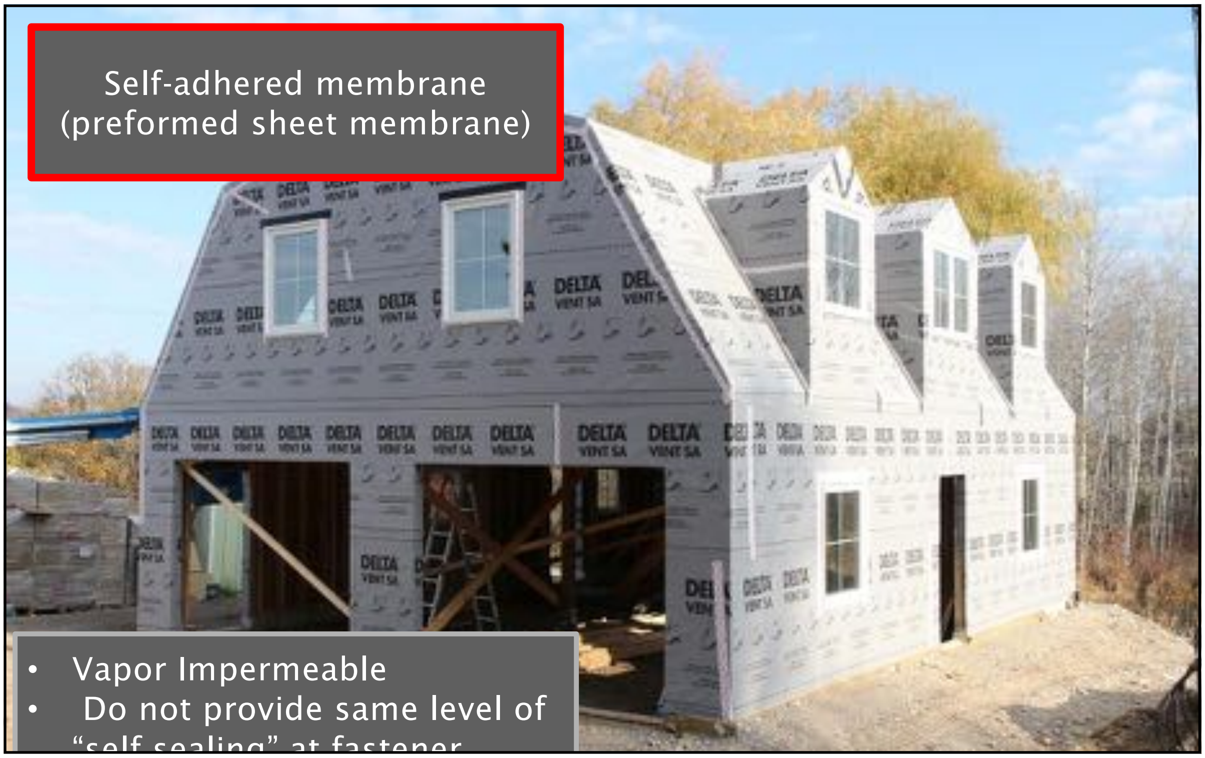
37

Self-adhered membrane
(preformed sheet membrane)



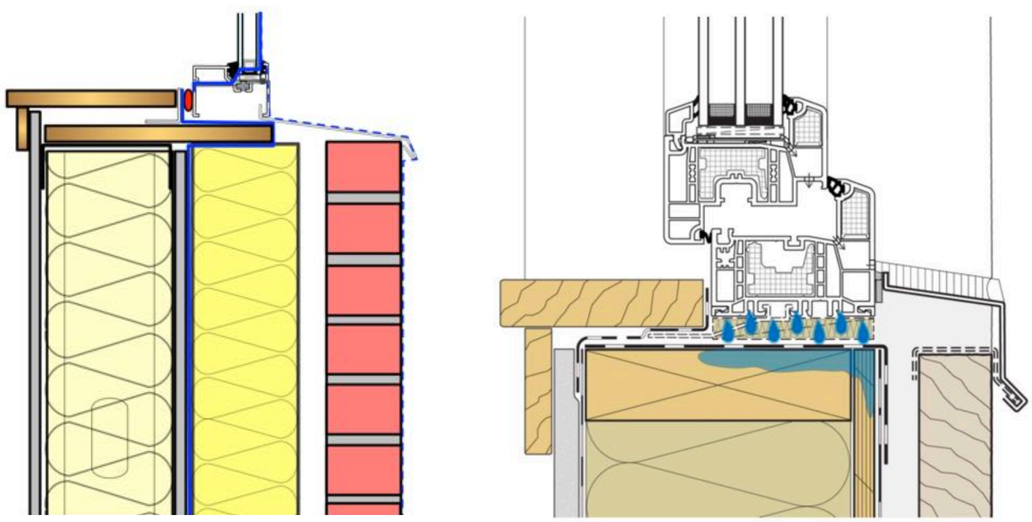
- Vapor Permeable
- Good water-air control

38



39

What happens at windows?



→ Permeable sub-sill may allow diffusion

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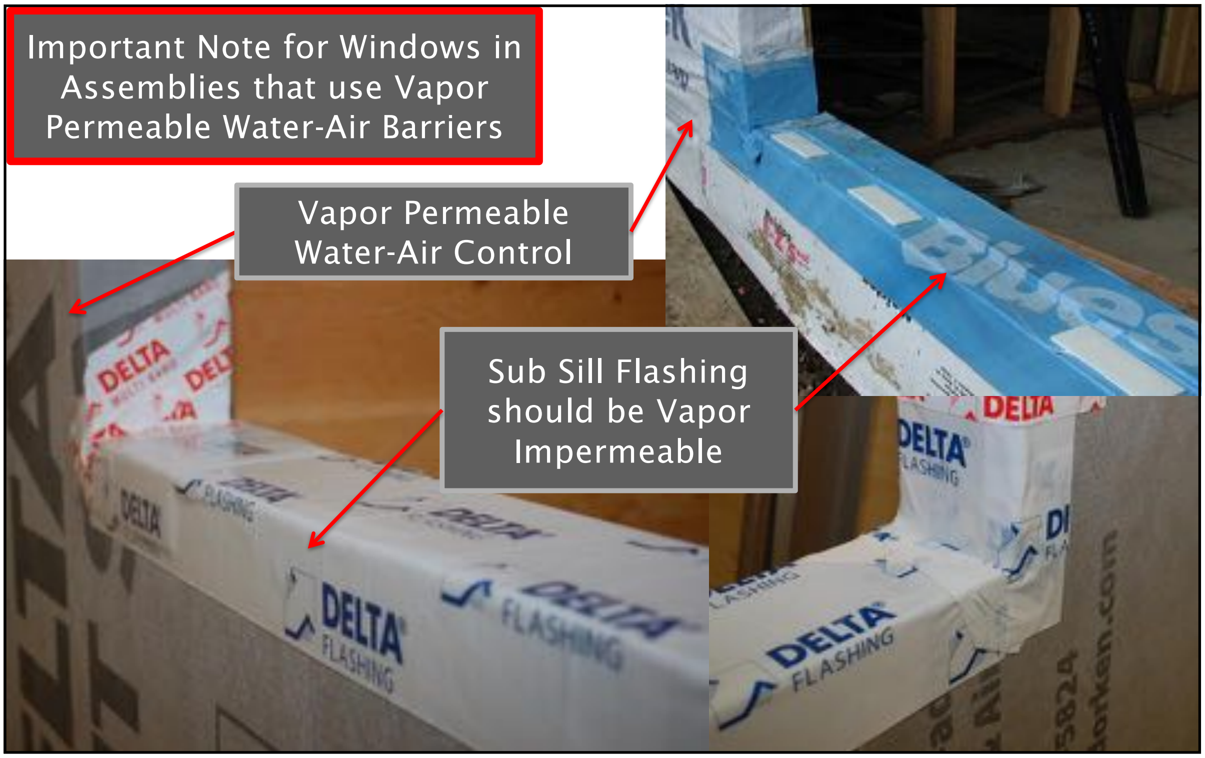
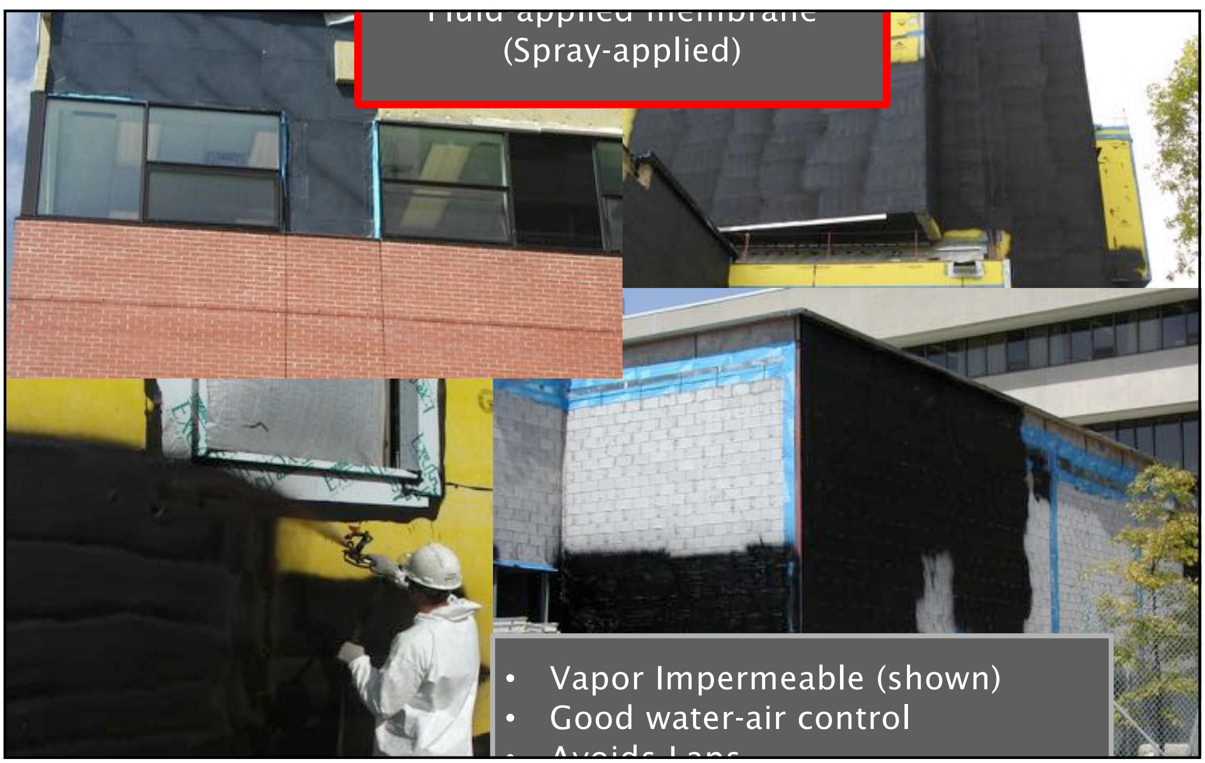
40


Important Note for Windows in Assemblies that use Vapor Permeable Water-Air Barriers
Vapor Permeable Water-Air Control
Sub Sill Flashing should be Vapor Impermeable
DELTA FLASHING

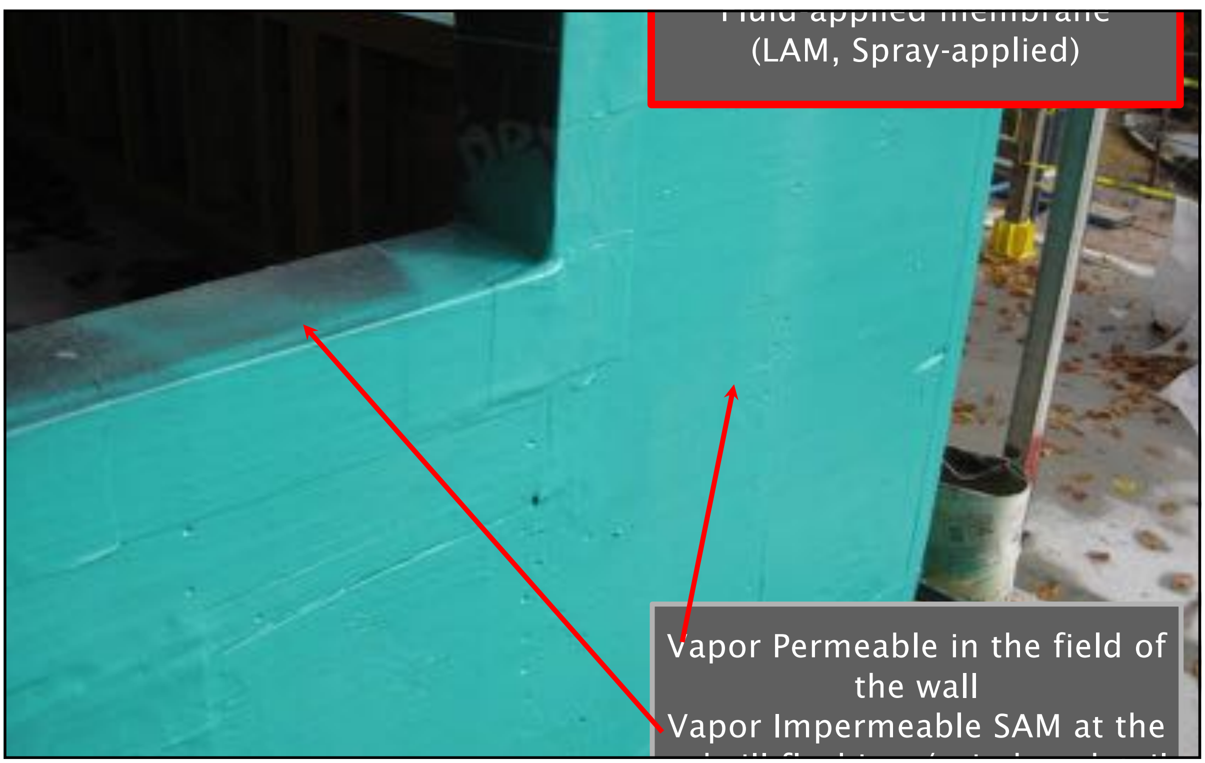
41


(Spray-applied)
• Vapor Impermeable (shown)
• Good water-air control

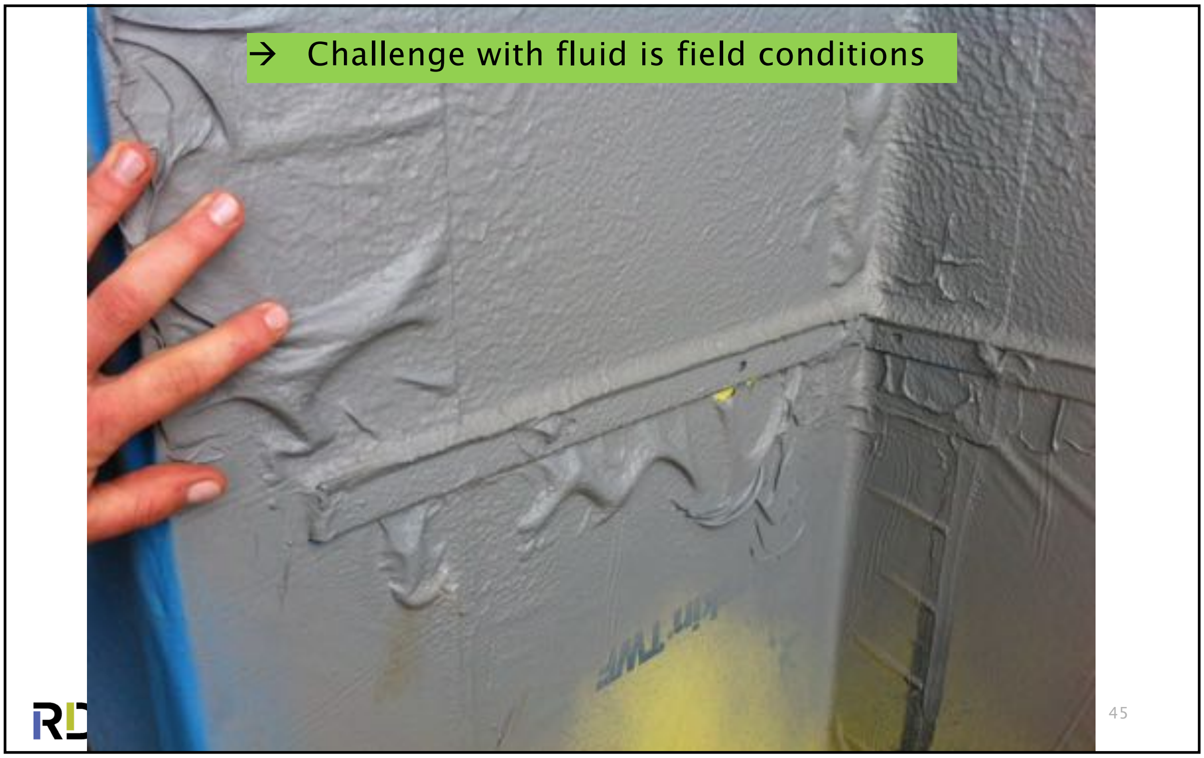
42


(roller, Spray-applied)
• Good water-air control
• Avoids Laps

43


(LAM, Spray-applied)
Vapor Permeable in the field of the wall
Vapor Impermeable SAM at the

44


→ Challenge with fluid is field conditions
45

45


Polyurethane Foam
(ccSPF, Spray-applied)
• Vapor Semi-permeable
• Requires Transition Flashings

46

Foamboard with Taped Joints

- Vapor Impermeable

48

Taped Rigid Foam Sheathing

49

49

Category's of Air Barrier Materials

ABAA Defined Air Barrier Classes

- Self Adhered Sheet Membranes — Section [illegible]
- Fluid Applied Membranes — Section [illegible]
- Sprayed Polyurethane Foam (Medium Density Closed Cell) — Section [illegible]
- Mechanically Fastened Commercial Building Wrap — Section [illegible]
- Boardstock – Rigid Cellular Thermal Insulation Board — Section [illegible]
- Factory-Bonded Membranes to Sheathing — ABAA Model Spec currently in development
- Adhesive Backed Commercial Building Wrap — ABAA Model Spec currently in development

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Example Water Control Products

- → Asphalt-impregnated felt
- → Asphalt-coated paper
- → Polymeric housewraps
- → Faced (plastic, aluminum) SBS Bitumen and Butyl Sheets
- → Fluid-applied asphalts, urethanes, acrylics, silicones, etc.
- → Thick layers of monolithic masonry
- → 3-6" or more of high-quality reinforced concrete
- → EPDM, TPO, reinforced PVC, fabric reinforced SBS modified bitumen, fabric reinforced asphalt
- → Glass sheet
- → Metal (aluminum, steel, zinc, copper) sheets
- → Closed-cell plastic foams (spray, e.g. ccSPF; or board XPS, PIC)

51

Air Control Products (body of wall)

→ Polymeric housewraps
→ Faced (plastic, aluminum) SBS Bitumen and Butyl Sheets
→ Fluid-applied asphalts, urethanes, acrylics, silicones, etc.
→ Thick layers of monolithic masonry
→ 3-6” or more of high-quality reinforced concrete
→ EPDM, TPO, reinforced PVC, fabric reinforced SBS modified bitumen, fabric reinforced asphalt
→ Glass sheet
→ Metal (aluminum, steel, zinc, copper) sheets
→ Closed-cell plastic foams (spray, e.g. ccSPF; or board XPS, PIC)
→ Gypsum board
→ Wood panel boards (OSB, plywood)

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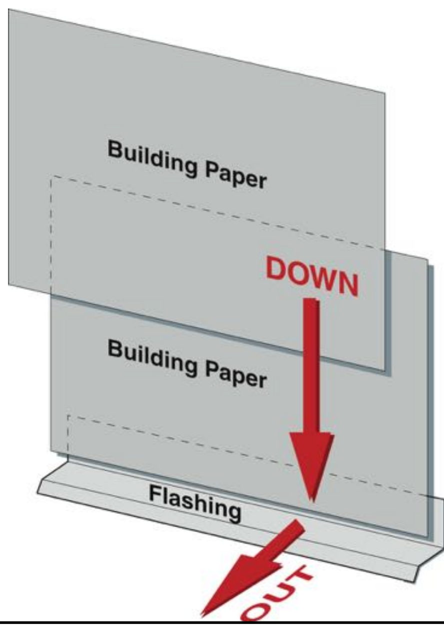
52

52

Air-Water control Layers

→ Many products can be both
→ BUT, may vary in installation
→ Rain control joint is not always air control



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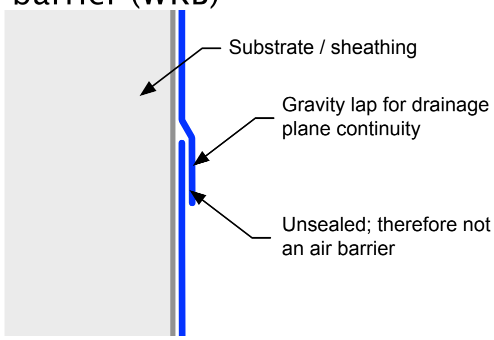
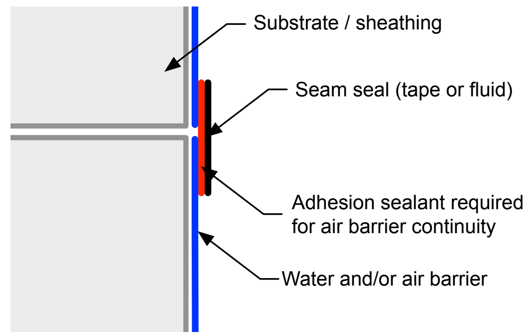
Housewrap as water barrier (WRB)



Housewrap taped as air barrier & water



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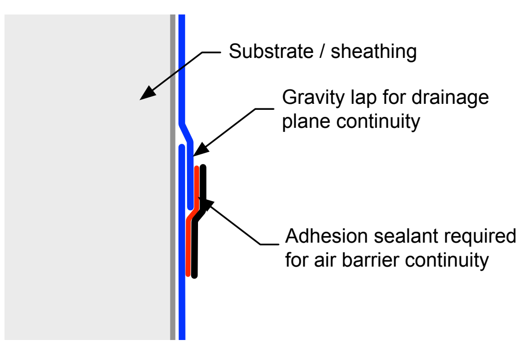
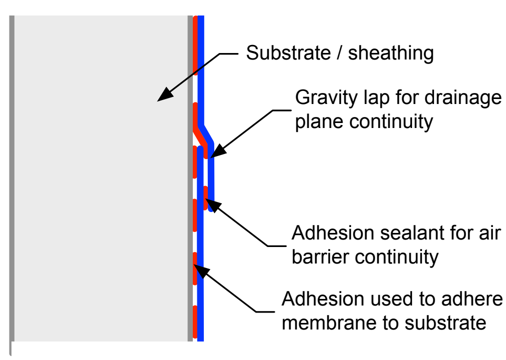
54

54

Housewrap as better air-water barrier



Peel-and-stick as air-water barrier



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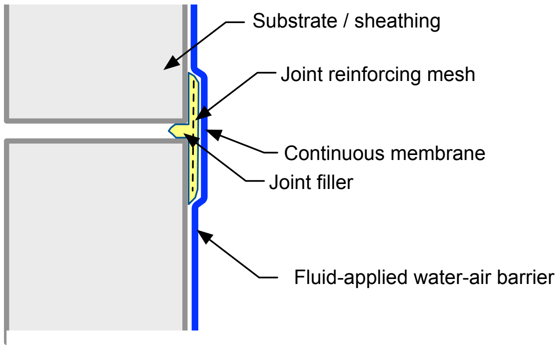
Fluid-applied air-water barrier



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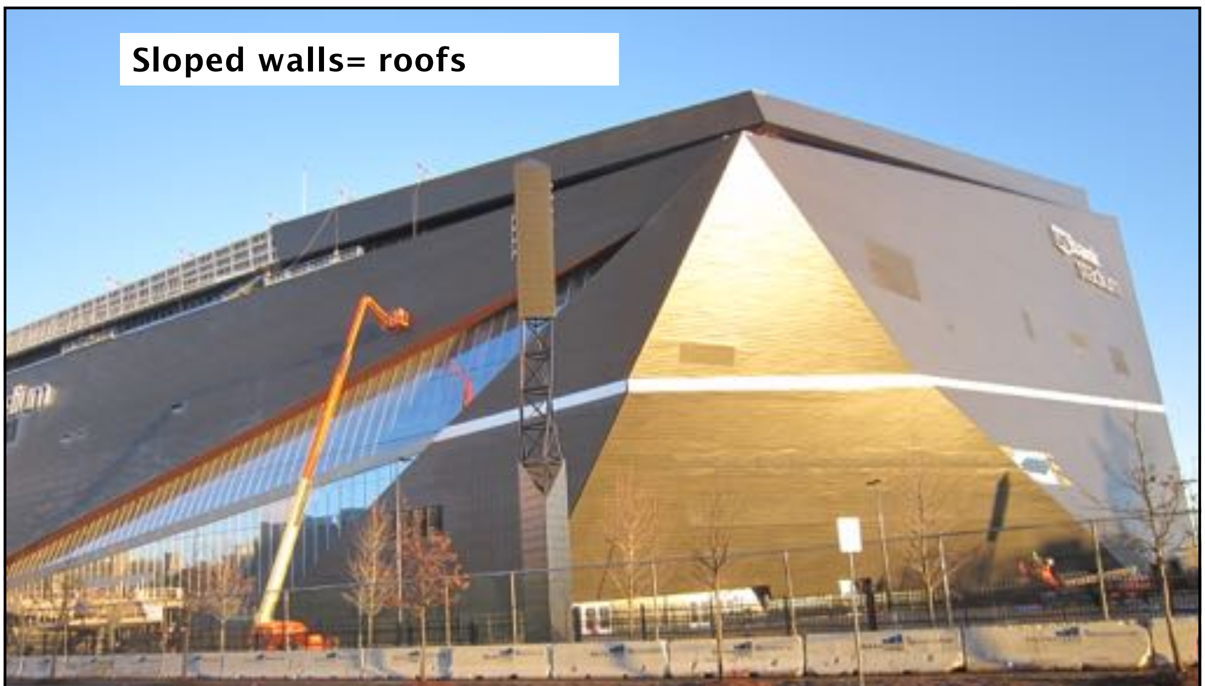
Sloped walls= roofs



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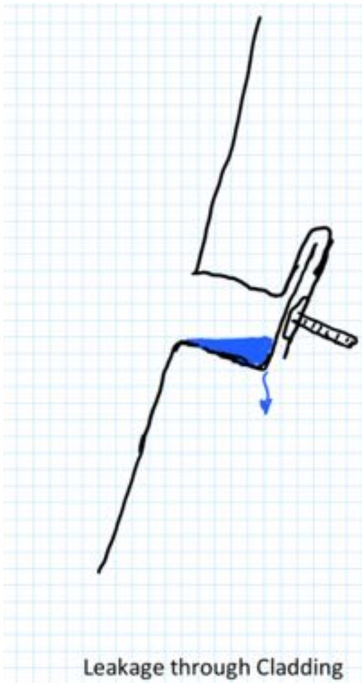
57

57



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58

58

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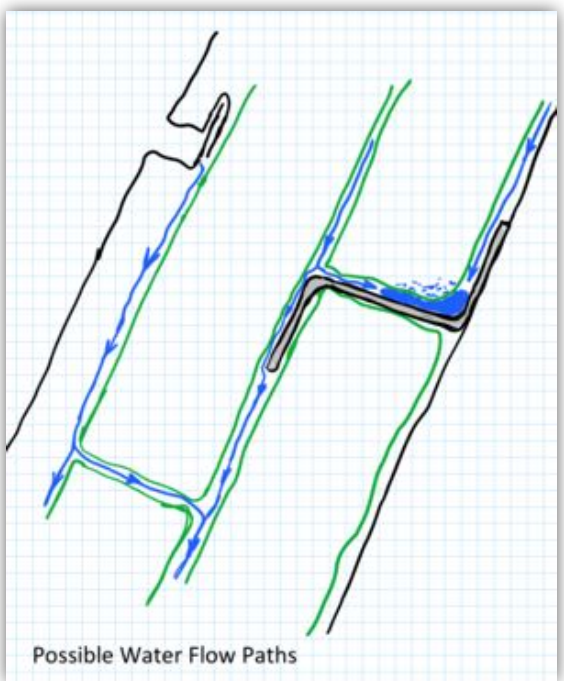
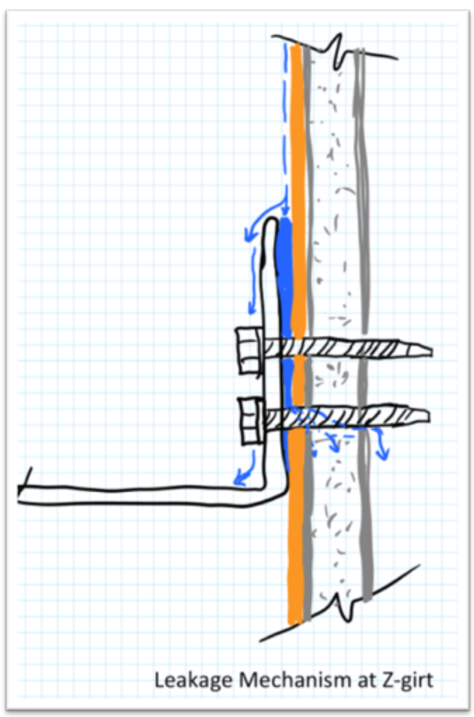
59

59

60





61

Doing it right

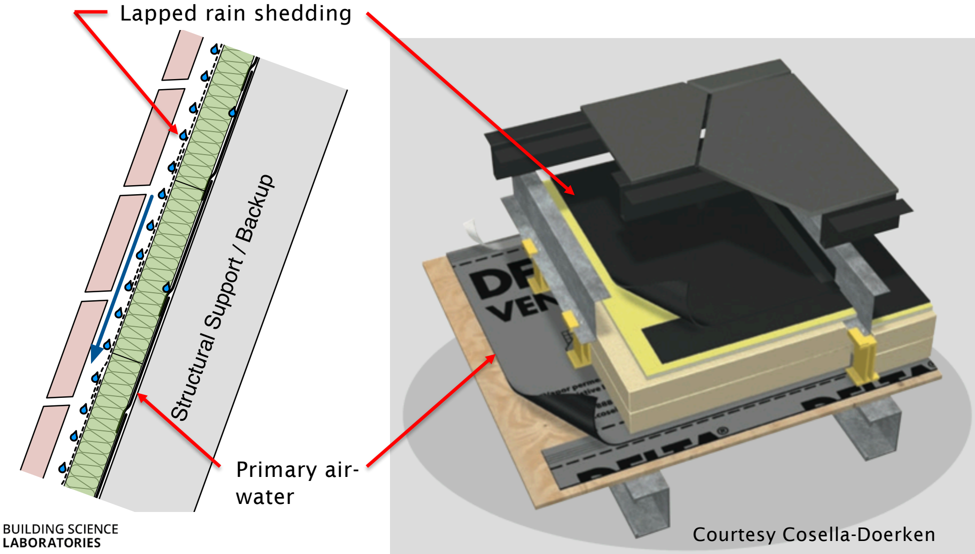
BURKETTDESIGN, Inc.

Denver Botanic Gardens Science Pyramid

62

Doing it right

Hidden rain shedding



Courtesy Cosella-Doerken

63

64

Vapor Barrier Products

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Classes for Vapor Control Layers

- **Impermeable**: <0.1 US Perms (<6 ng/Pa·s·m²)
  Type I
- **Semi-Impermeable**: 0.1-1 US Perms (6-60 ng/Pa·s·m²)
  Type II
- **Semi-Permeable**: 1-10 US Perms (60-600 ng/Pa·s·m²)
  Type III
- **Permeable**: >10 US Perms (>600 ng/Pa·s·m²)
  i.e. Not a vapor control layer
- What differences are meaningful?
  - 0.2 vs 0.1 vs 0.05 vs .005? 5 vs 10 vs 50 vs 500?

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Vapor Control Products (Type I, II)

- Specialty paints/coatings, such as epoxy, asphalt
- All metal sheets, extrusions, films, castings, Glass
- Asphalt butyl coatings, thick enough (e.g., over 1 mm is enough)
- Polyethylene, saran, polycarbonate, polypropylene as films, not woven or perforated
- Closed cell polyurethane foam (over 2")
- EXPS (over 1-2"), EPS (density matters, usually over 2" or so)
- Concrete (good quality, over 2-3", lower quality porous, 6-10")
- Dense stone (few pores, over 2-4" thickness or so)
- Closely spaced perforations usually mostly eliminate vapor resistance
- Wood, depending on density, species and thickness (over 4" for softwoods)

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67

67

Material	Dry Cup		Wet Cup	
Wide Range!	US Perms	Ng/Pa·s·m²	US Perms	Ng/Pa·s·m²
Self-Adhered Sheet Membranes	0.01 – 15	0.6–900	0.01 – 30	0.6–1800
Fluid-Applied Membranes	0.1 – 12	6–720	0.1 – 30	6–1800
Sprayed Polyurethane Foam (Closed Cell) @ 1-2”	0.4 – 1	24–60	1 – 50	6–3000
Mechanically-Fastened Commercial Building Wrap	10 – 95	600–5700	30 – 40	1800–3200
Boardstock-Rigid Cellular Thermal Insulation Board @ 1-2”	0.02 – 1	1 –60	0.02 – 1	1 –60
Factory-Bonded Membranes to Sheathing	0.02 – 25	1 –1500	0.02 – 30	1 –1800
Adhesive-Backed Commercial Building Wrap	10 – 30	600–1800	15 – 60	900–3600

68

Vapor Permeance of Other Layers

Material	Inches to reach 60 ng (1 perm)
polyethylene	0.6 mille
Metal (facer)	>0 (assuming no pinholes)
wood	0.5 – 5.0 (depends on MC, species)
XPS EPS	1-1.2 1.5 to 3
Polyiso	1.5-2.5 (unfaced)
ccSPF ocSPF	1.5-2+ 48
Concrete	3-10 (depends on density, porosity)
gypsum	16

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69

69

Where does the air barrier go?

→Inside, outside, middle?

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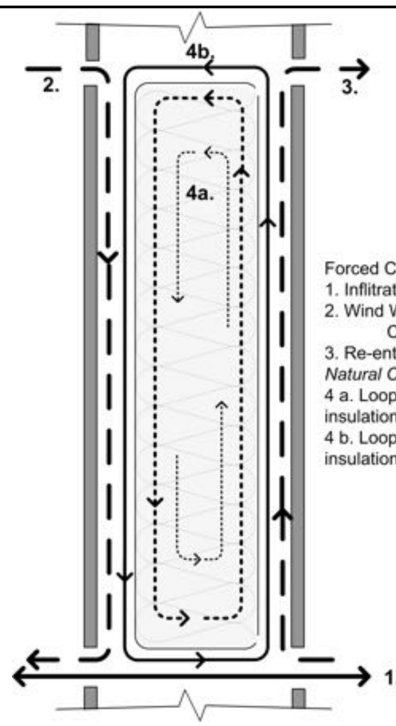
Other airflow paths

→Air Leakage is only part of the picture



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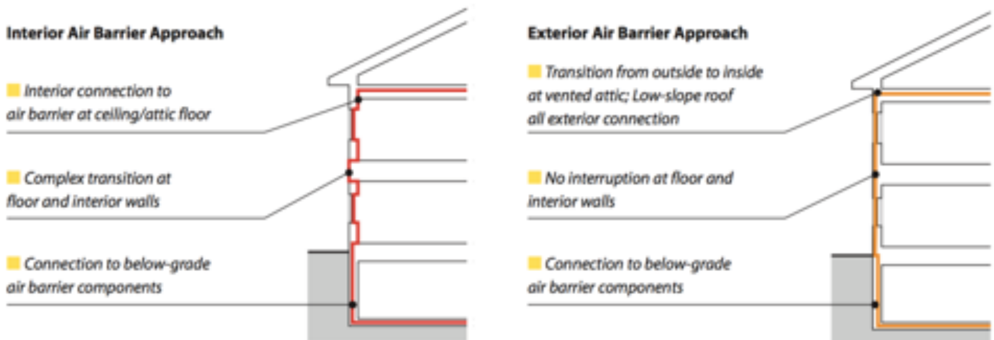
"Exterior of the structure" Air Barriers

→ Interior air barrier = Many penetrations and details

→ "Exterior of the structure" is preferred today



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72

Inside

→ 1960's, the beginning, loose membrane

→ Confusion with vapor barriers

→ Summer condensation

73

73

Commercial Buildings: often exterior air barrier is only practical solution

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74

Outside the Inside

- →But inside the outside: separate service wall
- →Inside structure
- →Hard to seal flexible membrane
- →1980's housing
- →Exterior was easier

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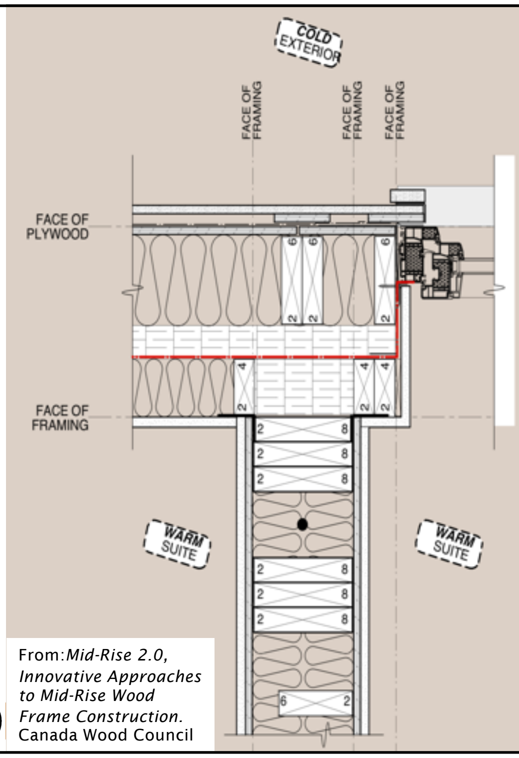


From: *Mid-Rise 2.0, Innovative Approaches to Mid-Rise Wood Frame Construction.* Canada Wood Council

Euro House

→Well-insulated but risky

→Lots of complexity (double wall)

→Continues 1980’s approach

→Hard won building science being ignored

76

76

→

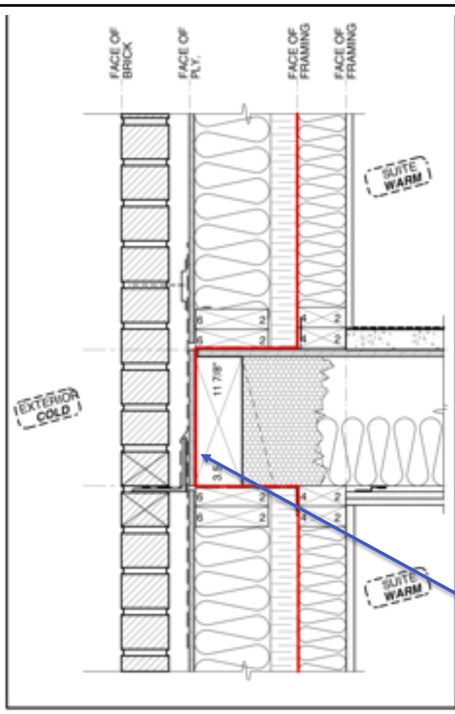


Fig. 2.4: Floorline junction

were installed
reducing costs.
only responsibl
the vertical shafts to the silencer box located on the inside wall of each suite (Fig. 2.6).

From: *Mid-Rise 2.0, Innovative Approaches to Mid-Rise Wood Frame Construction.* Canada Wood Council

Fig. 2.5: View showing vapour barrier wrapped over floor lines

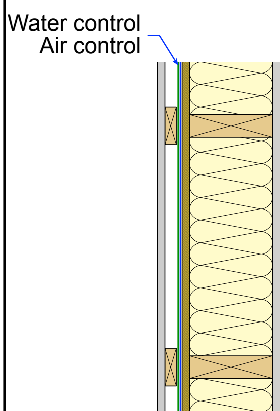
77

77

Outside the wall

→Commercial 1980s

→Residential Tyvek



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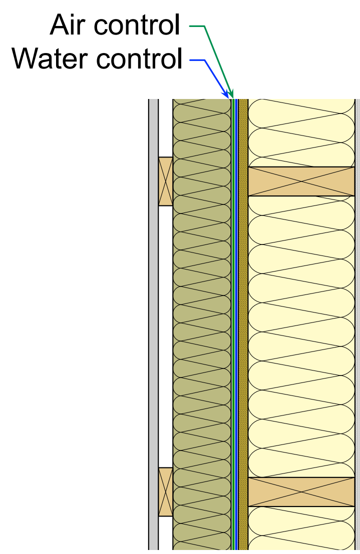
78

Outside the structure

→Supported by, but over structure



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79

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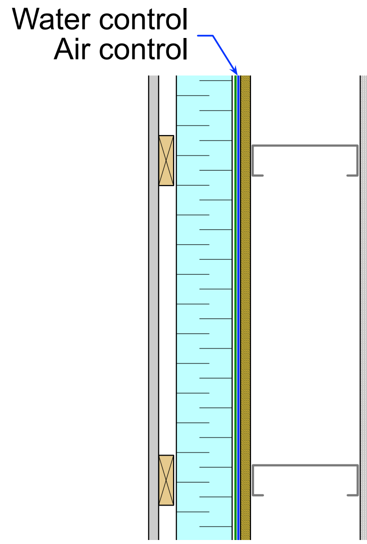
Outside the structure

→Supported by, but over structure



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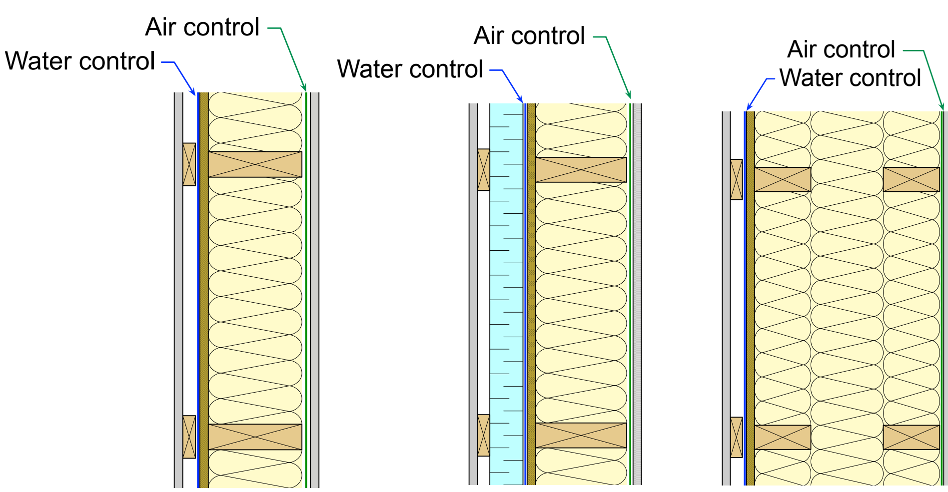
Location, location



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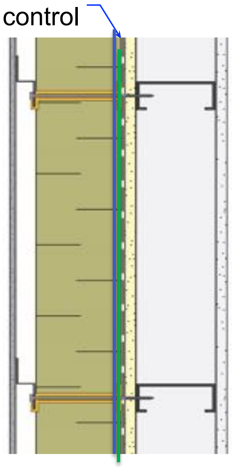
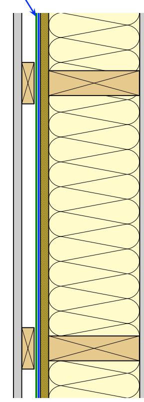
Remaining Questions



All insulation
outside air barrier
Risk: ***wind washing***



All insulation inside
air barrier
Risk: ***natural convection***

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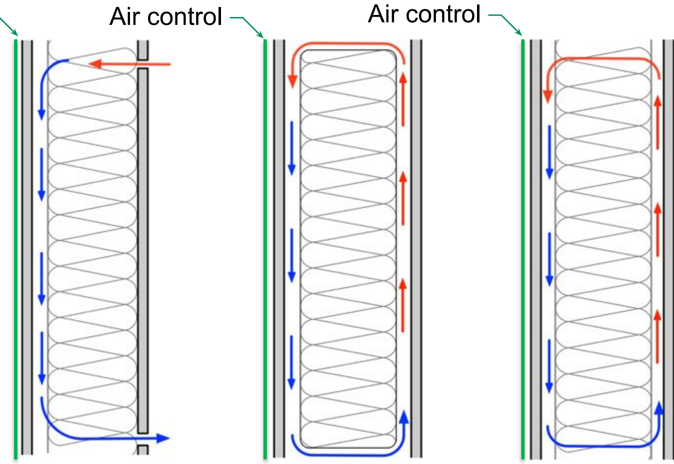
82

82

Natural Convection



Natural Convection Loop to Inside

Natural Convection Around Material

Natural Convection Around & Through Material

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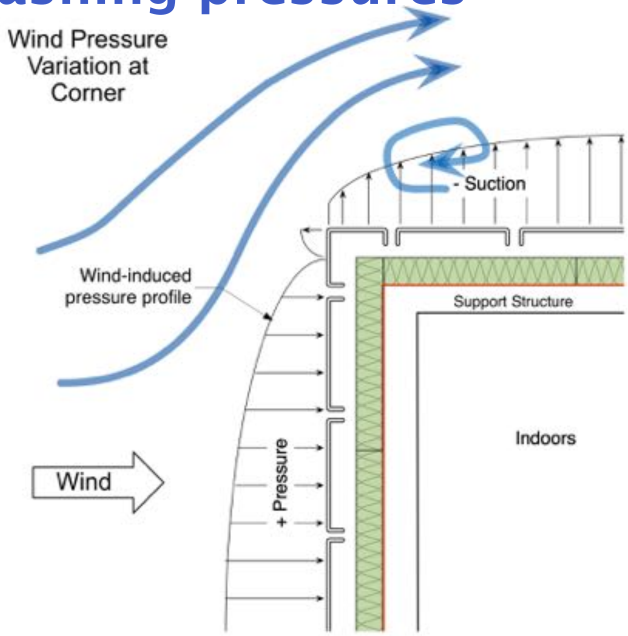
83

Wind washing pressures



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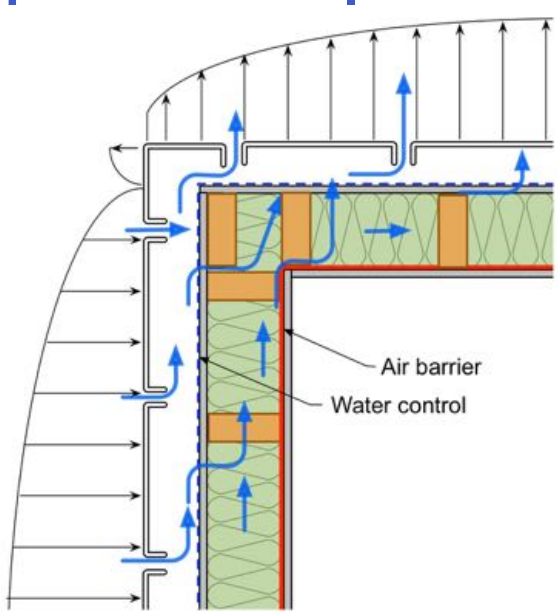
Historic problems experienced



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85

85

JOURNAL OF **THERMAL INSULATION** *Volume 15—July 1991*

The Control of Wind Cooling of Wood Frame Building Enclosures*

J. TIMUSK AND A. L. SESKUS
University of Toronto

N. ARY
The IBI Group

ABSTRACT: An extensive investigation of moisture problems in wood frame houses revealed that one of the most common problems was the formation of mould and mildew on inside wall surfaces of exterior corners (Van Poorten, 1983). The majority of the problem houses were of recent construction (around 1975), electrically heated yet "naturally ventilated." Clearly, inadequate ventilation was one of the contributing factors.

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86

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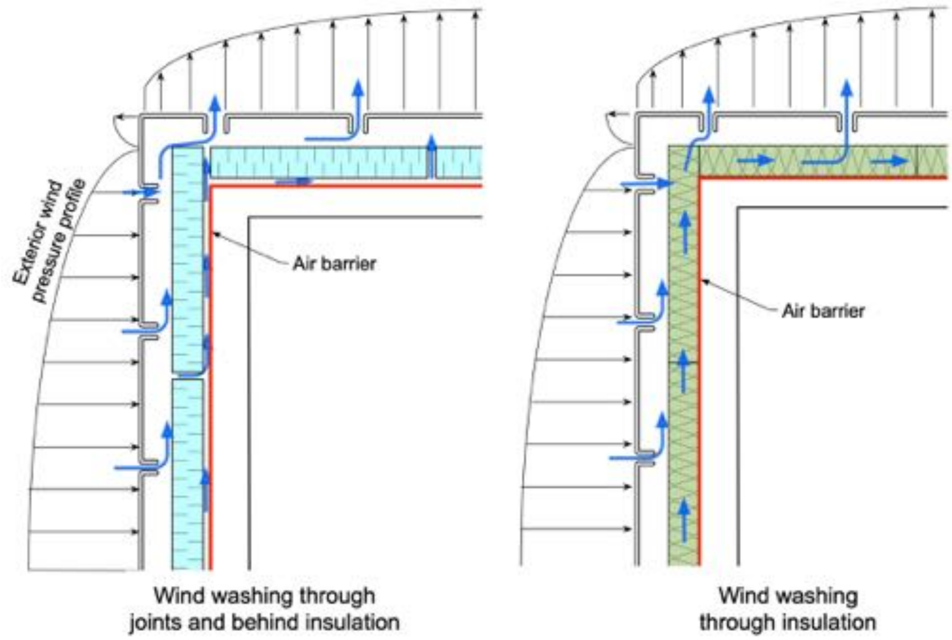
87

87



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89

89

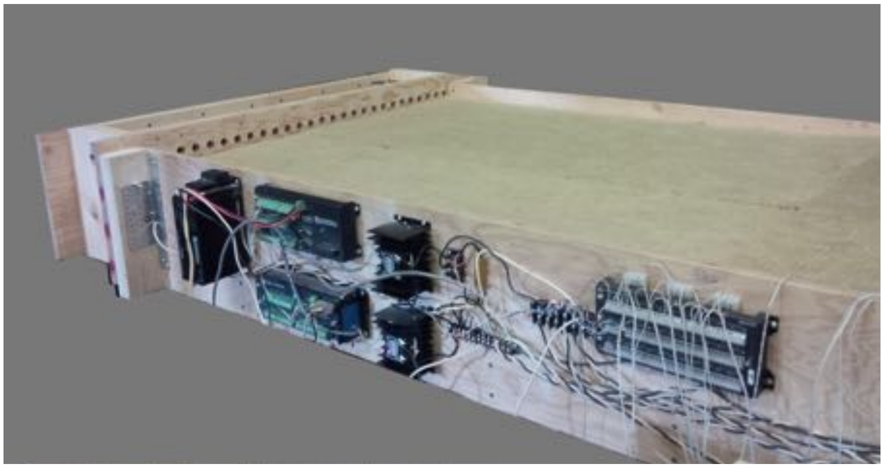
Exterior air seal via tape

90

Common
to place
insulation
outside

91

Measuring Wind Washing in the Lab



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92

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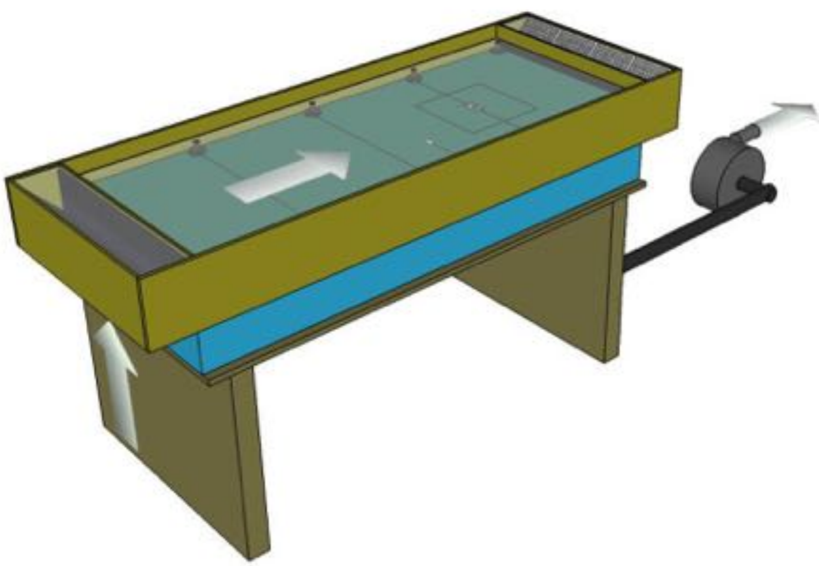

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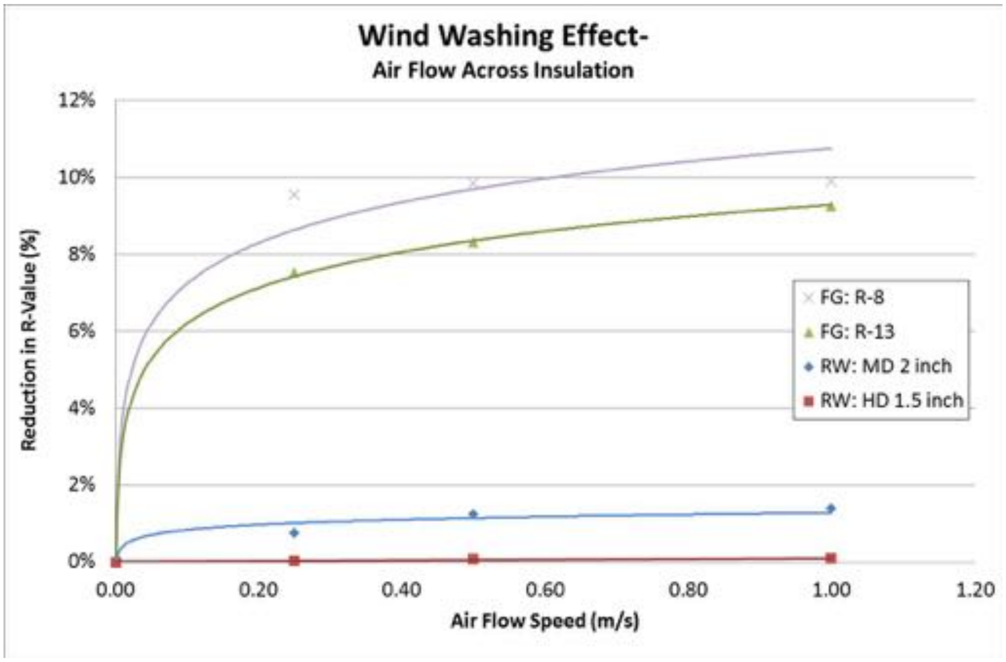

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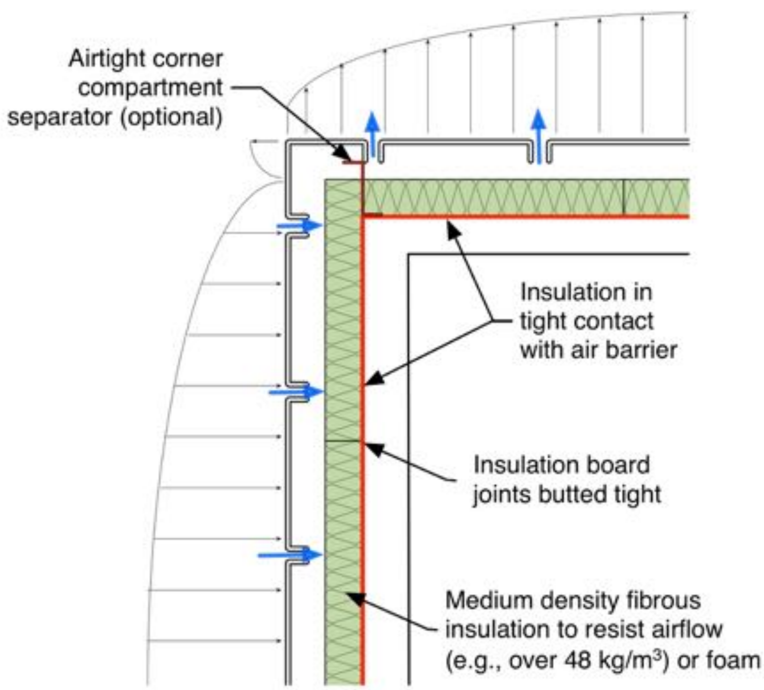
→ RDH Lab testing

94

94



95

95

So, where does the air barrier go?

- →Best would be outside the structure
  - →Minimize the number of penetrations
  - →Protects membrane
- →In the middle is OK
  - →Provided it is outside structure
  - →Can usually accept more temperature swings
- →But is it also water barrier?
  - →Then depends more on assemly

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96

Moisture Issues

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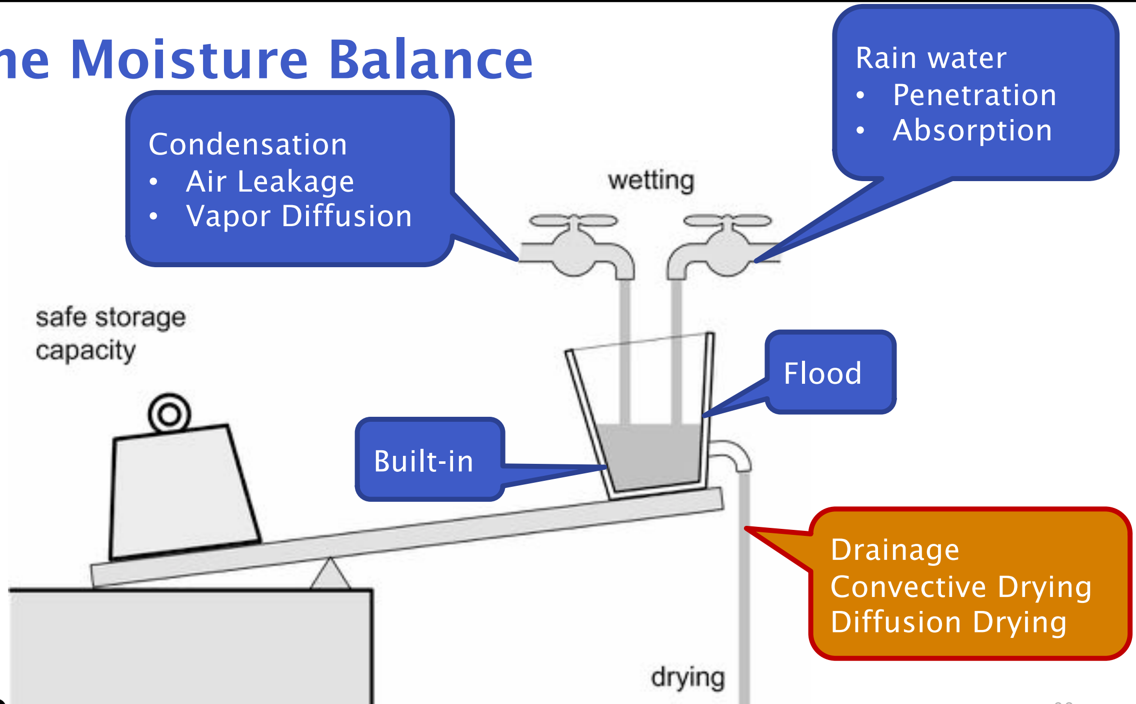
97

The Moisture Balance



Why consider the Moisture Balance?

→The industry tends to think about vapor diffusion w.r.t.

- → Dew Point
- → Condensation

→But there is much more:

- → moisture sources and sinks (storage)
- → multiple transport mechanisms
  (gravity, capillary, convection, diffusion)
- → moisture sensitivity of materials
- → transport paths
- → Driving forces

Considering Wetting/Drying, Transport & Storage

→Vapor diffusion control strategy is often informed by/complicated by other mechanisms, e.g.

- → Rain water absorption in masonry
- → Rising damp in old masonry
- → Built-in moisture in a CIP concrete floor or roof
- → CMU or Laminated Timber, rain-wet during construction
- → any assembly surrounding a pool or similar environment
- → assemblies for refrigerated spaces

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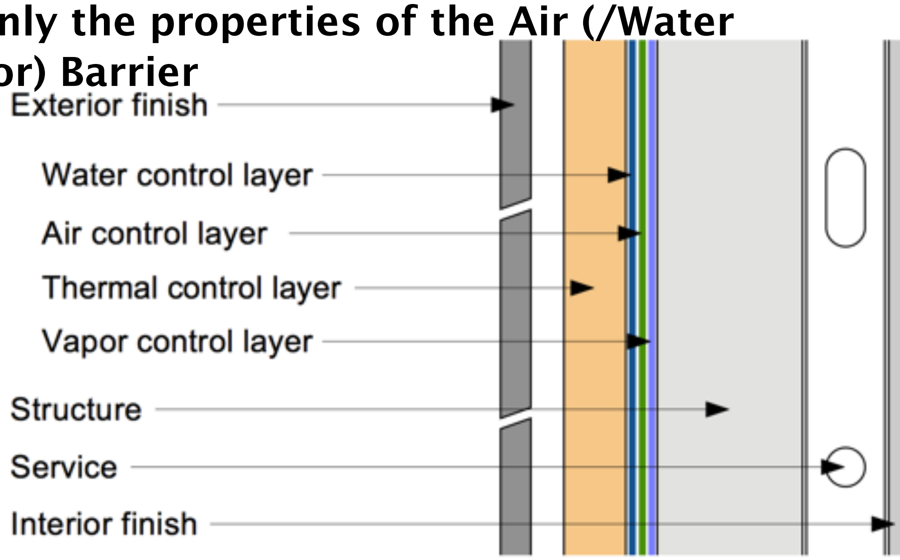
Consider Diffusion through ALL Layers

→**Must consider the whole assembly, not only the properties of the Air (/Water /Vapor) Barrier**



101

Controlling Interstitial Condensation

→ **Limit / stop flow** of vapor *to* cold surfaces in enclosures

- → Stop air leakage [AIR BARRIER]
- → Control vapor diffusion *into* assembly [VAPOR BARRIER]

→ **Keep sensitive surfaces warm** (above "dewpoint temperature")

- → Insulate outside of condensation plane [EXTERIOR INSULATION]

→ **Encourage drying** or moisture removal from enclosure

- → Allow vapor diffusion *out of* assembly?
- → Encourage ventilation around low permeance claddings?

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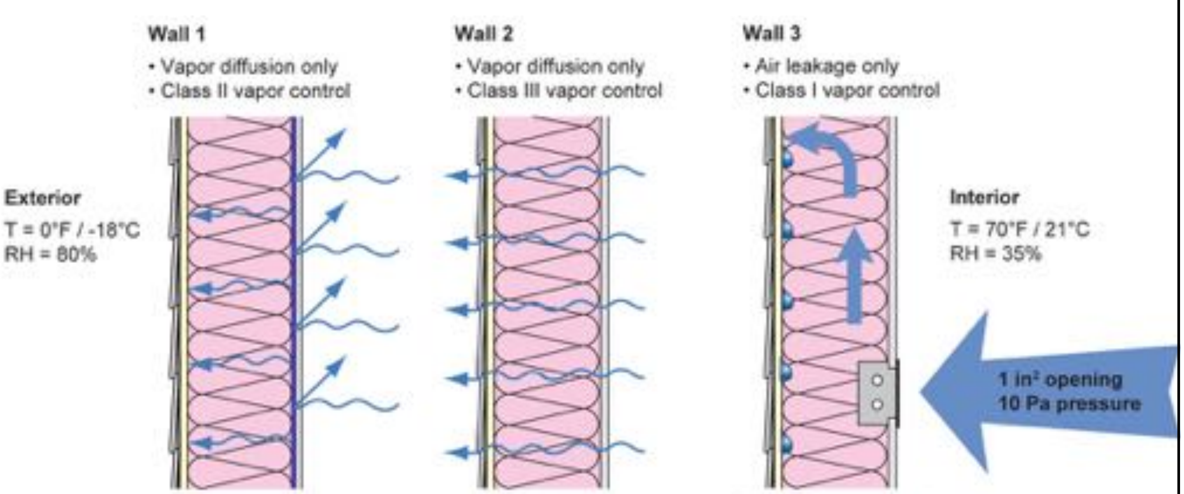
102

102

Controlling Interstitial Condensation

→ Diffusion is not that important in many walls



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103

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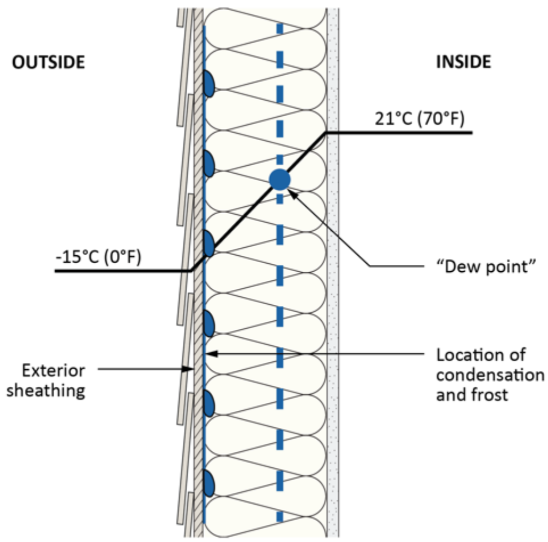
Where does condensation occur?
Diffusion or Air Leakage (Convection)



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104

Find the cold spot.

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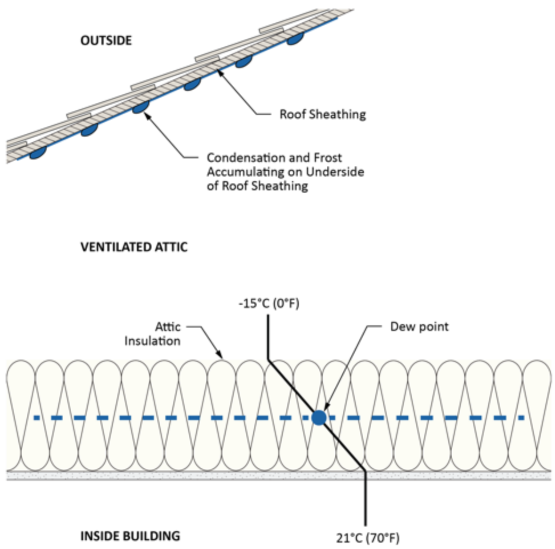
105

Roof Condensation: Air leaks



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Frost accumulation on cold surface

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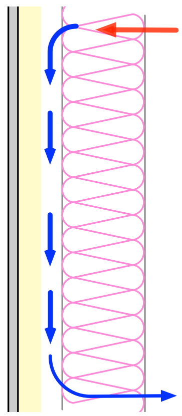
1.5" ccSPF with R-28 batt inside

→ No interior air barrier hence convection



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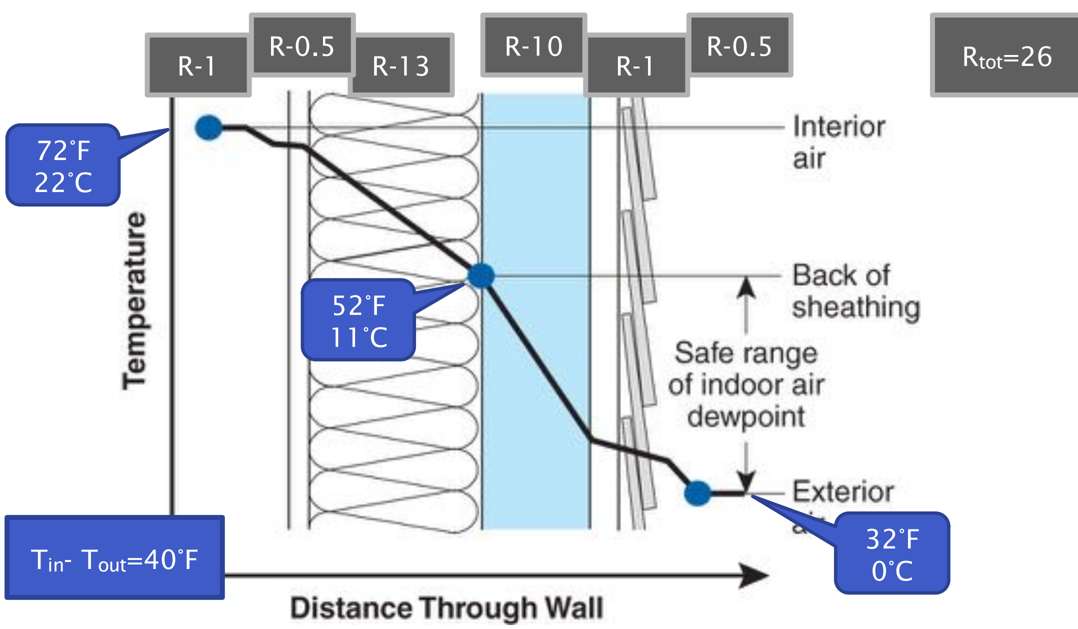
Steady State Analysis (Temperature Drop)



See: BSD-163 at buildingscience.com

$T_{back\ of\ sheathing} = T_{interior} - (T_{interior} - T_{exterior})\ R_{batt}/R_{total}$

109

Moisture and exterior insulation

- →Exterior insulation reduces condensation
  - →Fewer hours per year
  - →Lower quantity
- →Exterior insulation slows outward drying
  - →Drainage and ventilation enhance drying

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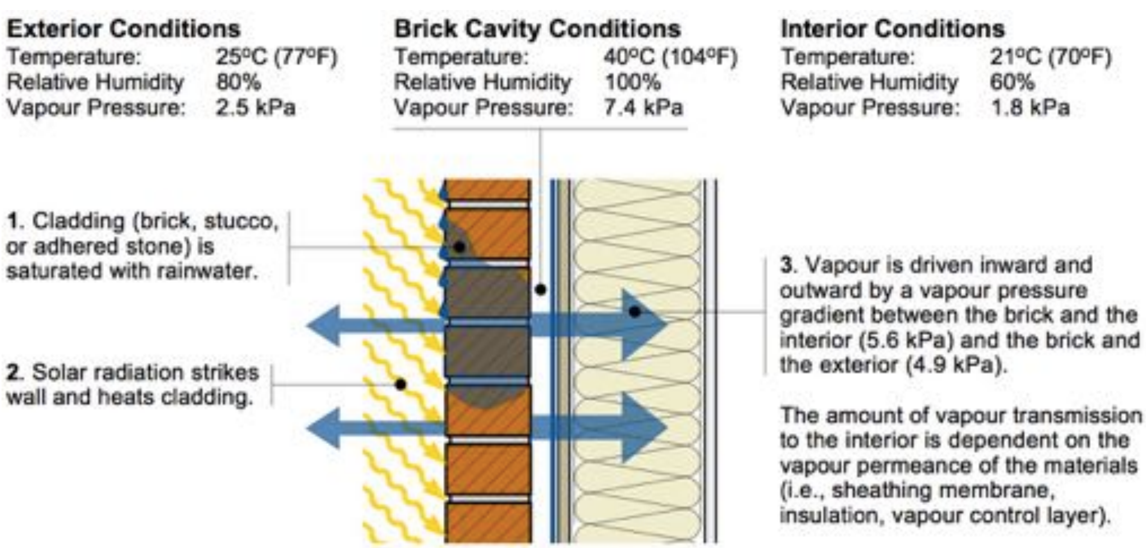
Controlling Interstitial Condensation from Sun-Driven Moisture



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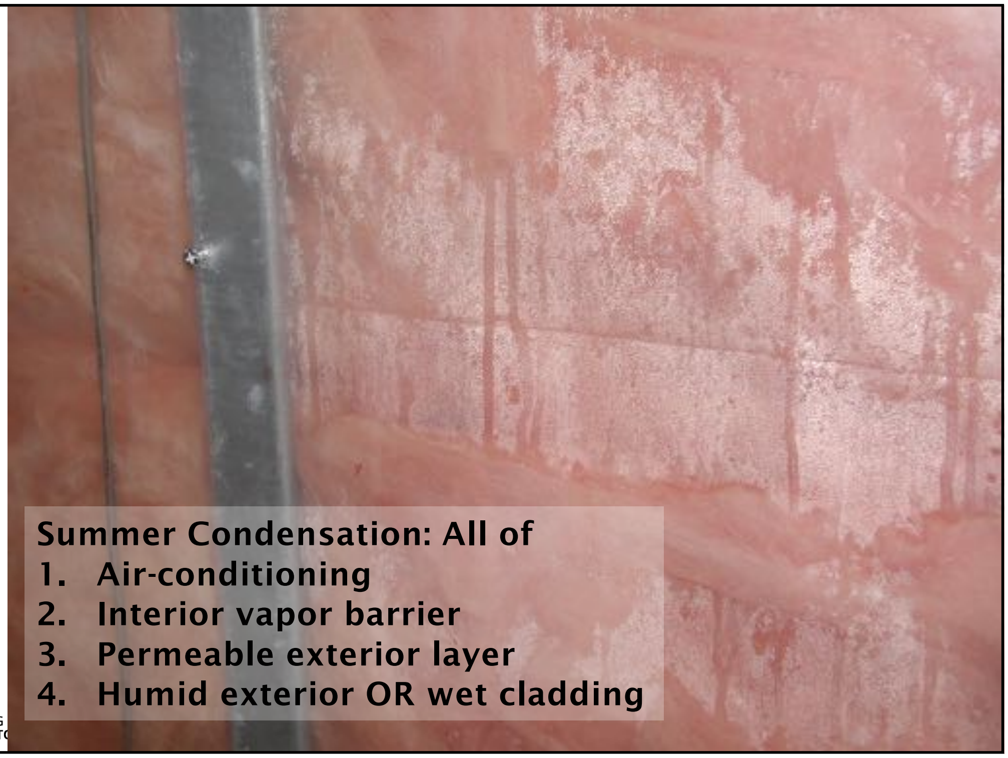

Summer Condensation: All of
1. Air-conditioning
2. Interior vapor barrier
3. Permeable exterior layer
4. Humid exterior OR wet cladding

112

Vinyl wallpaper = Vapor barrier

113

Take Aways

- →Understand your control layers, label them
- →Be careful specifying air/water/vapor products
  - →Watch substitutions
- →Recognize other products have vapor resistance / airtightness

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