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

Building Science

Adventures In Building Science

www.buildingscience.com

What is a Building?

- Control heat flow
- Control airflow
- Control water vapor flow
- Control rain
- Control ground water
- Control light and solar radiation
- Control noise and vibrations
- Control contaminants, environmental hazards and odors
- Control insects, rodents and vermin
- Control fire
- Provide strength and rigidity
- Be durable
- Be aesthetically pleasing
- Be economical

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

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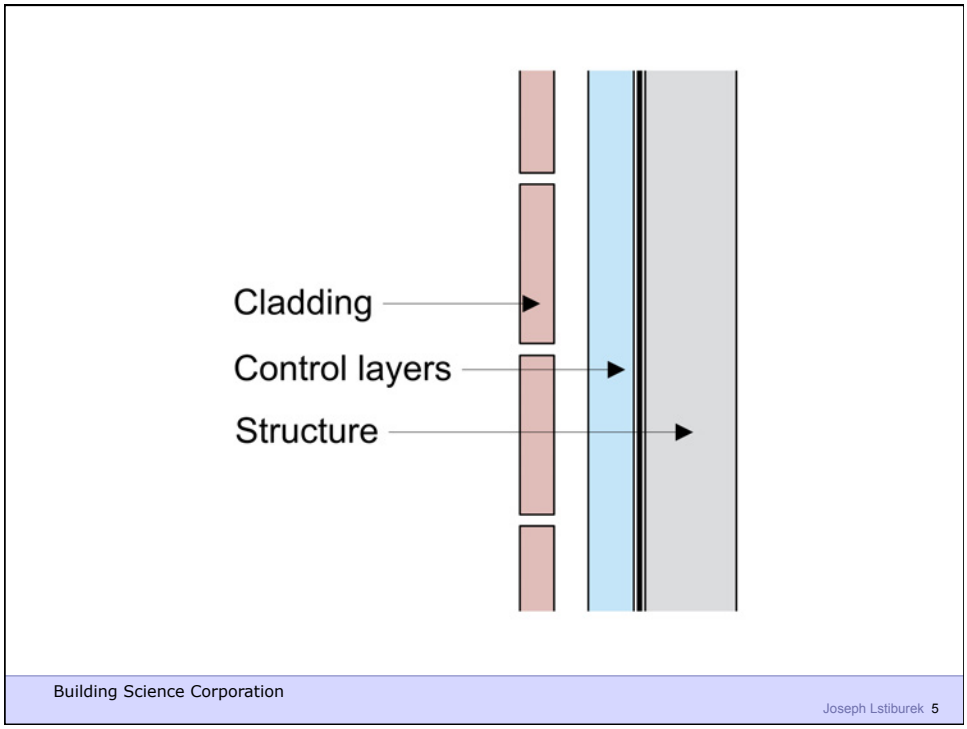
Cladding
Control layers
Structure
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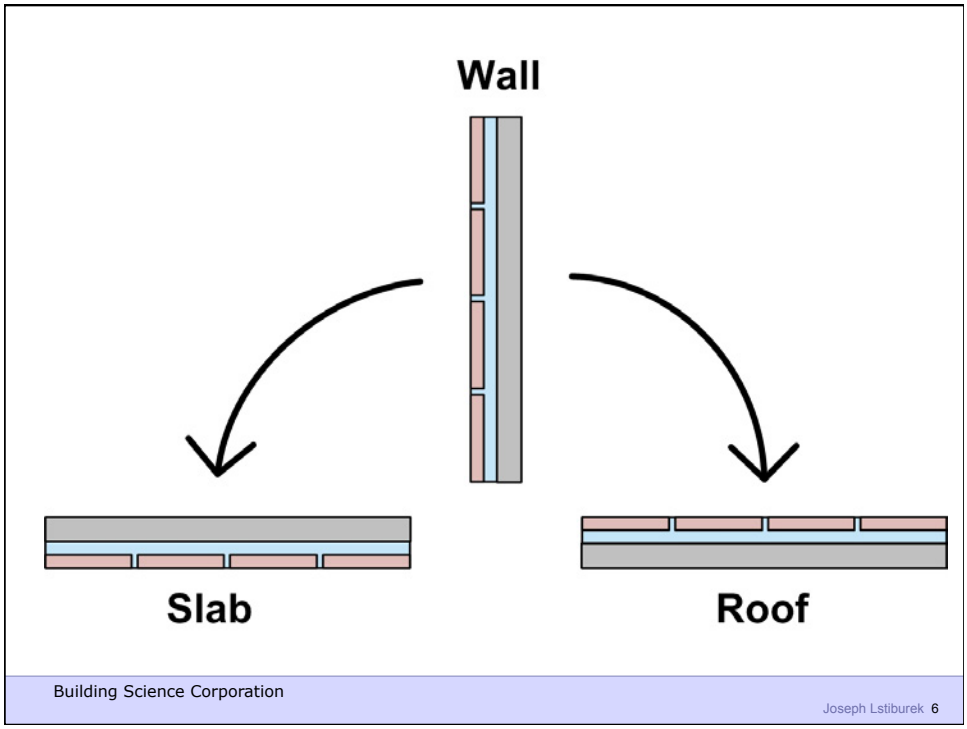
Wall
Slab
Roof
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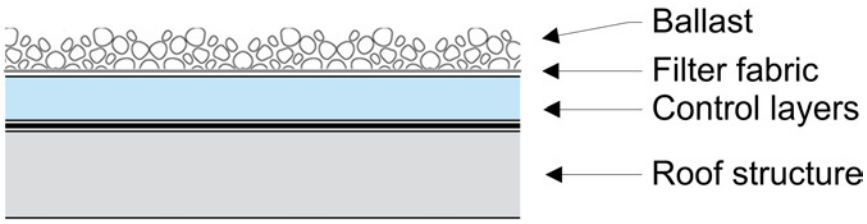

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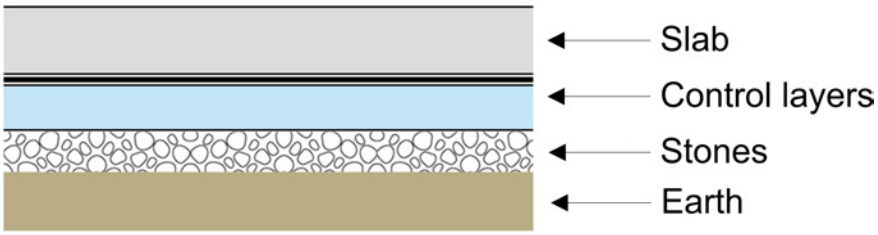

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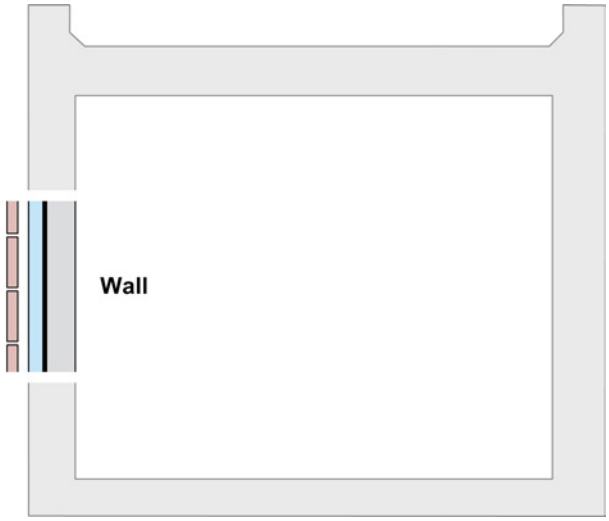

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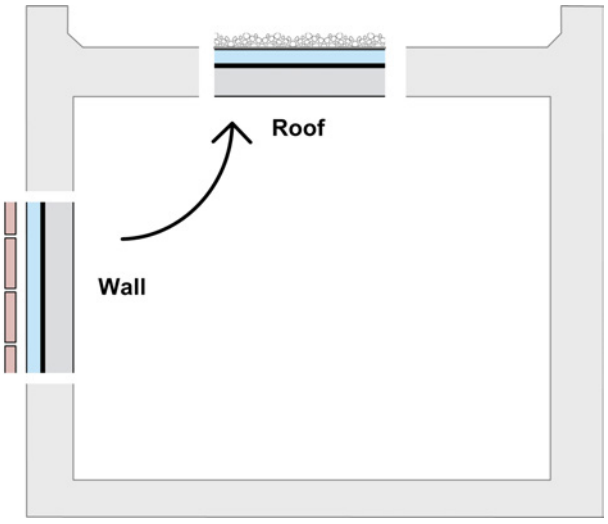

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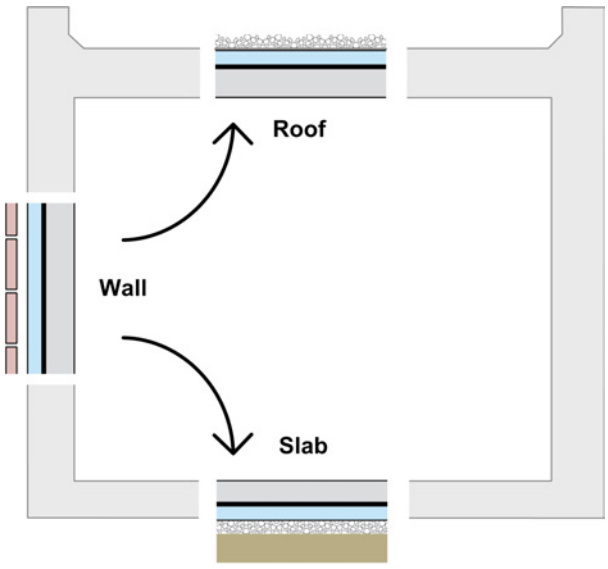

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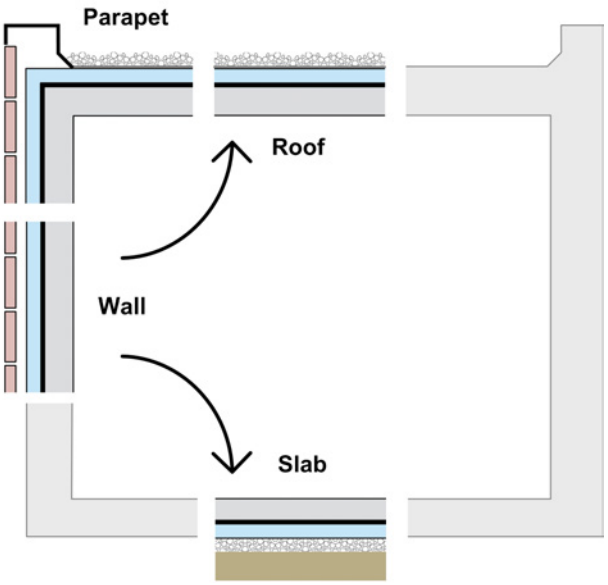

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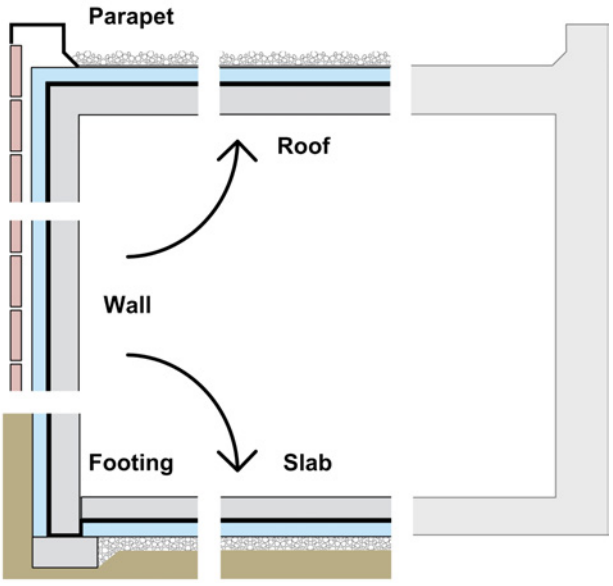

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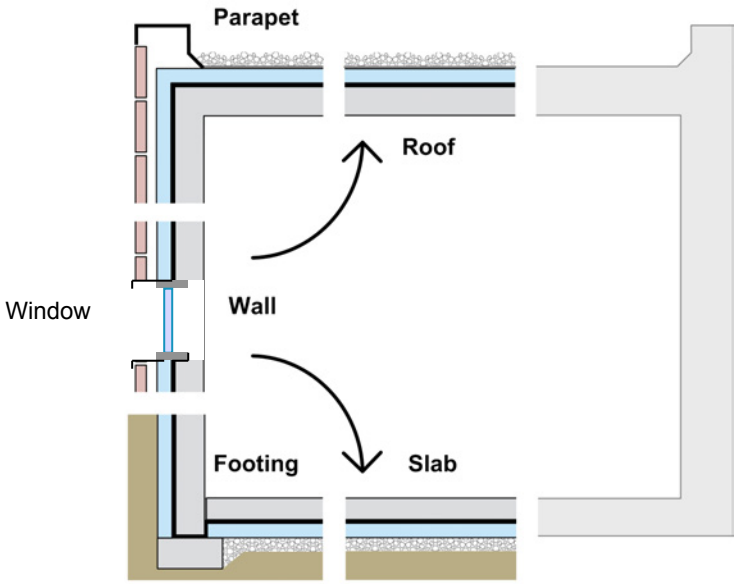

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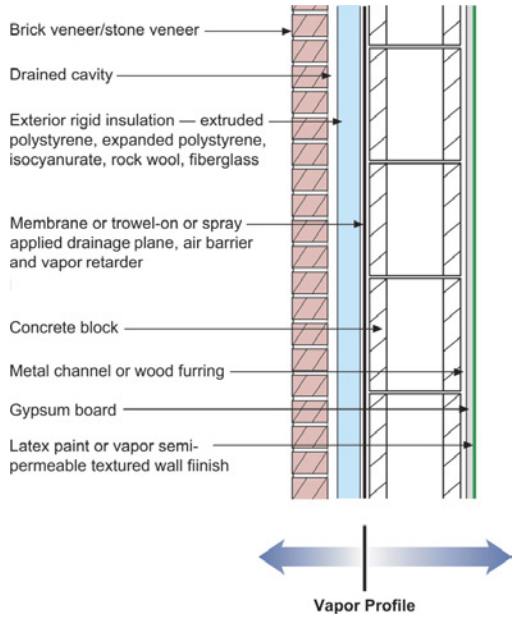

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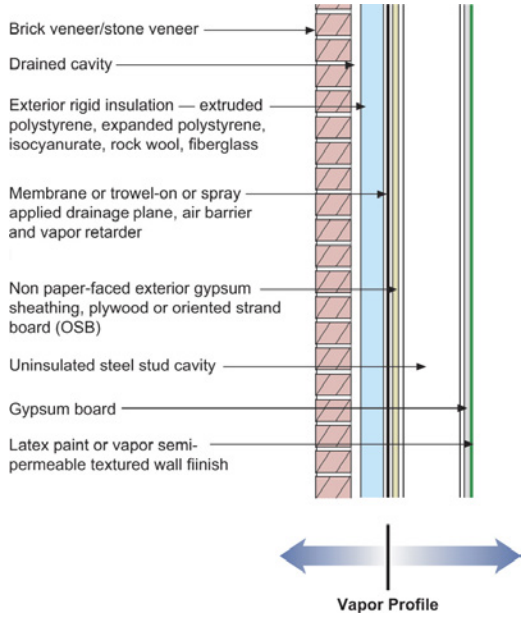

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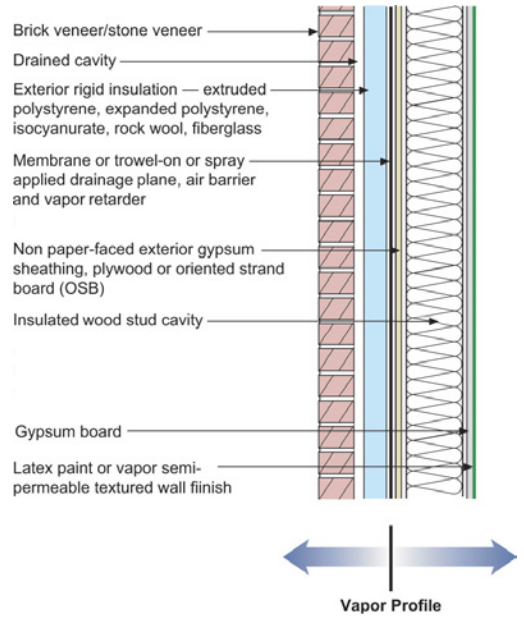

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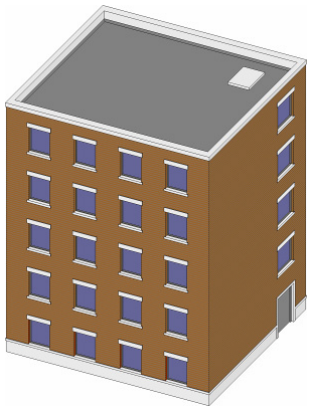
Commercial Enclosure: Simple Layers



- Structure
- Rain/Air/Vapor
- Insulation
- Finish

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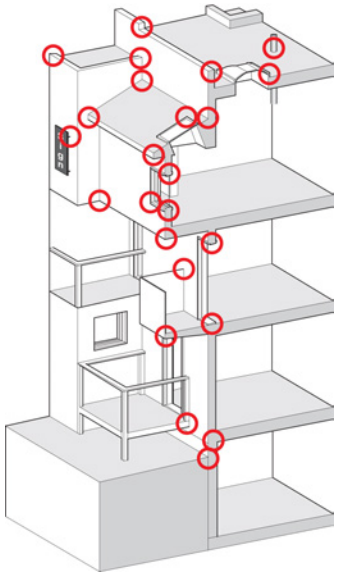

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Joseph Lstiburek 22

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Joseph Lstiburek 23

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Joseph Lstiburek 24

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Joseph Lstiburek 34

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Joseph Lstiburek 35

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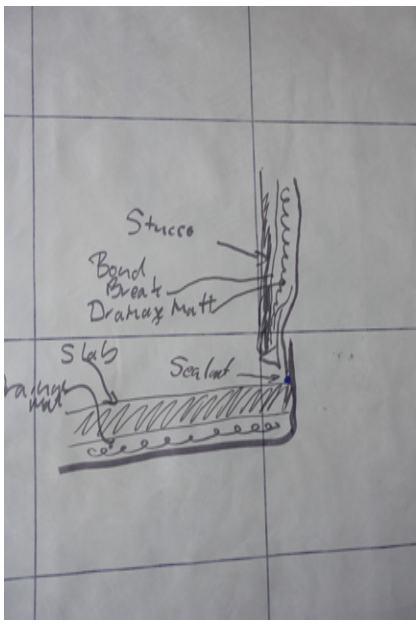
Joseph Lstiburek 36



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Joseph Lstiburek 38

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Joseph Lstiburek 39

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Joseph Lstiburek – HVAC 43

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Joseph Lstiburek 44

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Joseph Lstiburek 45

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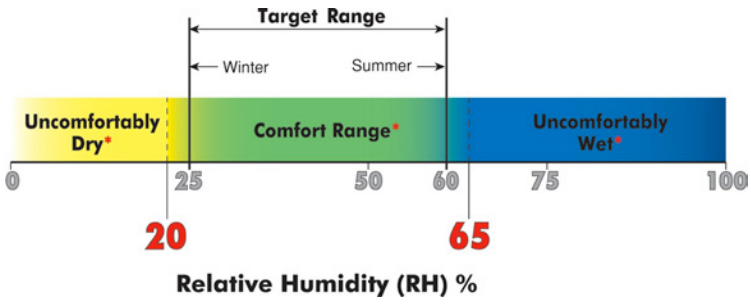
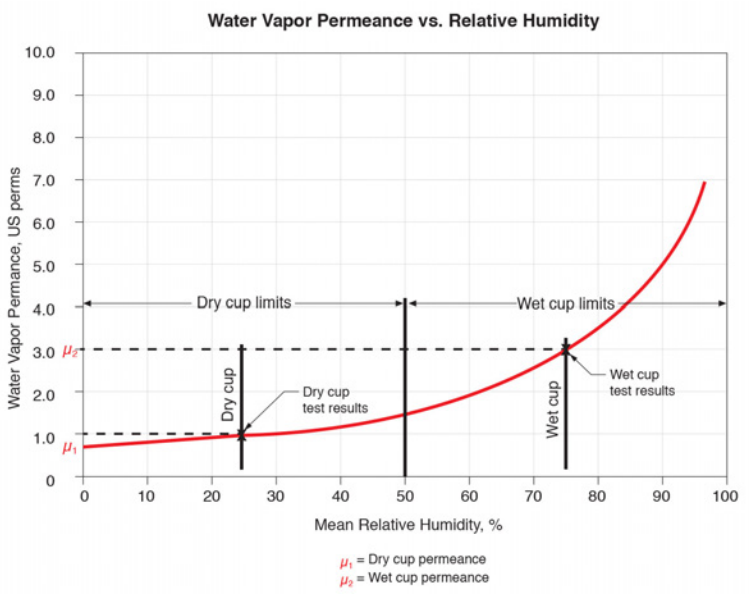
Joseph Lstiburek – HVAC 46


Target Range
Winter
Summer
Uncomfortably Dry*
Comfort Range*
Uncomfortably Wet*
0
25
50
60
75
100
20
65
Relative Humidity (RH) %



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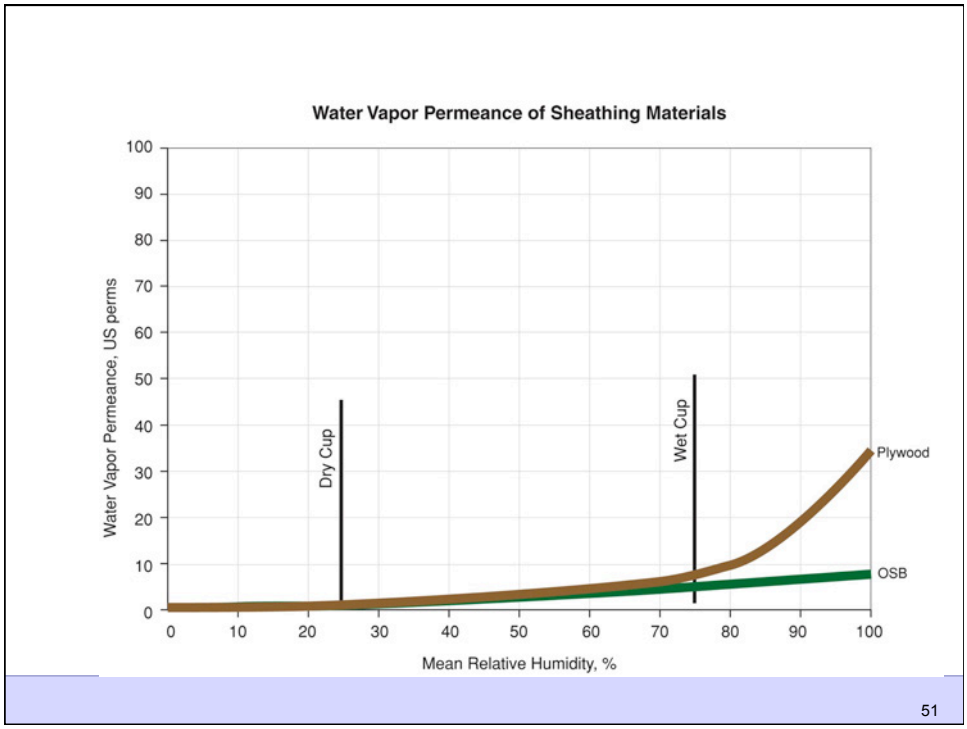
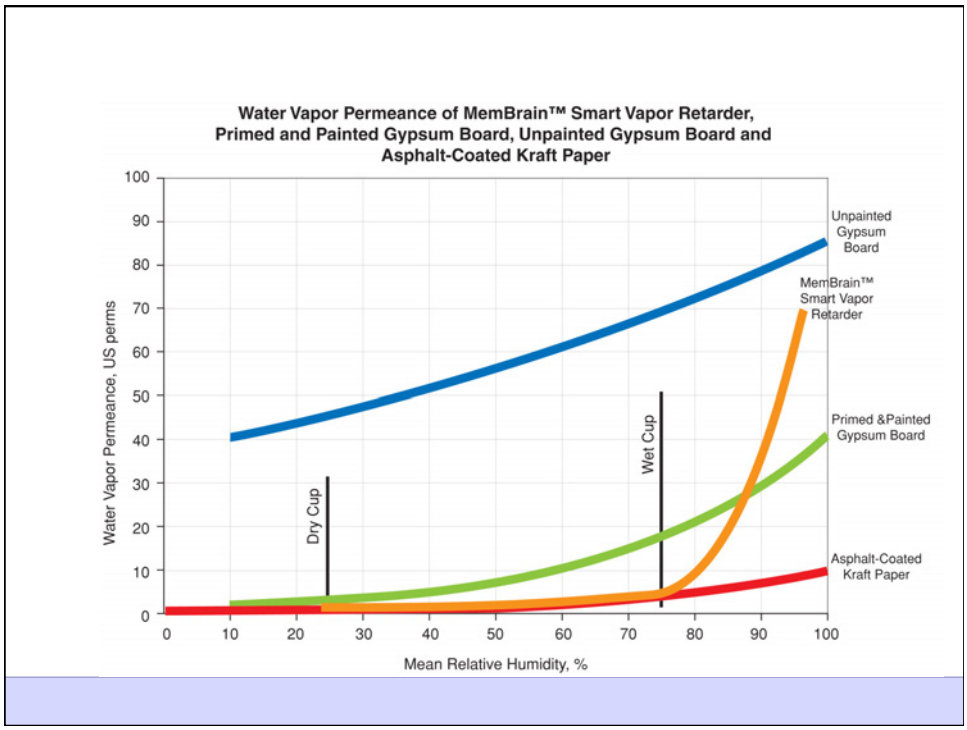
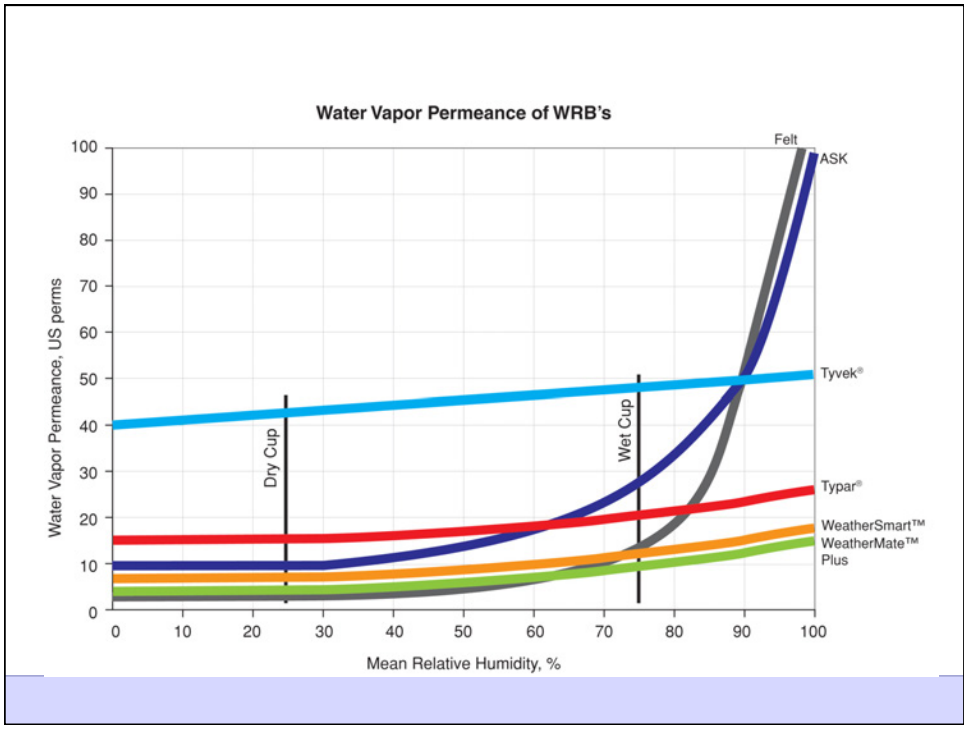
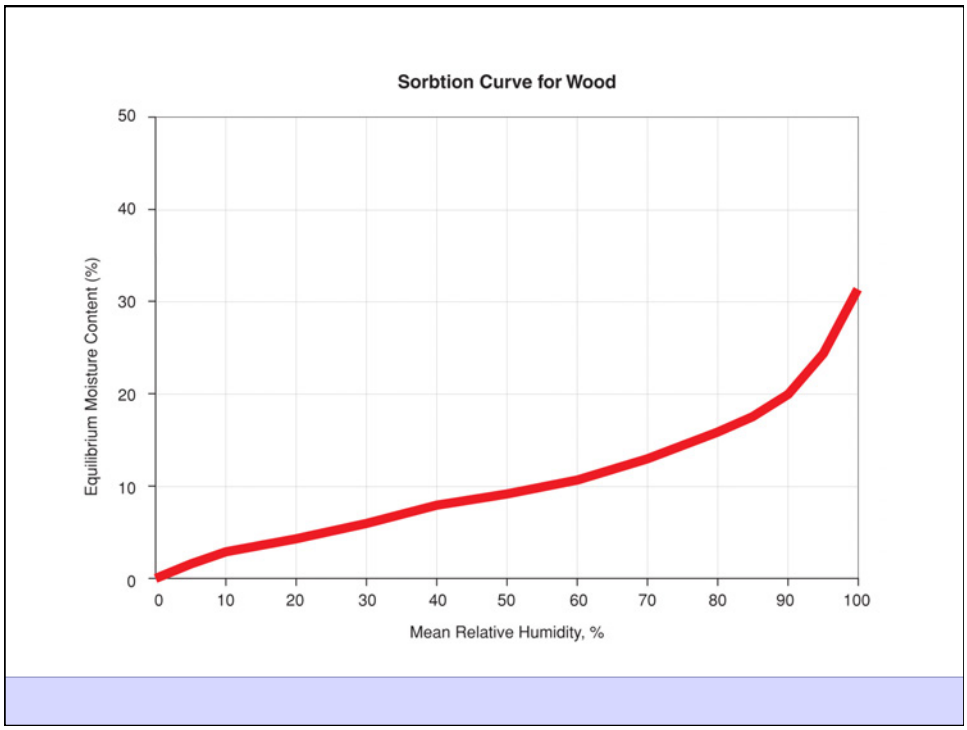
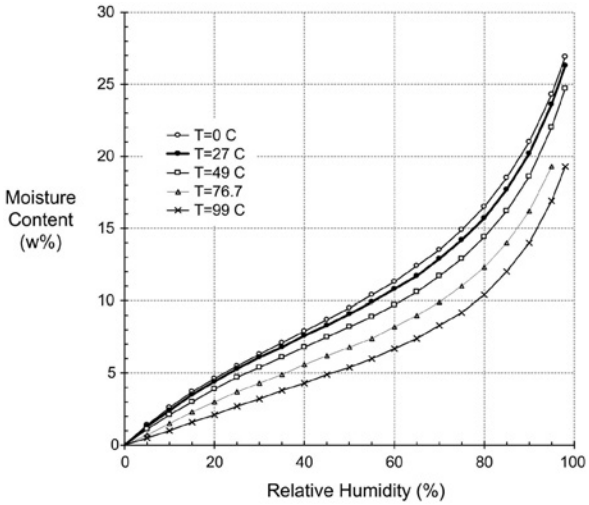

Water Vapor Permeance of Sheathing Materials
Water Vapor Permeance, US perms
100
90
80
70
60
50
40
30
20
10
0
Dry Cup
Wet Cup
Plywood
OSB
0
10
20
30
40
50
60
70
80
90
100
Mean Relative Humidity, %
51


Water Vapor Permeance of MemBrain™ Smart Vapor Retarder, Primed and Painted Gypsum Board, Unpainted Gypsum Board and Asphalt-Coated Kraft Paper
Water Vapor Permeance, US perms
100
90
80
70
60
50
40
30
20
10
0
Dry Cup
Wet Cup
Unpainted Gypsum Board
MemBrain™ Smart Vapor Retarder
Primed &Painted Gypsum Board
Asphalt-Coated Kraft Paper
0
10
20
30
40
50
60
70
80
90
100
Mean Relative Humidity, %


Water Vapor Permeance of WRB's
Water Vapor Permeance, US perms
Mean Relative Humidity, %
Dry Cup
Wet Cup
Felt
ASK
Tyvek®
Typar®
WeatherSmart™
WeatherMate™
Plus
0
10
20
30
40
50
60
70
80
90
100


Sorbtion Curve for Wood
Equilibrium Moisture Content (%)
Mean Relative Humidity, %
0
10
20
30
40
50
60
70
80
90
100



Average sorption isotherm for wood as a function of temperature
From Straube & Burnett, 2005

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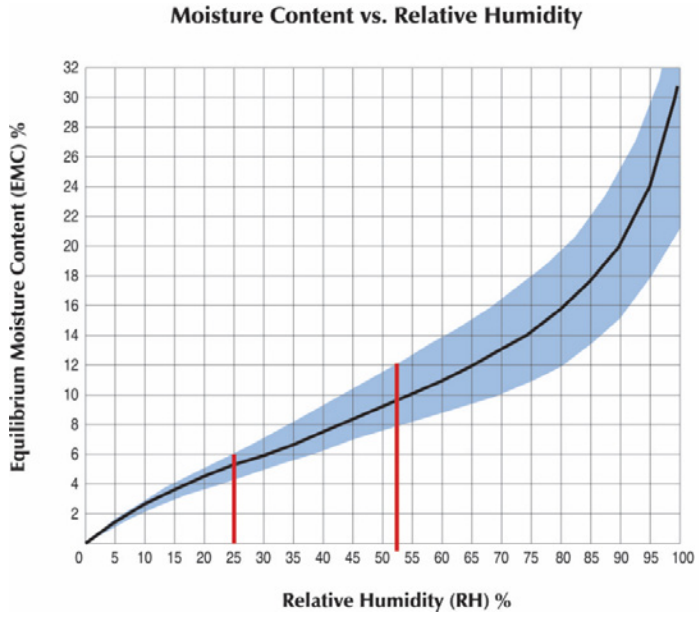

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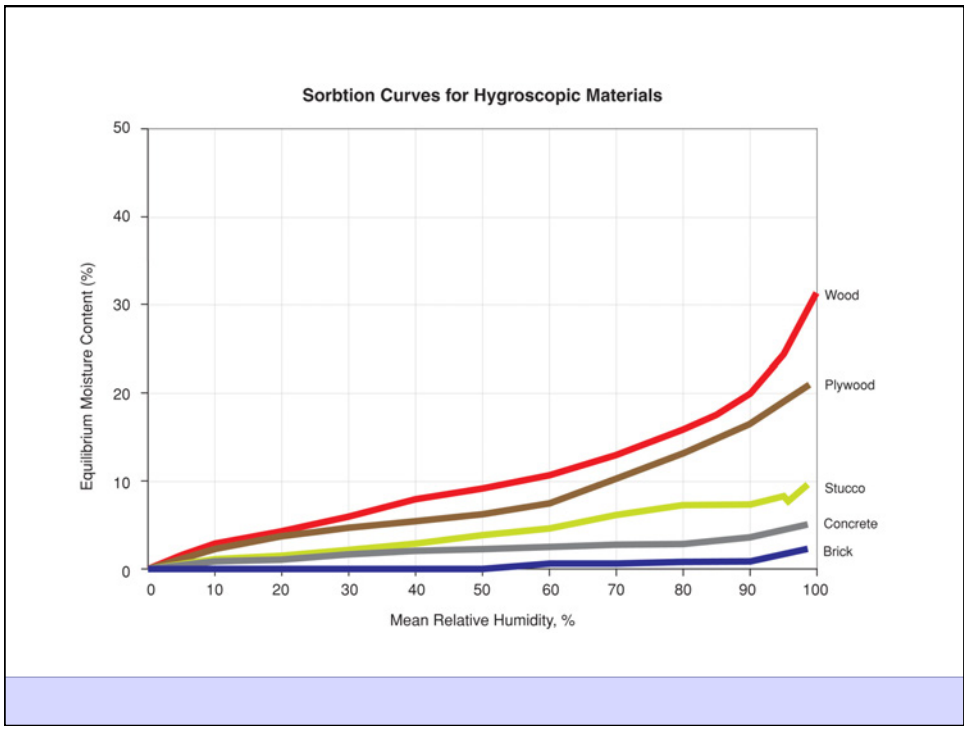
Sorbtion Curves for Hygroscopic Materials
Equilibrium Moisture Content (%)
0
10
20
30
40
50
0
10
20
30
40
50
60
70
80
90
100
Mean Relative Humidity, %
Wood
Plywood
Stucco
Concrete
Brick

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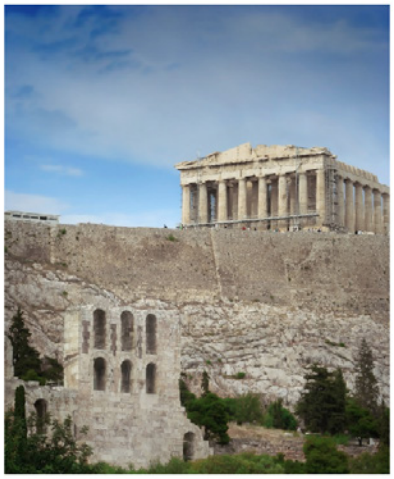

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Joseph Lstiburek 62

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Joseph Lstiburek 63

Building Science Corporation

Joseph Lstiburek 64

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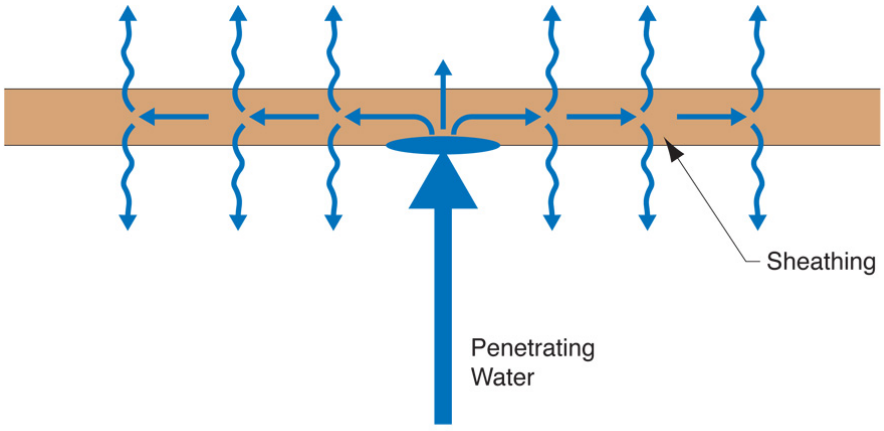
Joseph Lstiburek 65



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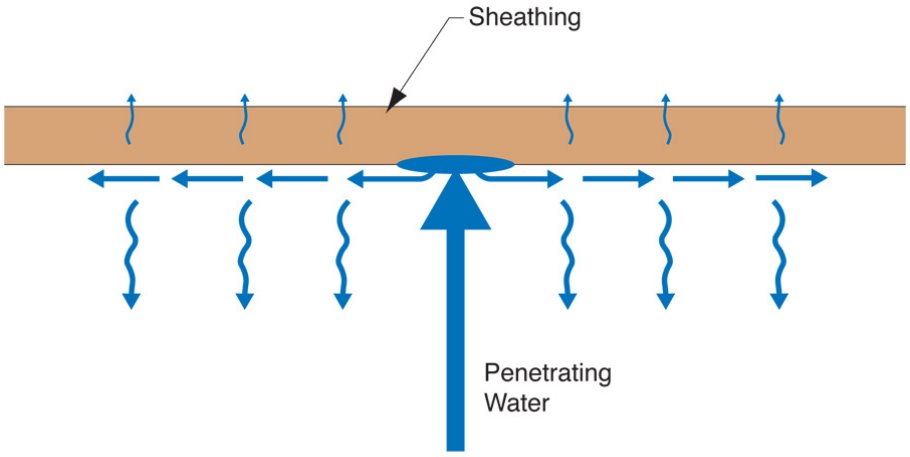

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Joseph Lstiburek – Rain Control 67

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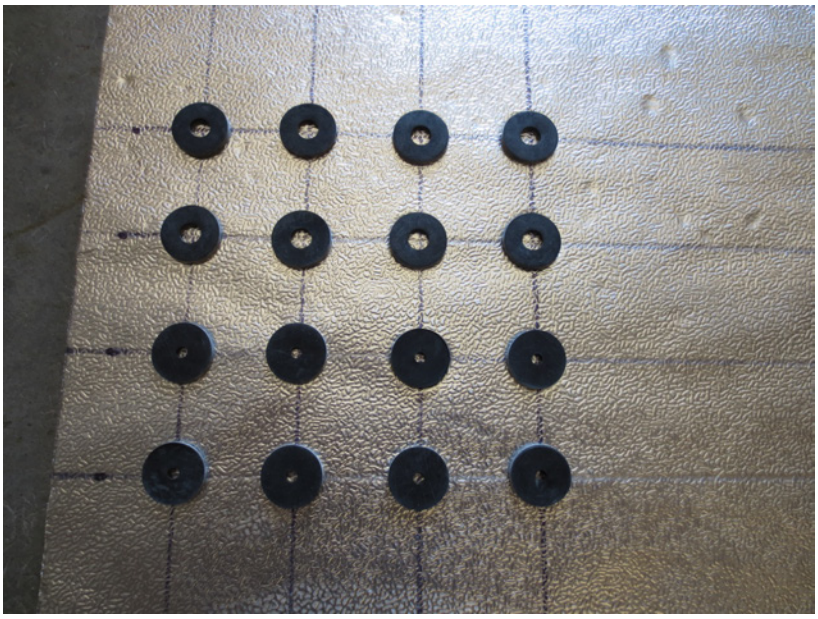
Joseph Lstiburek – Rain Control 68

Rain Screen



Beer Screen?

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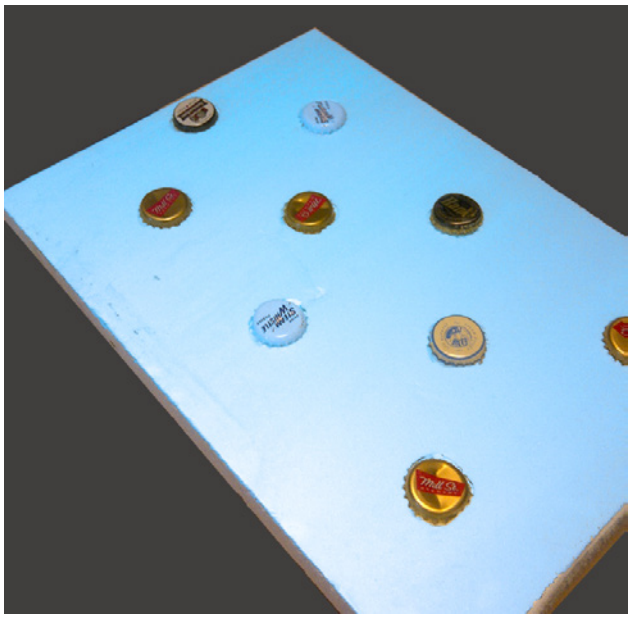

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2010

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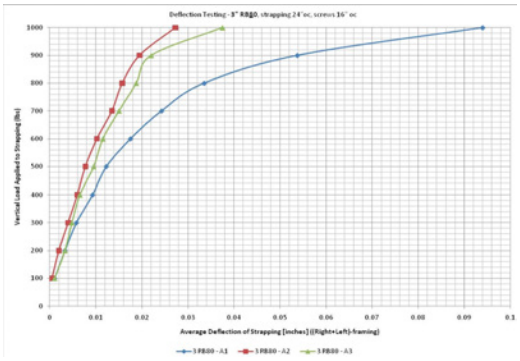
Rockwool

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



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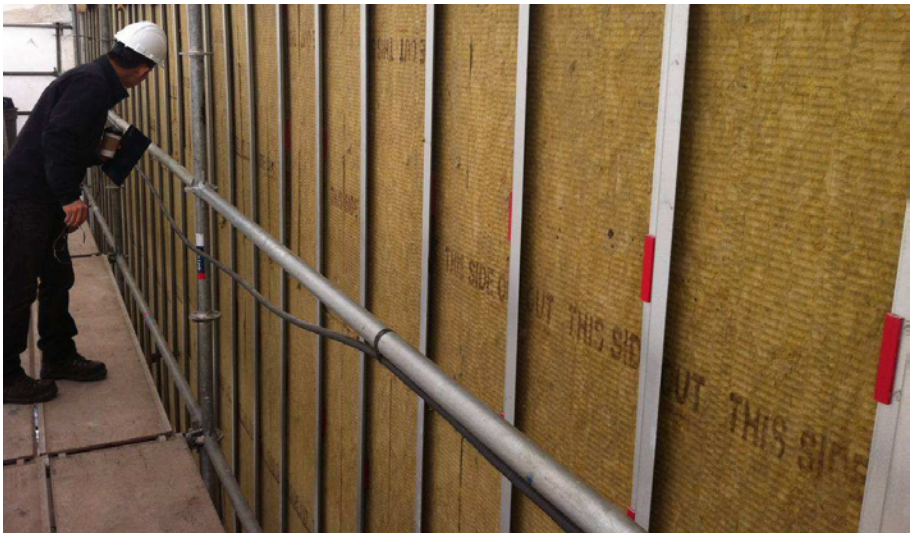
78



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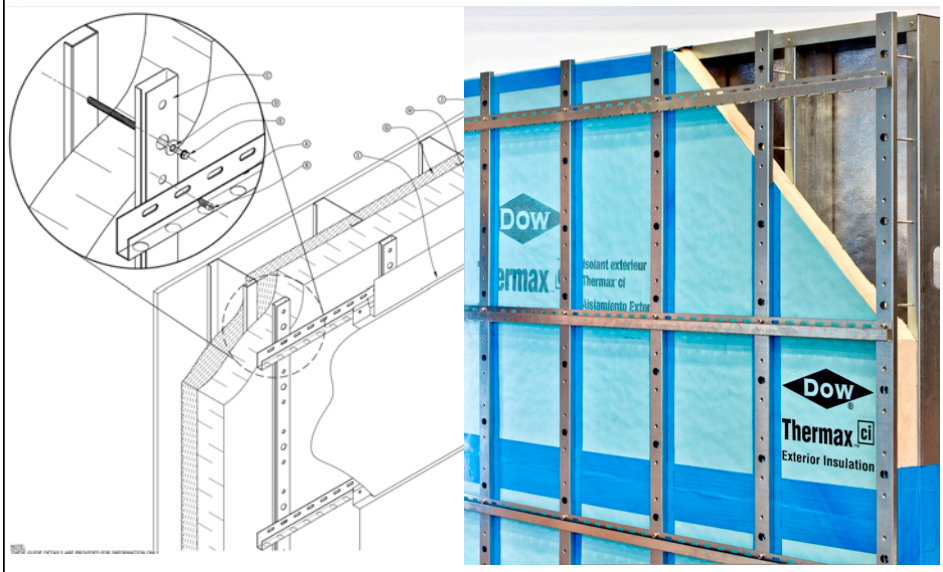

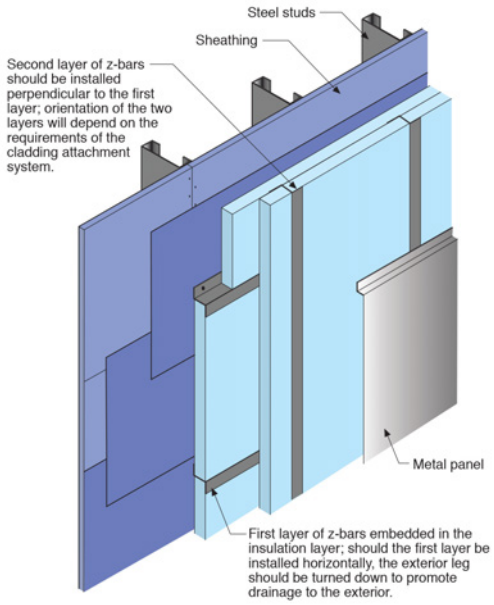

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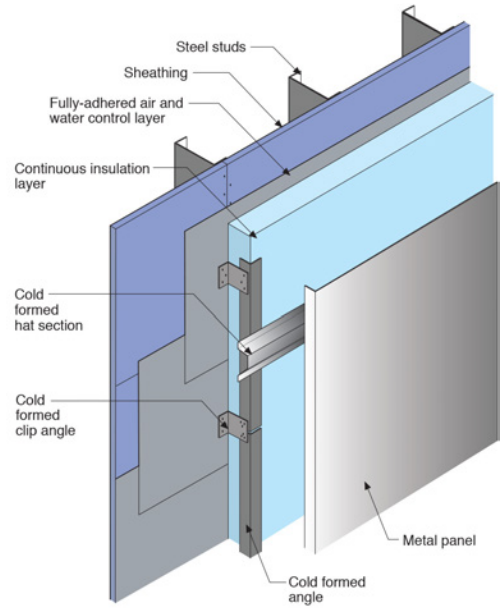

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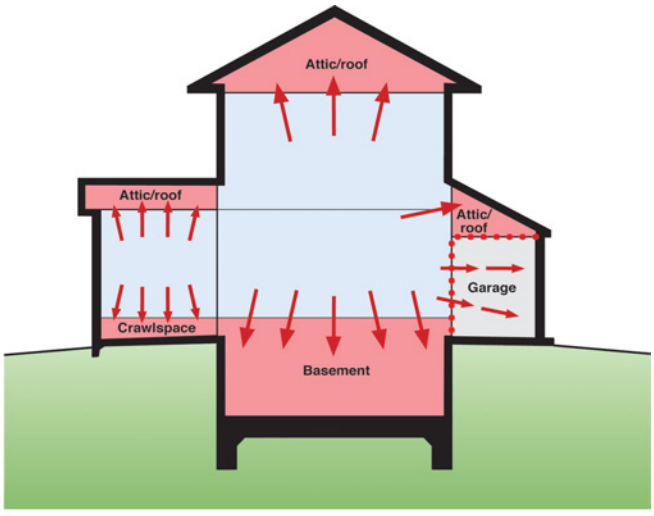
Foundations

presented by www.buildingscience.com



Expansion of Conditioned Space

- Conditioned space boundaries moving towards exterior surfaces of building
- Garage isolated from house by air barrier/pressure boundary
- Garage ventilated and conditioned independently of rest of conditioned spaces

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Mechanisms of Flow

• Liquid	Gravitational	Hydrostatic Pressure
	Capillary	Suction Pressure
	Osmosis	Solute Concentration
• Vapor	Diffusion	Vapor Pressure
	Convective	Air Pressure

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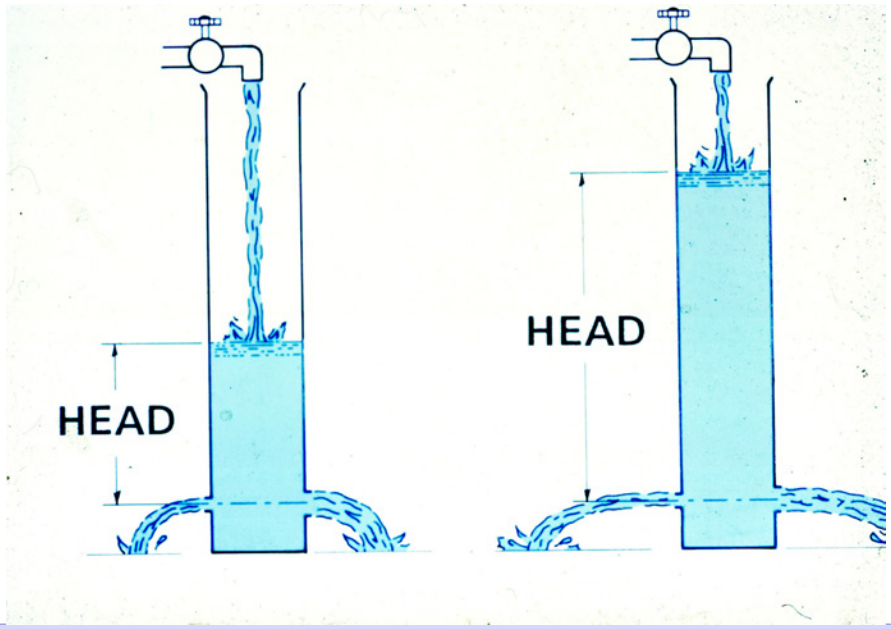

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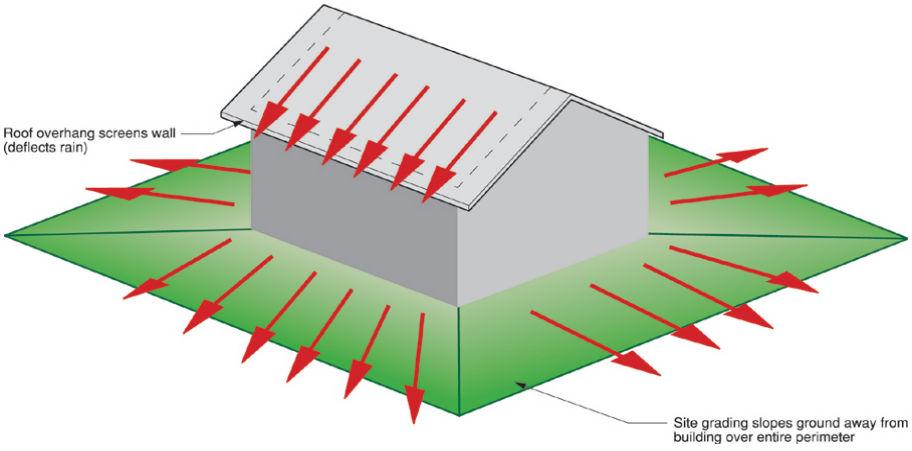
Joseph Lstiburek 4



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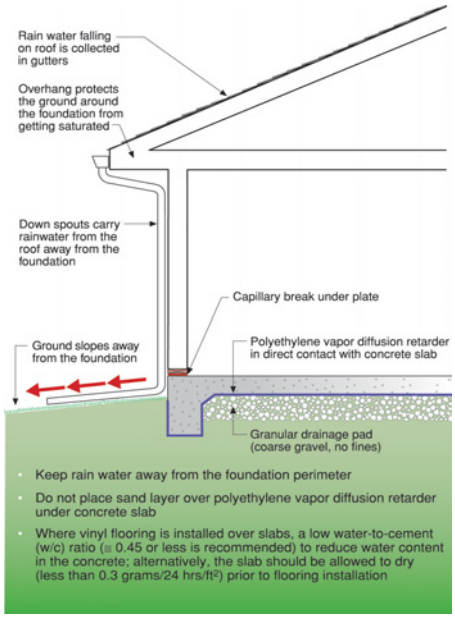

- Keep rain water away from the foundation perimeter
- Do not place sand layer over polyethylene vapor diffusion retarder under concrete slab
- Where vinyl flooring is installed over slabs, a low water-to-cement (w/c) ratio (≅ 0.45 or less is recommended) to reduce water content in the concrete; alternatively, the slab should be allowed to dry (less than 0.3 grams/24 hrs/ft²) prior to flooring installation

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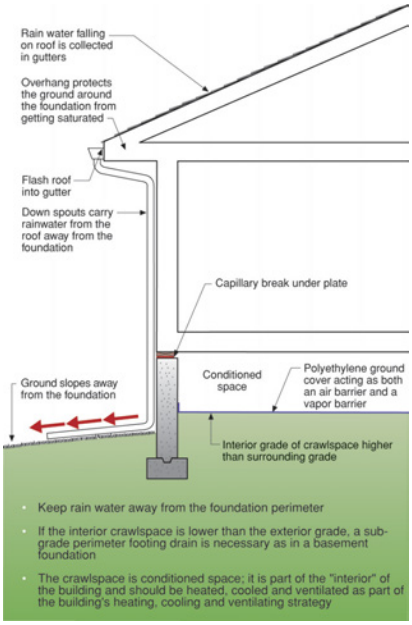

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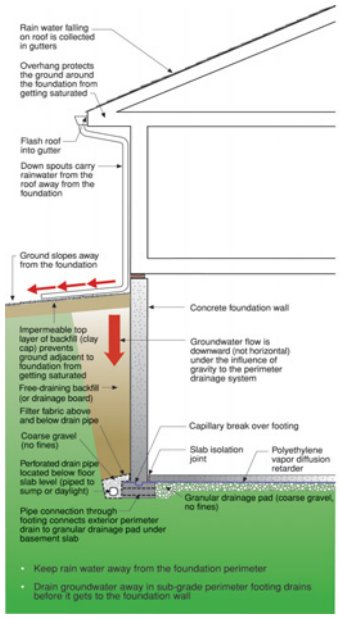

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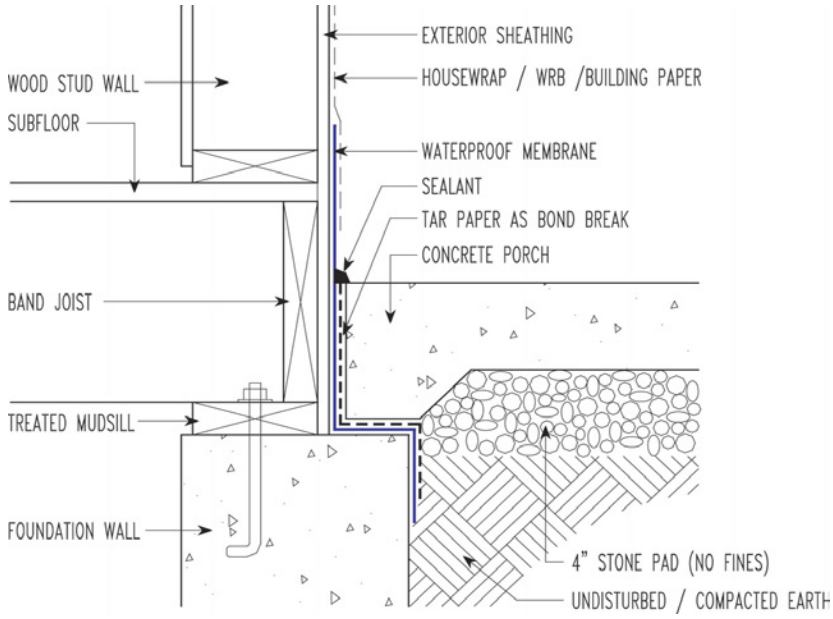

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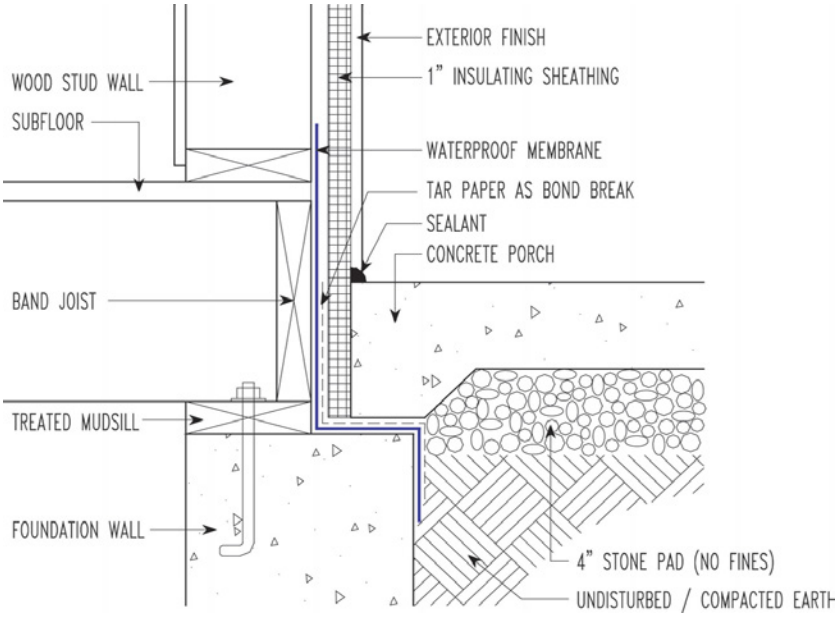

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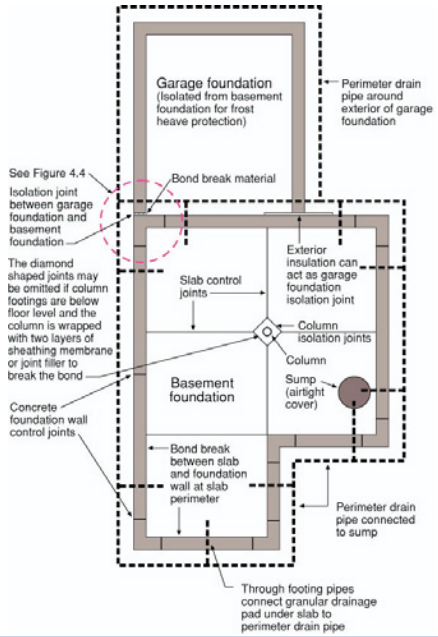

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Joseph Lstiburek 13

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Joseph Lstiburek 14

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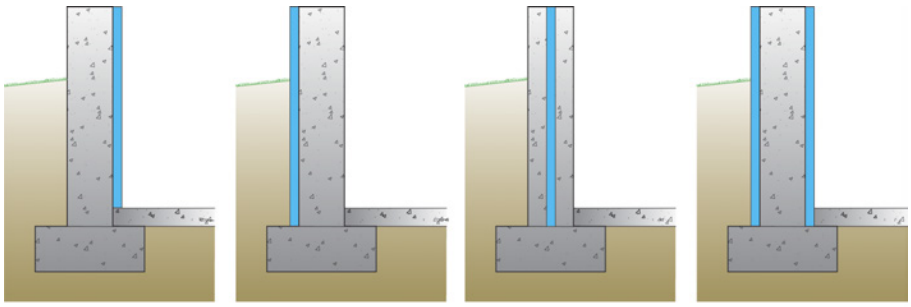
Joseph Lstiburek 15



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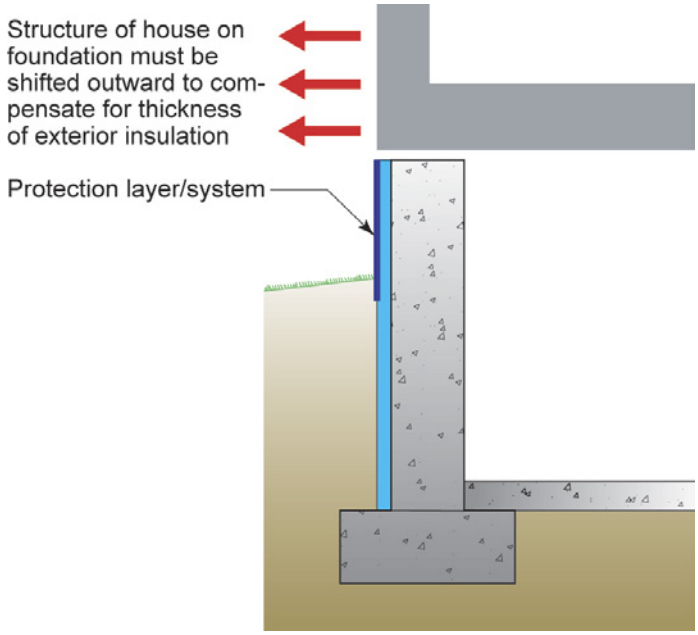

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Joseph Lstiburek 19

Building Science Corporation

Joseph Lstiburek 20

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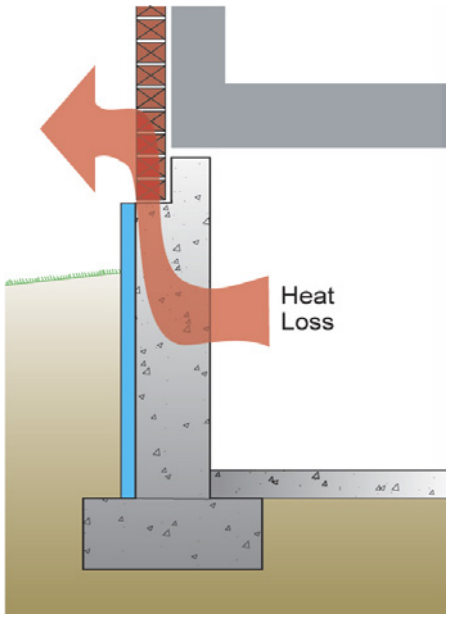

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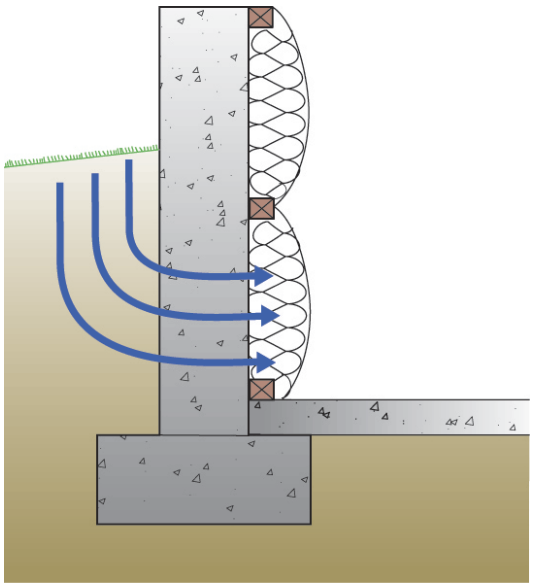

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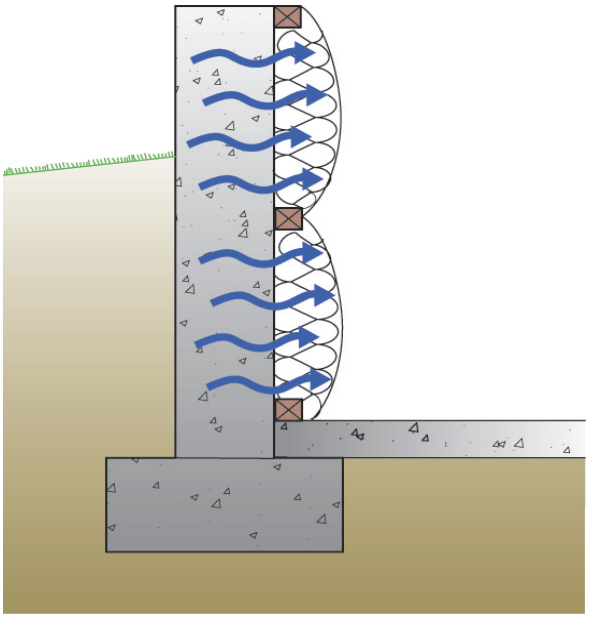

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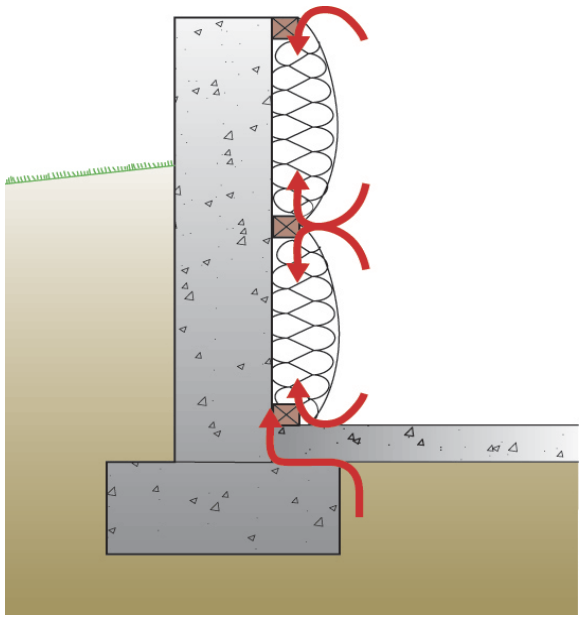

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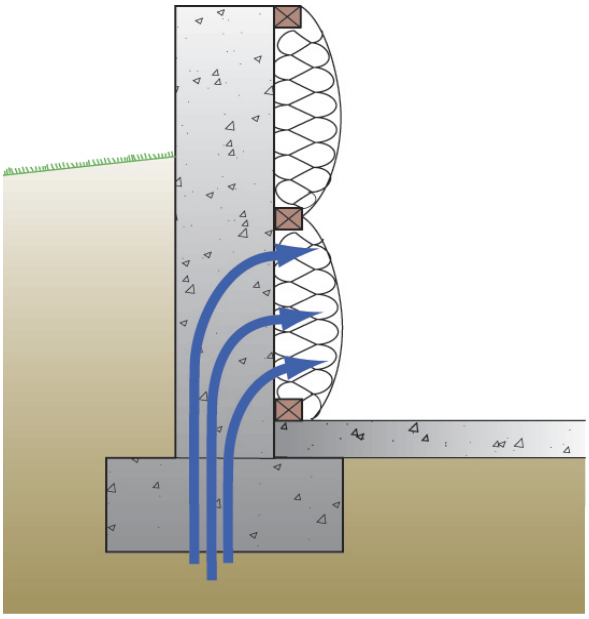

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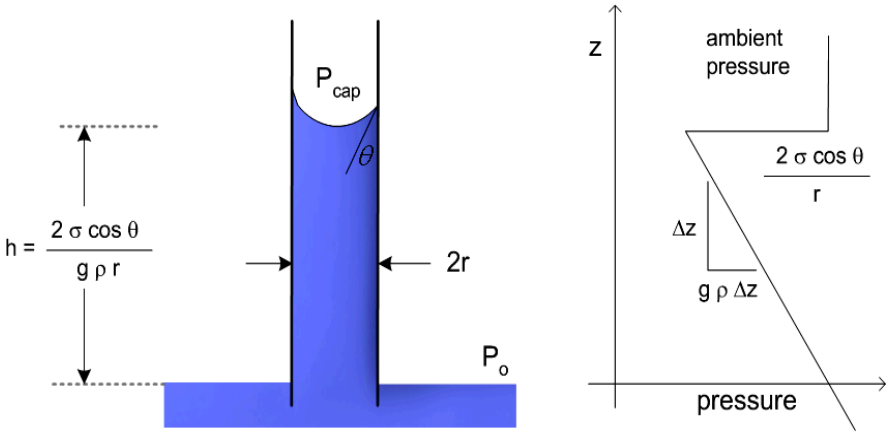
Calculating capillary rise



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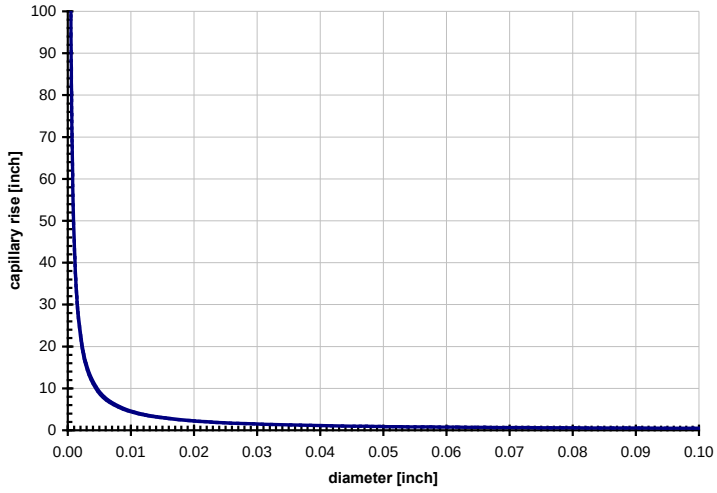
Capillary rise versus diameter



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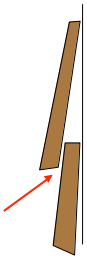
Capillary Flow

Siding laps



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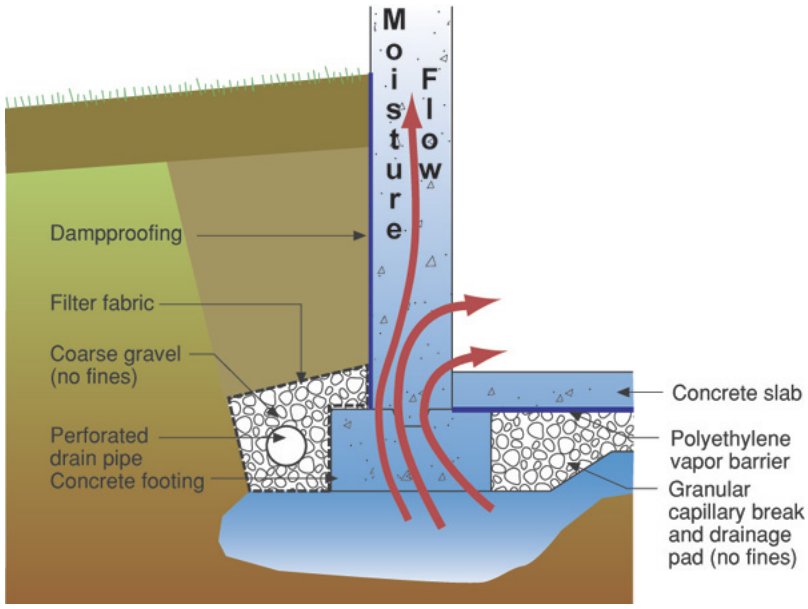
Joseph Lstiburek 37



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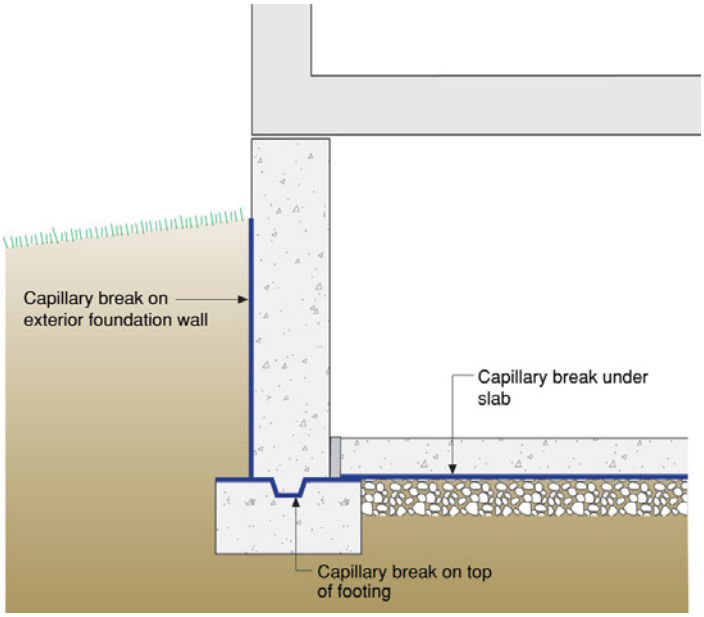

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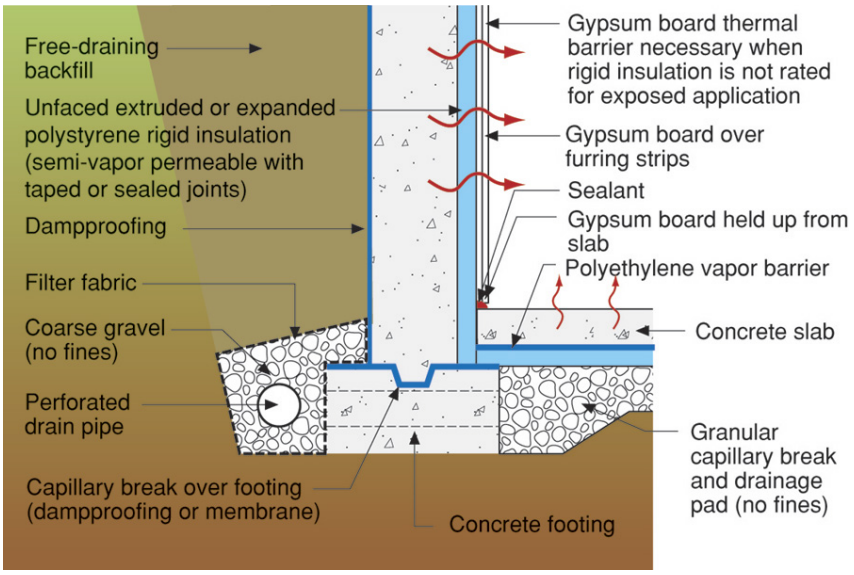

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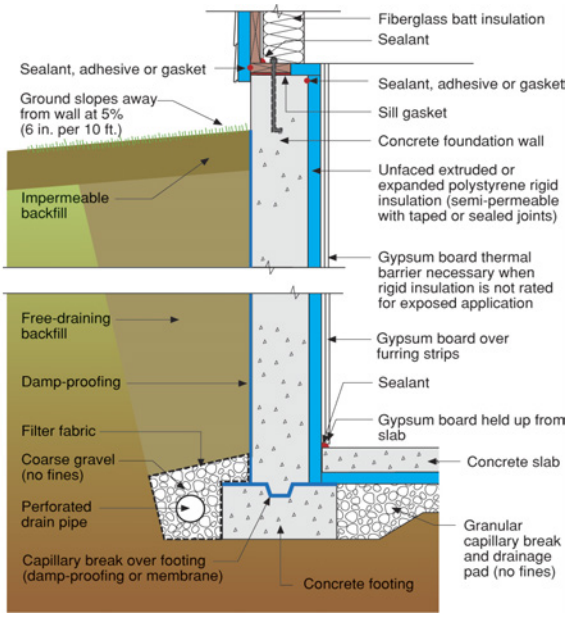

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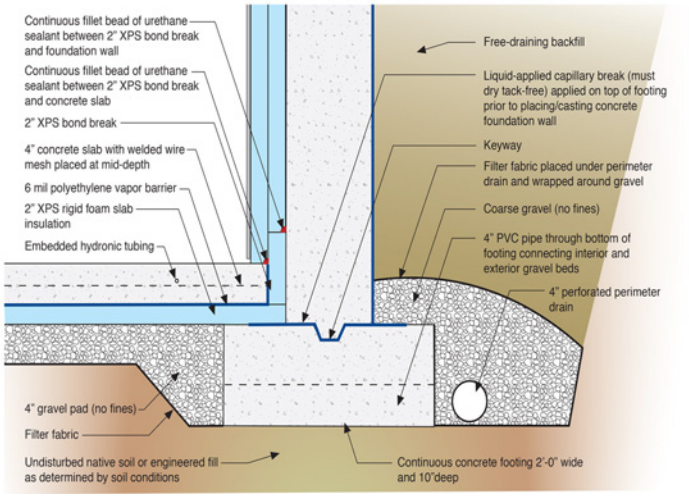

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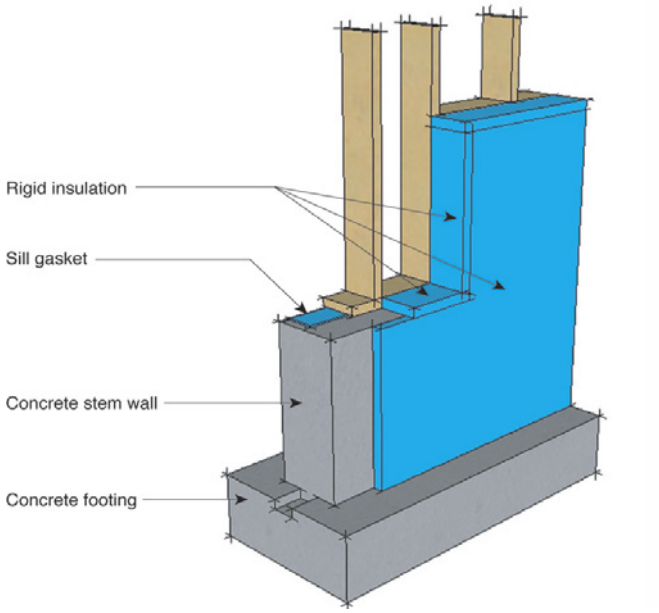

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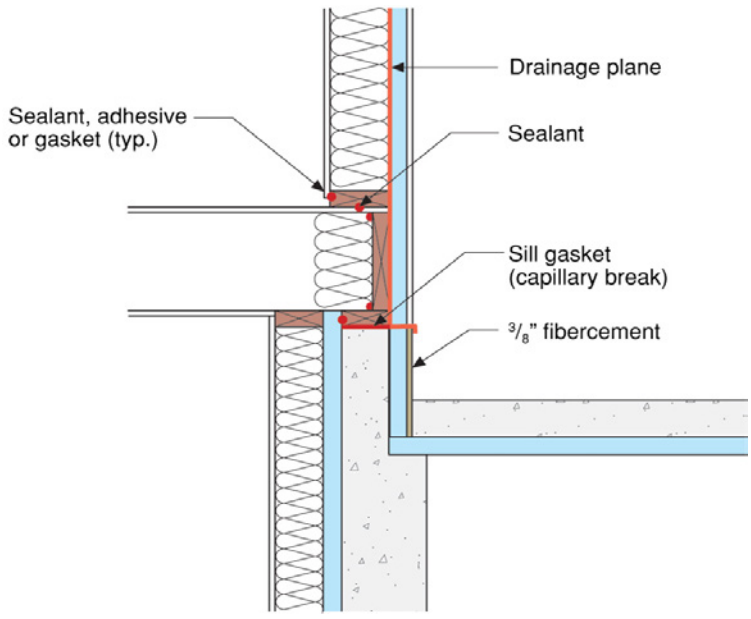

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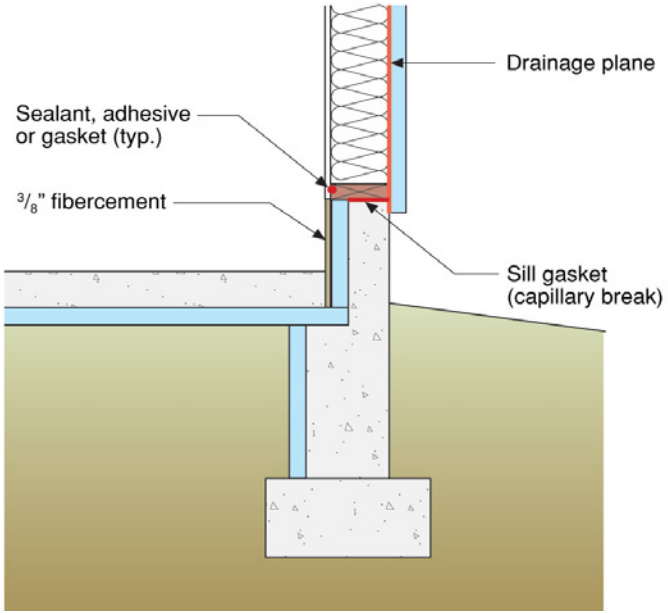

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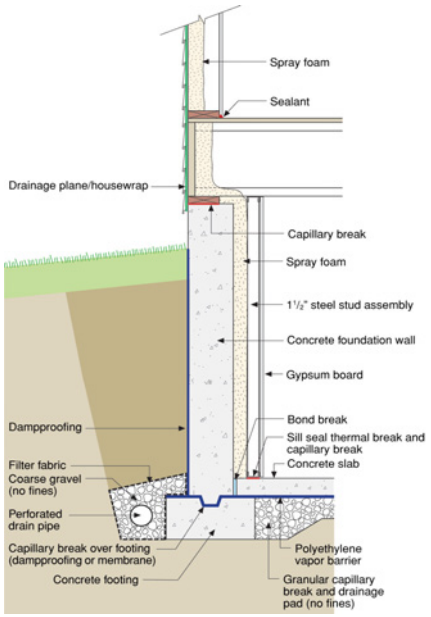

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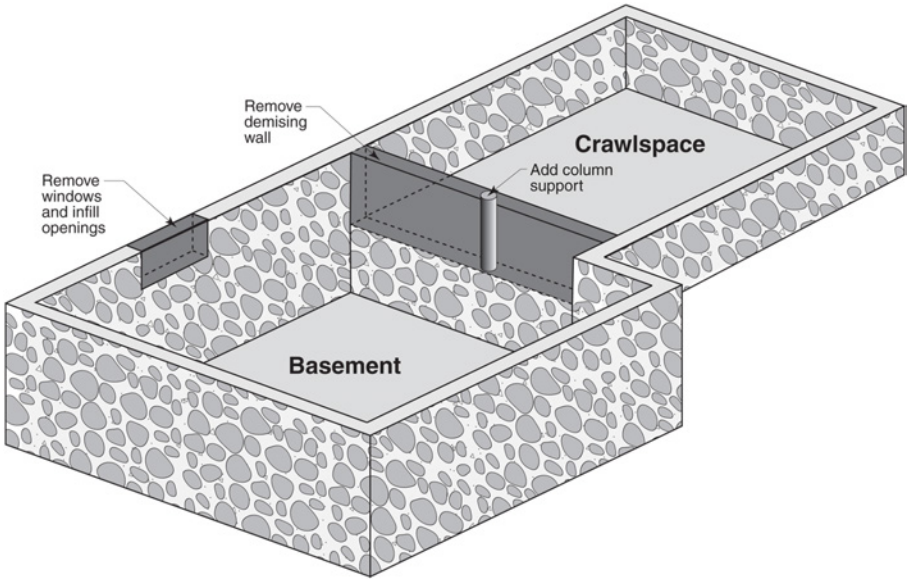

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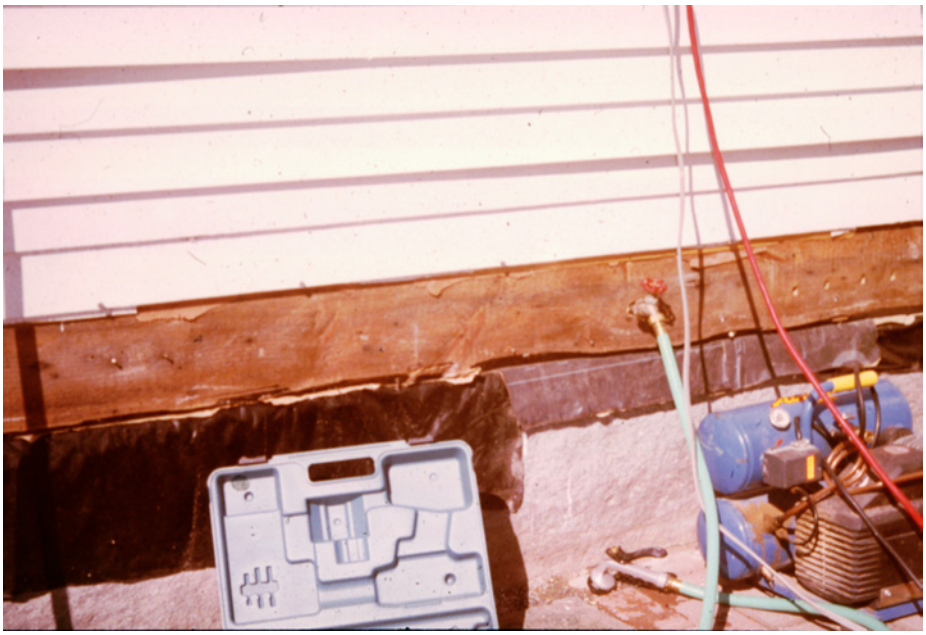

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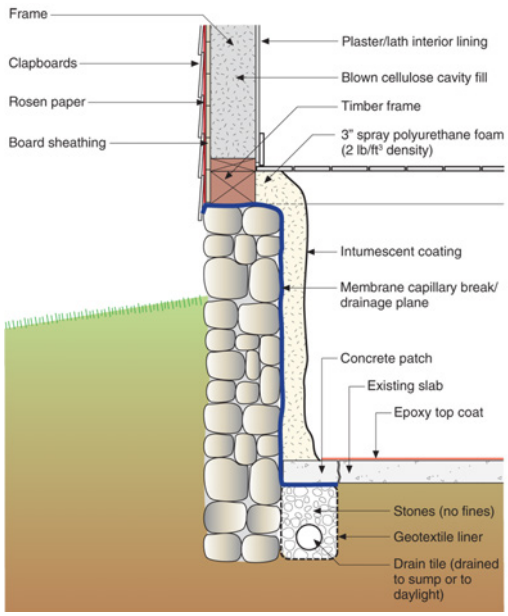

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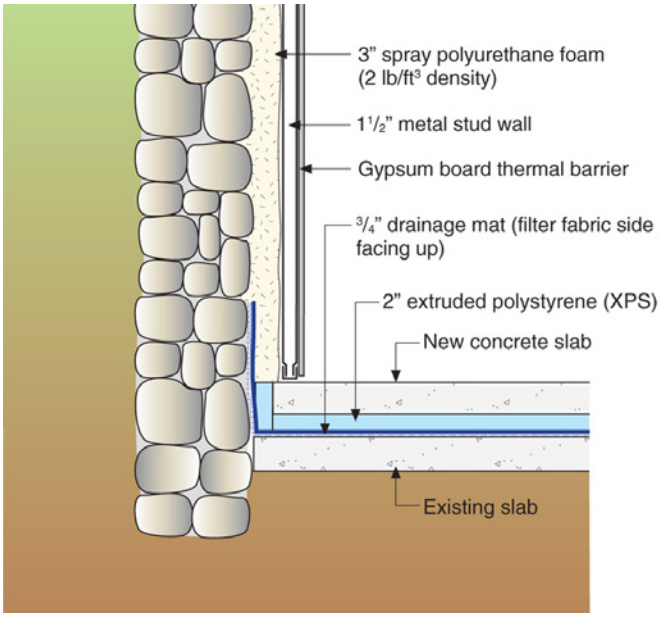

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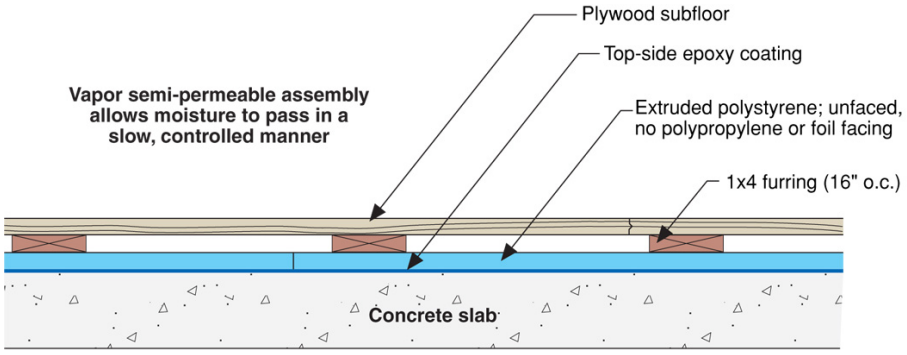

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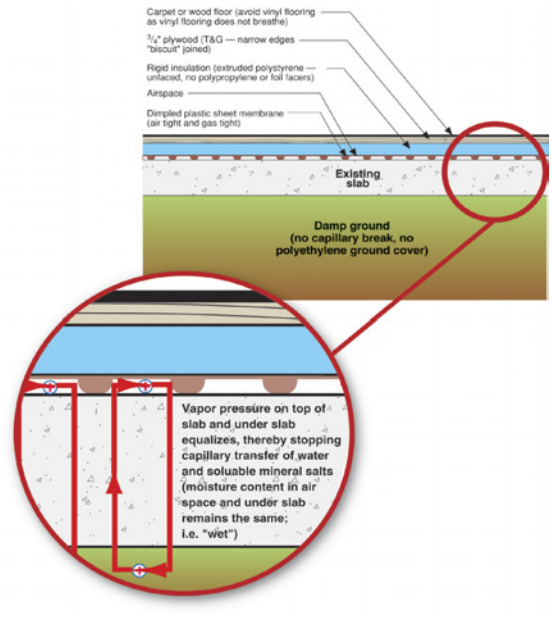

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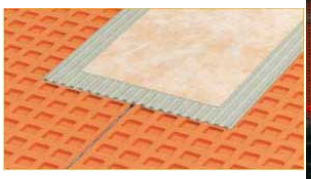

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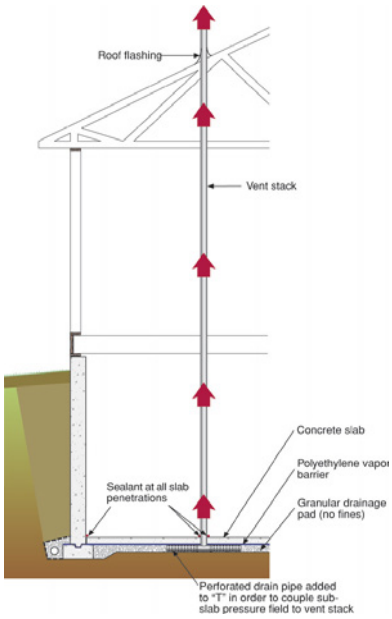

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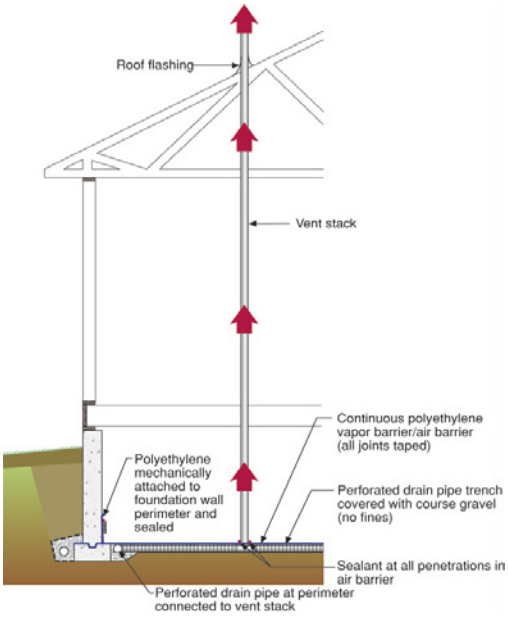

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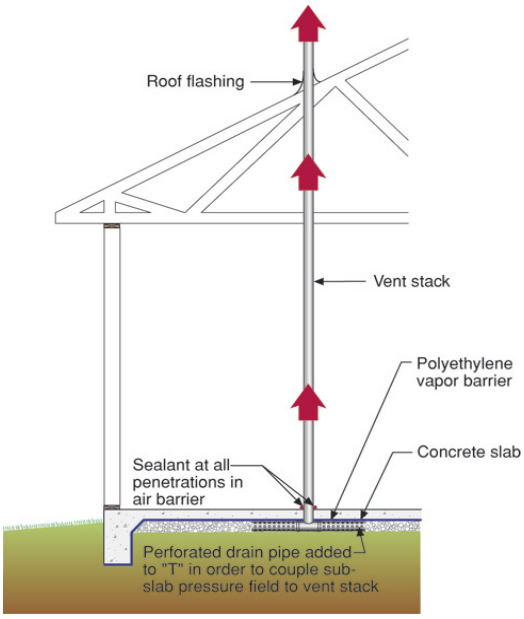

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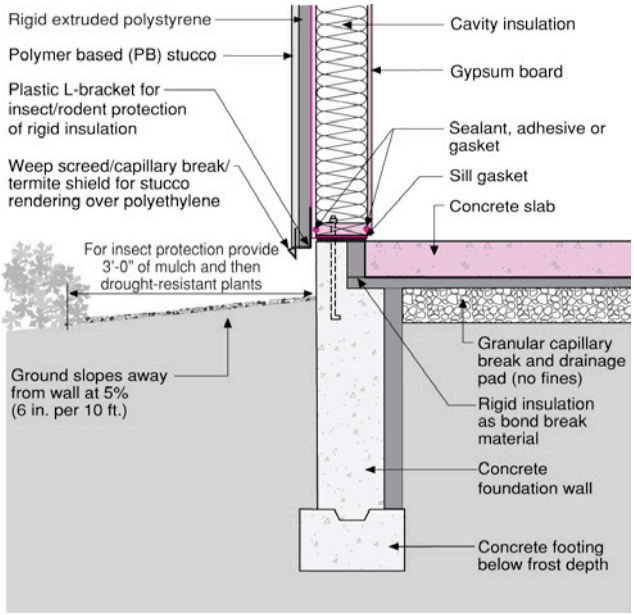

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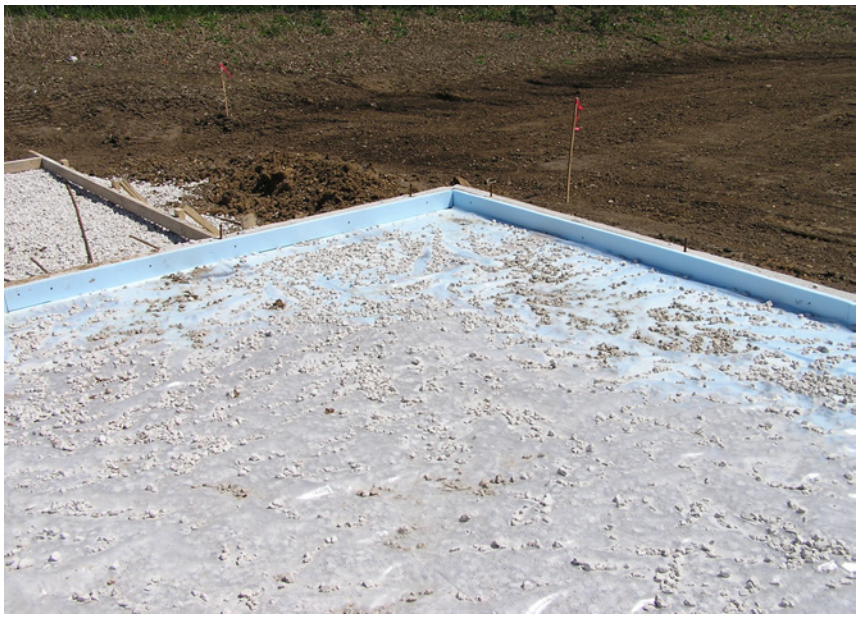

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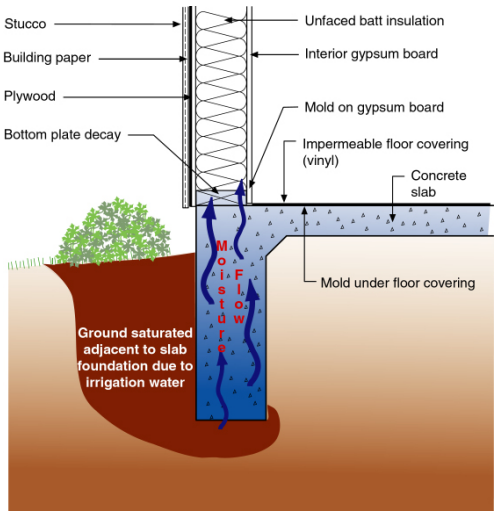
Capillary Moisture Flow



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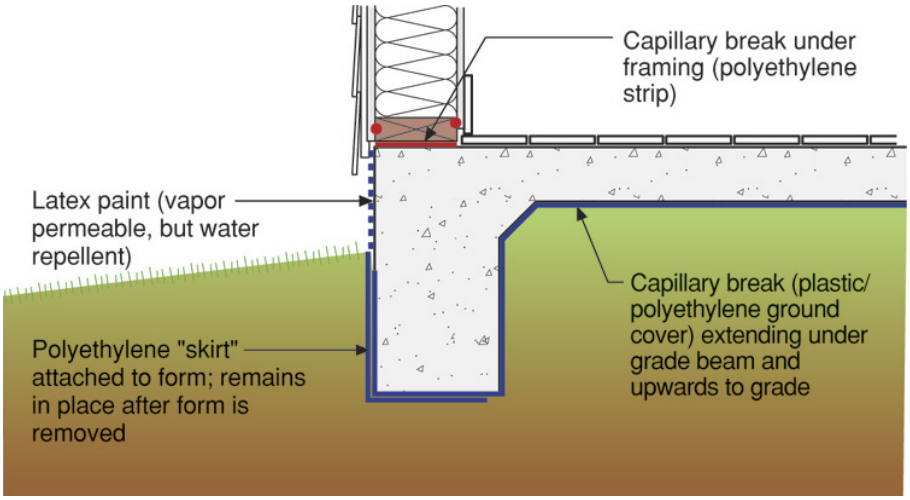

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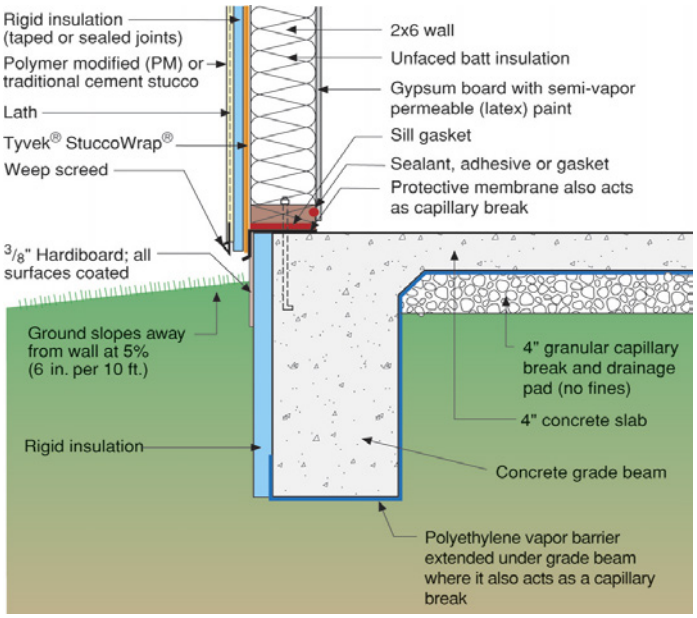

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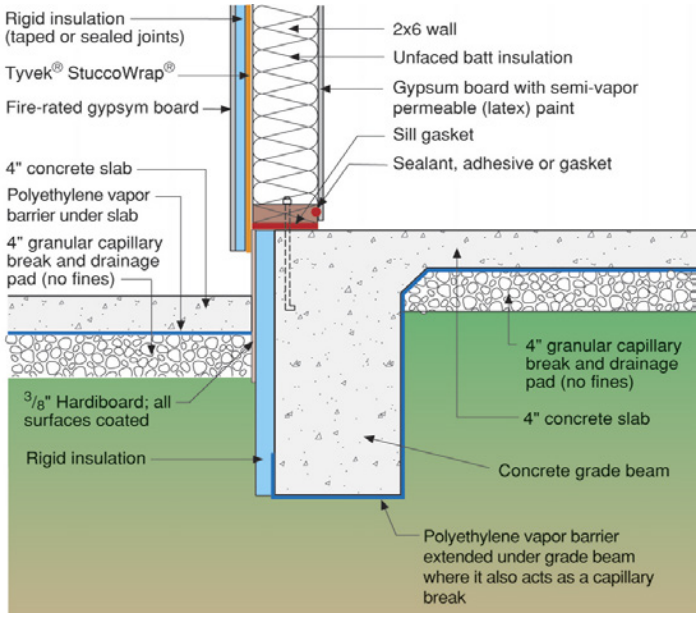

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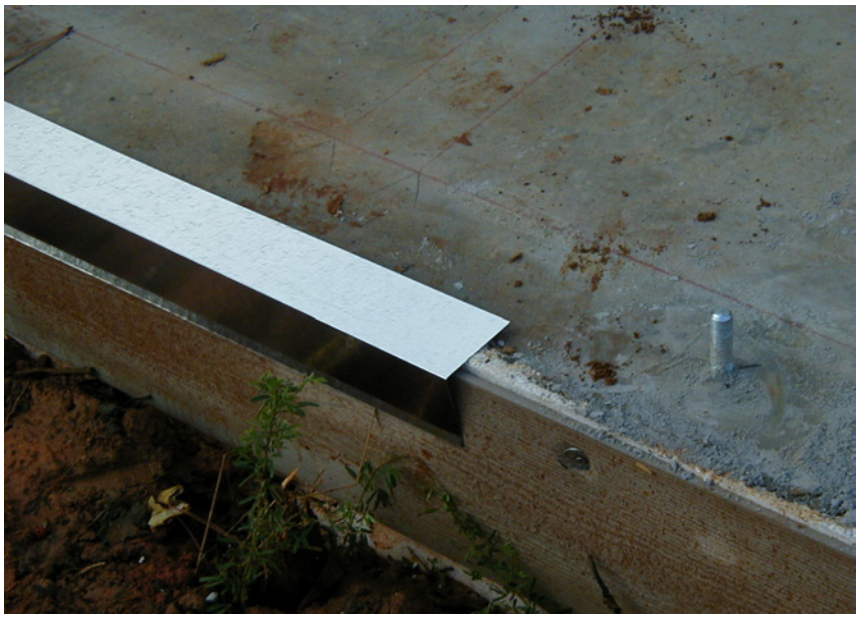

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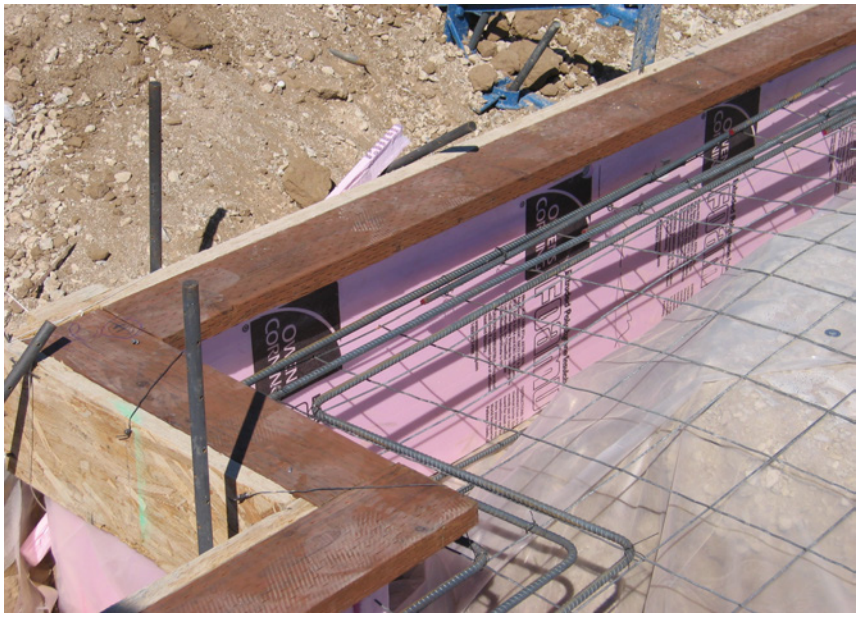

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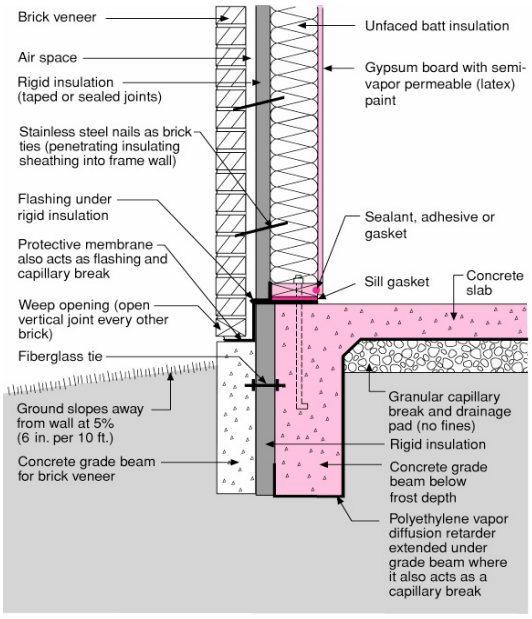

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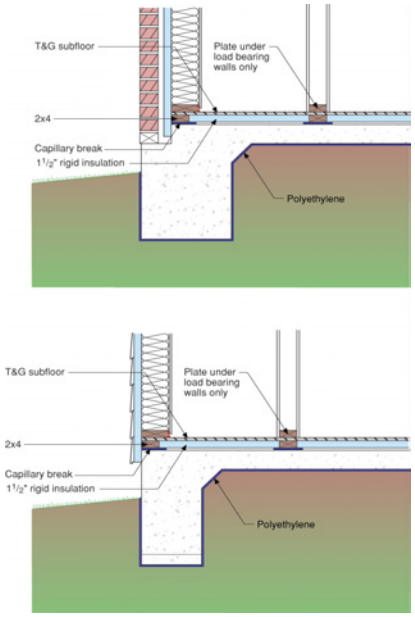

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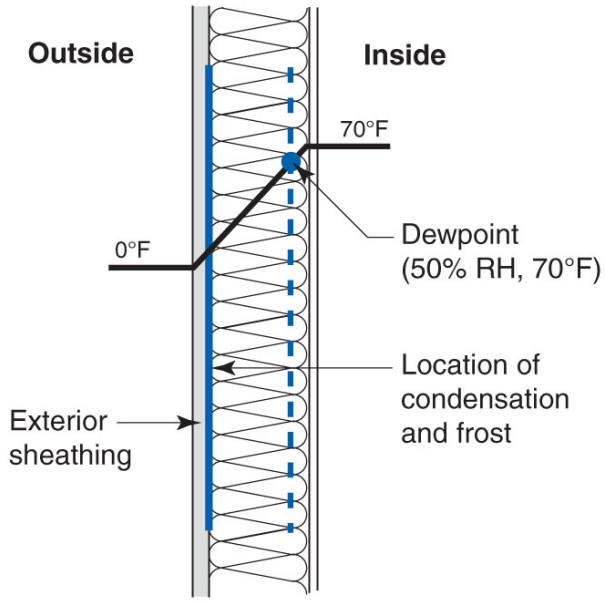

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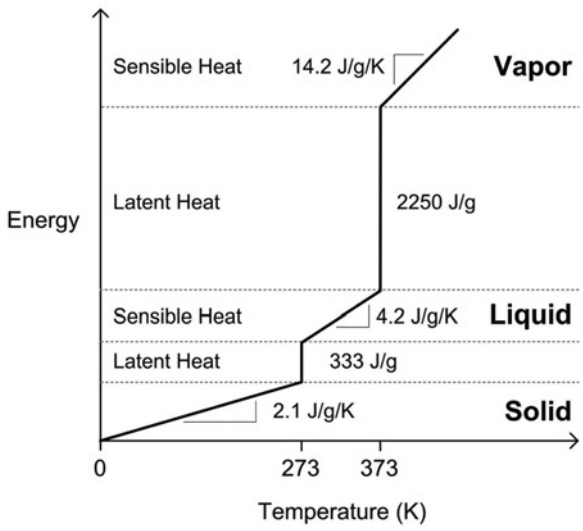

Simple linearized energy-temperature relation for water
From Straube & Burnett, 2005

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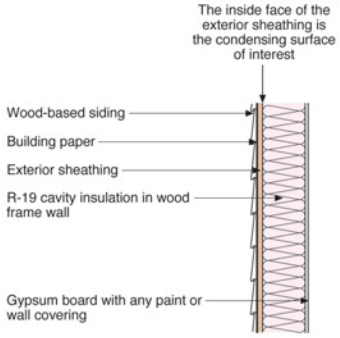

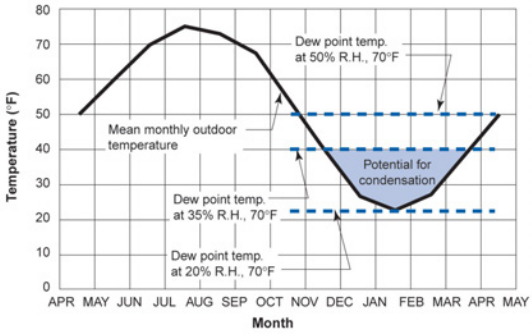

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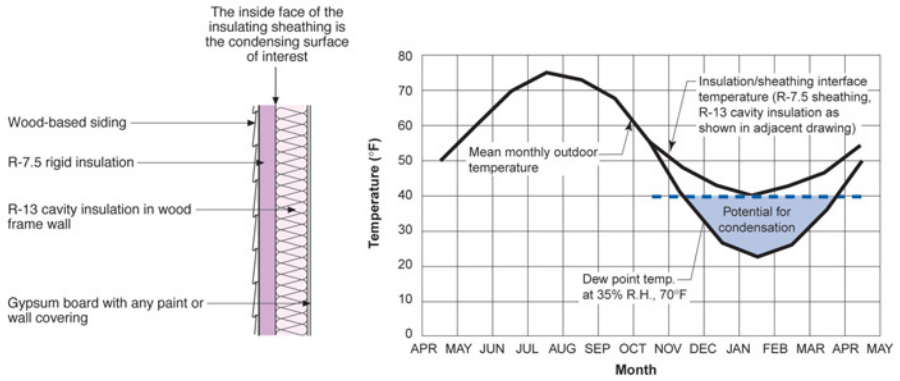

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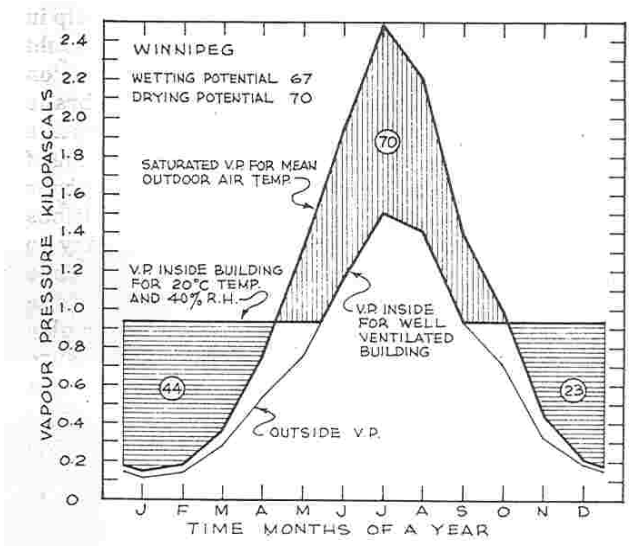

Figure 8-7. Outside vapour pressure, saturated vapour pressure and inside vapour pressure for Winnipeg.

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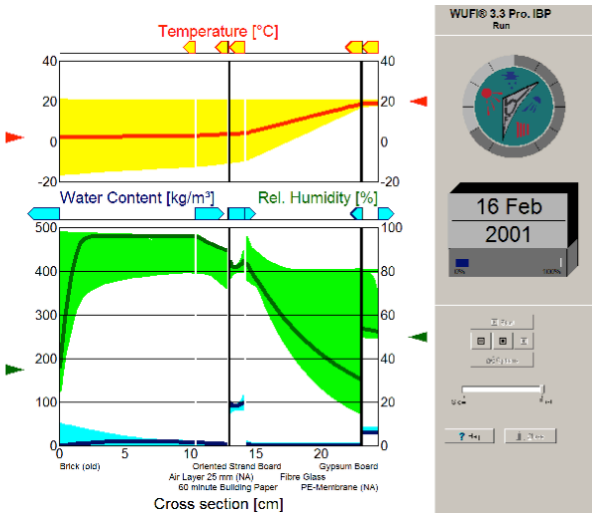

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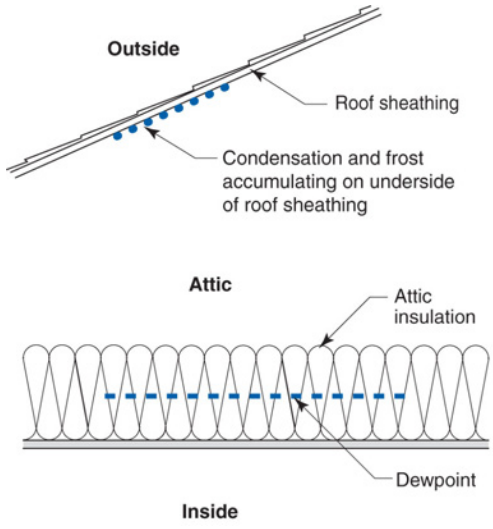

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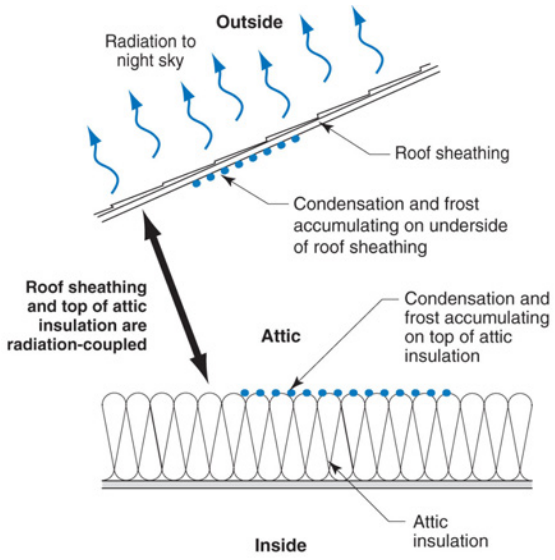
Joseph Lstiburek 11



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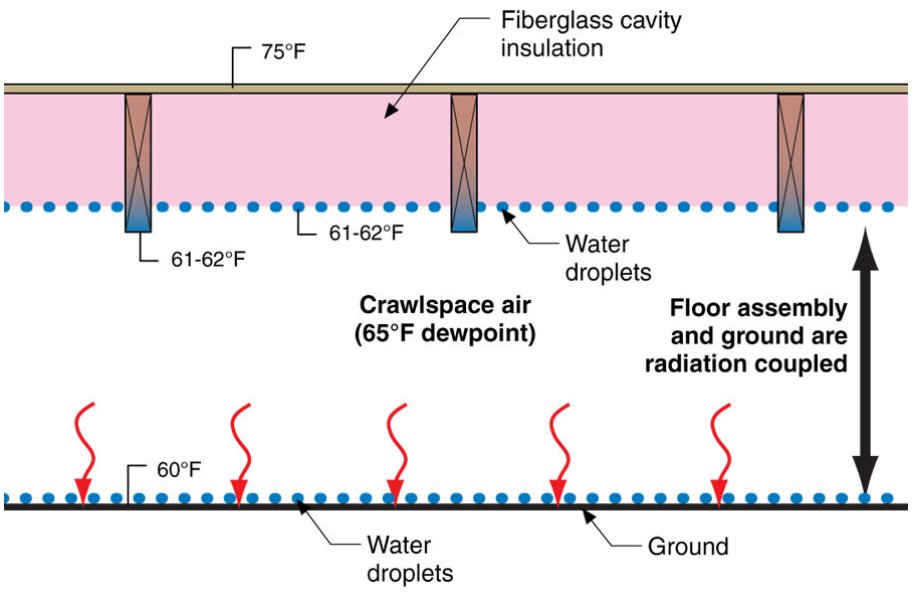
Joseph Lstiburek 14



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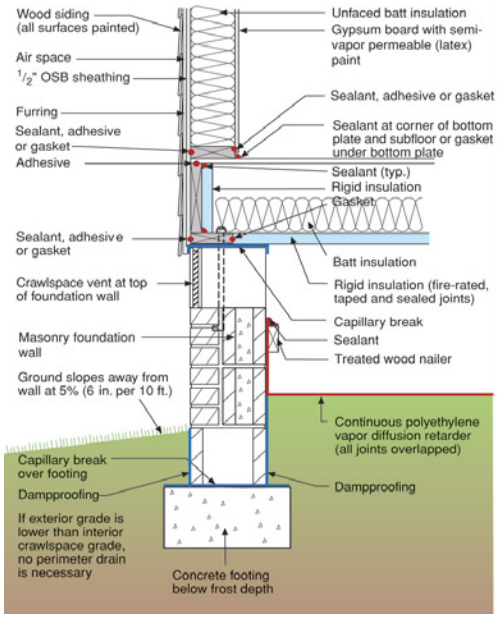

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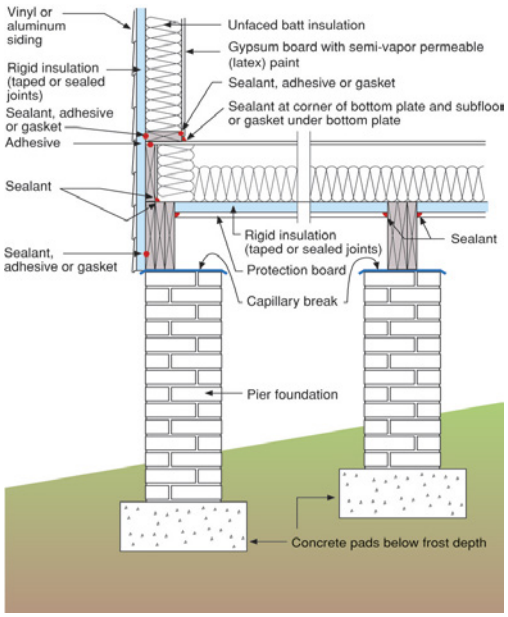

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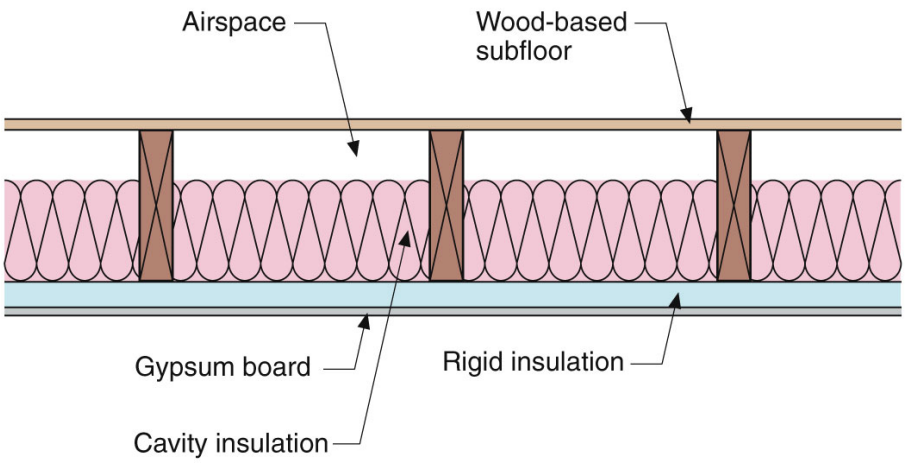

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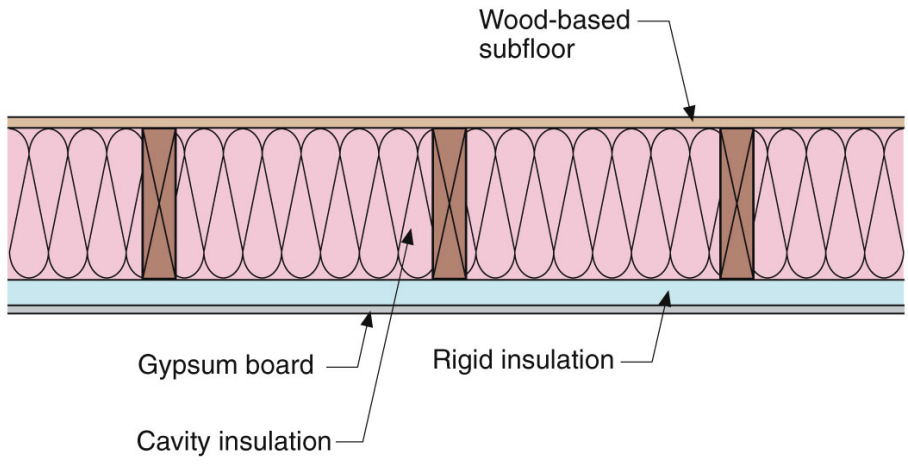

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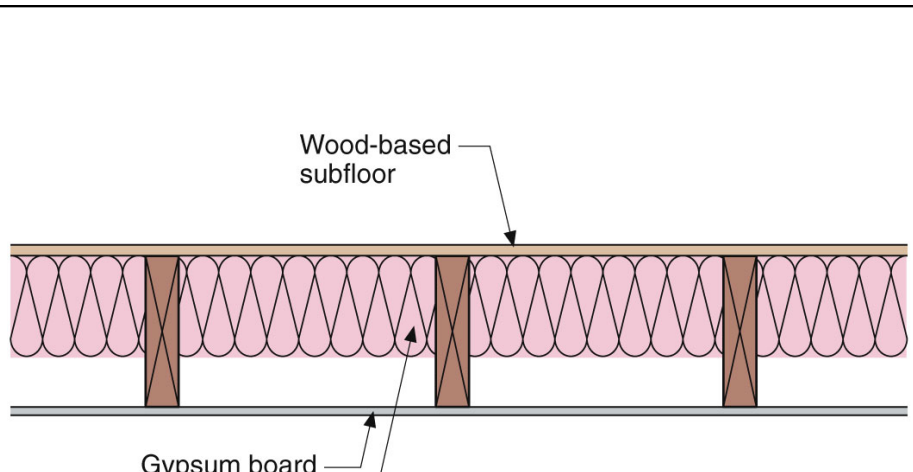

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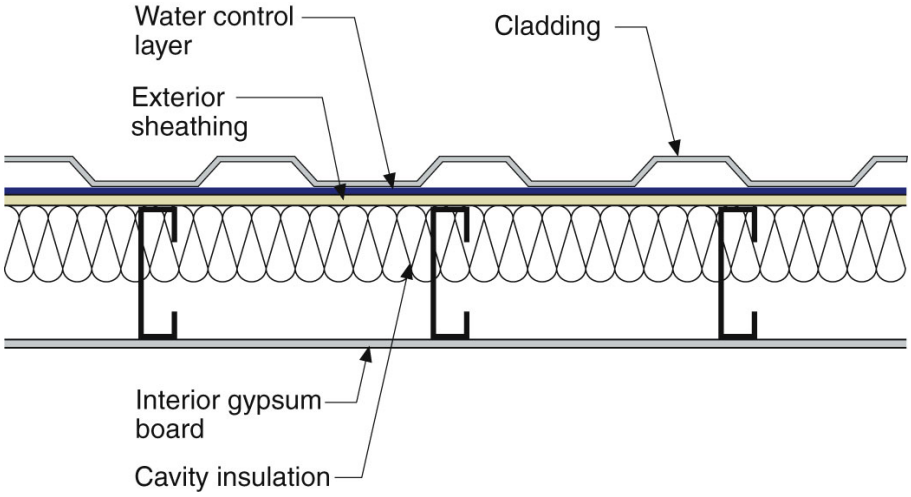

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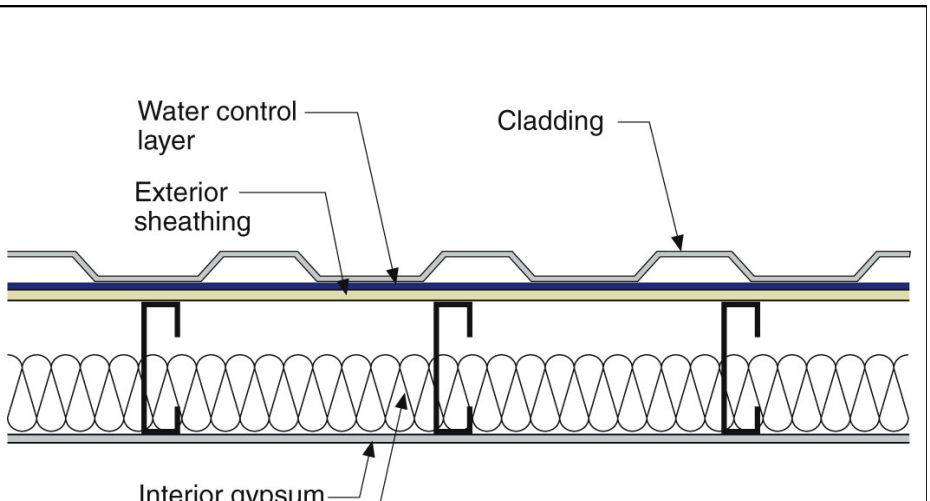

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Joseph Lstiburek, Ph.D., P.Eng, ASHRAE Fellow

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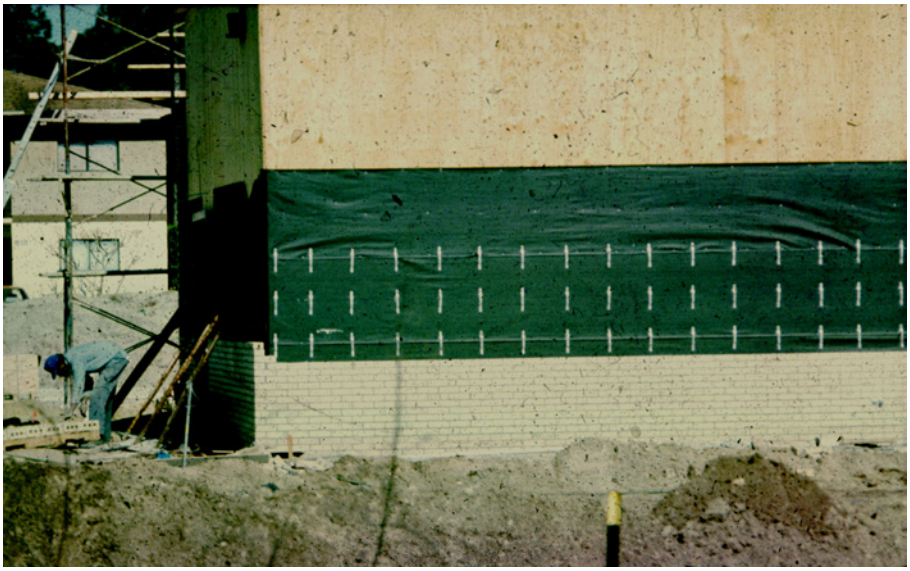

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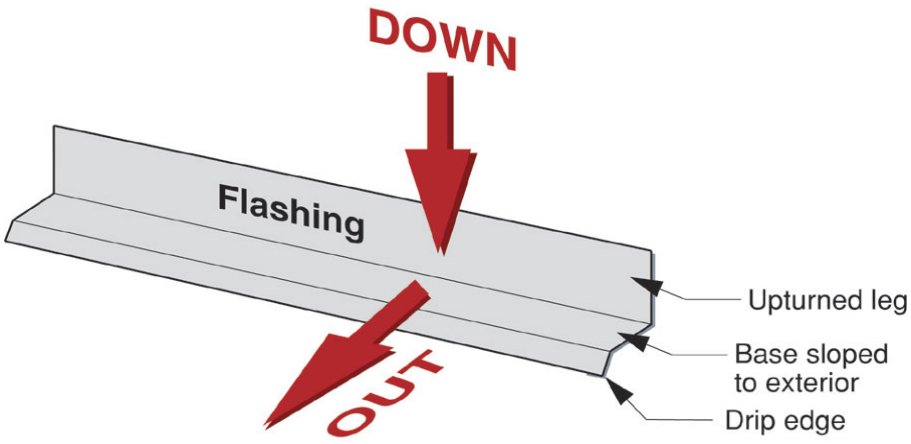

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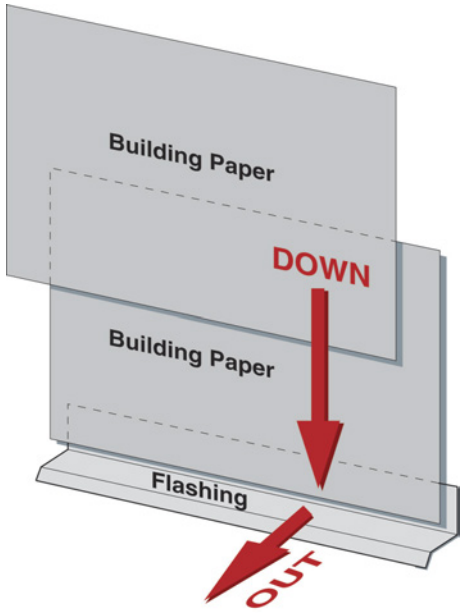

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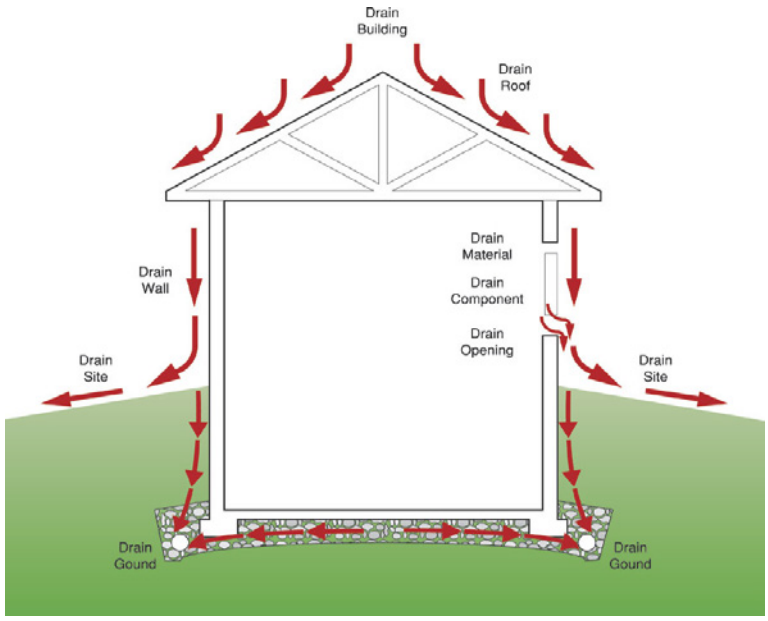

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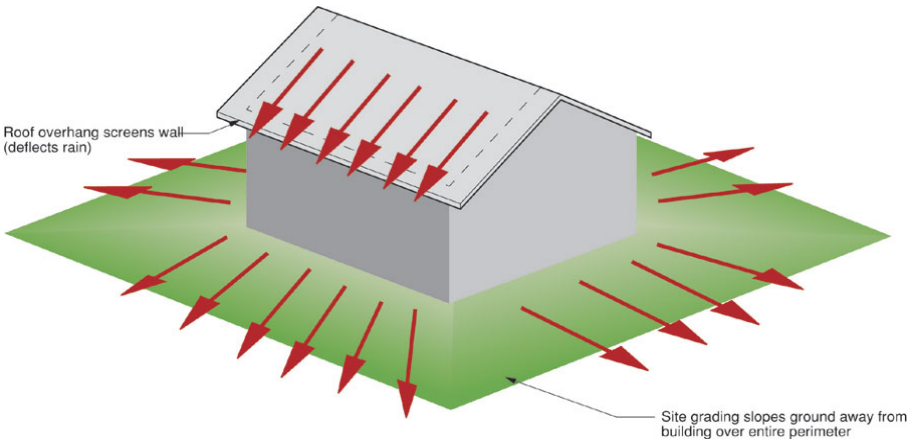

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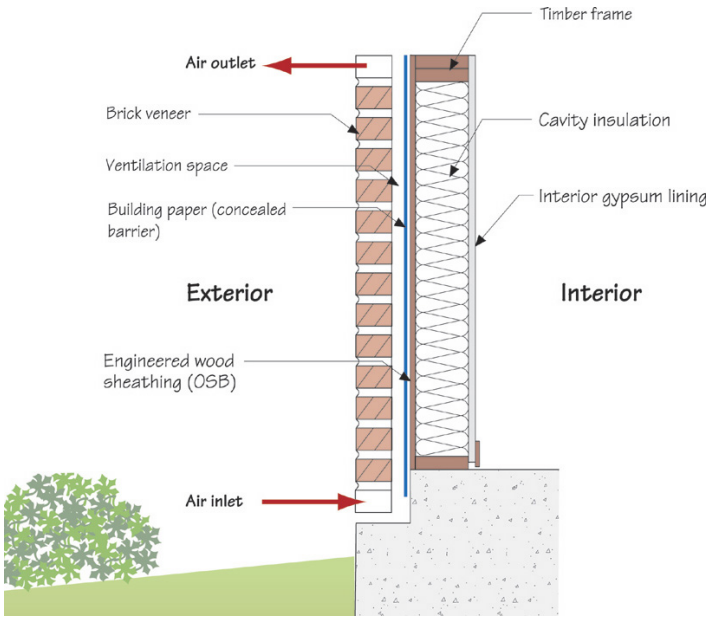

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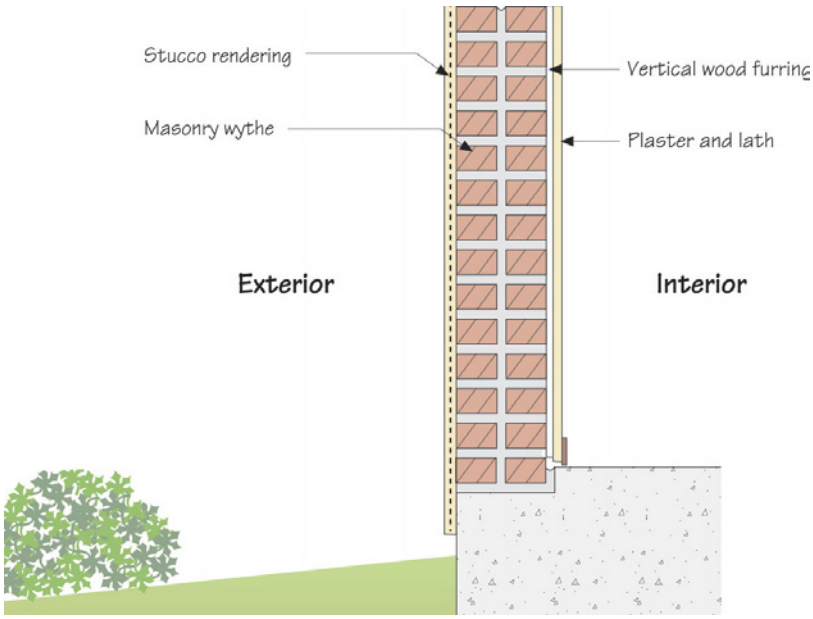
Joseph Lstiburek 18



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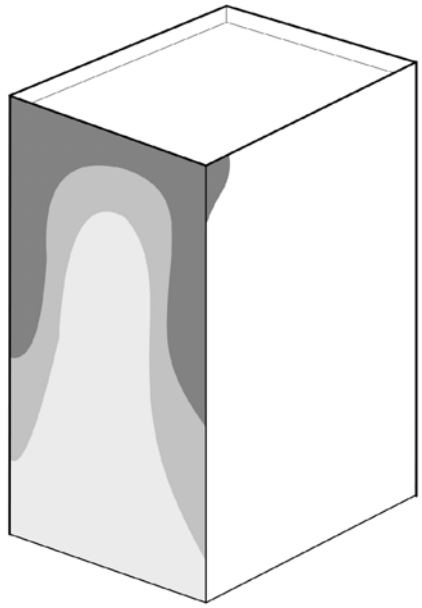

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Joseph Lstiburek – Rain Control 34

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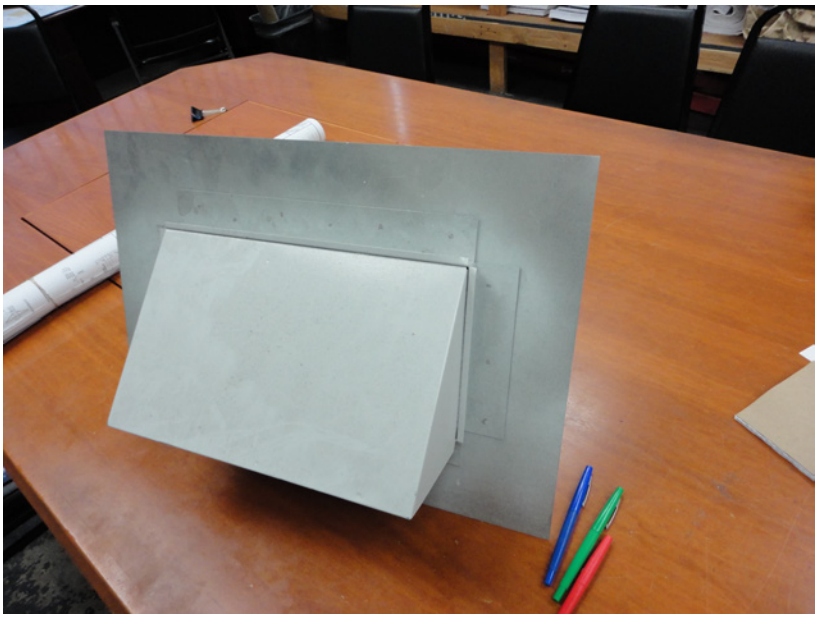
Joseph Lstiburek – Rain Control 35



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Joseph Lstiburek 39

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Joseph Lstiburek 40

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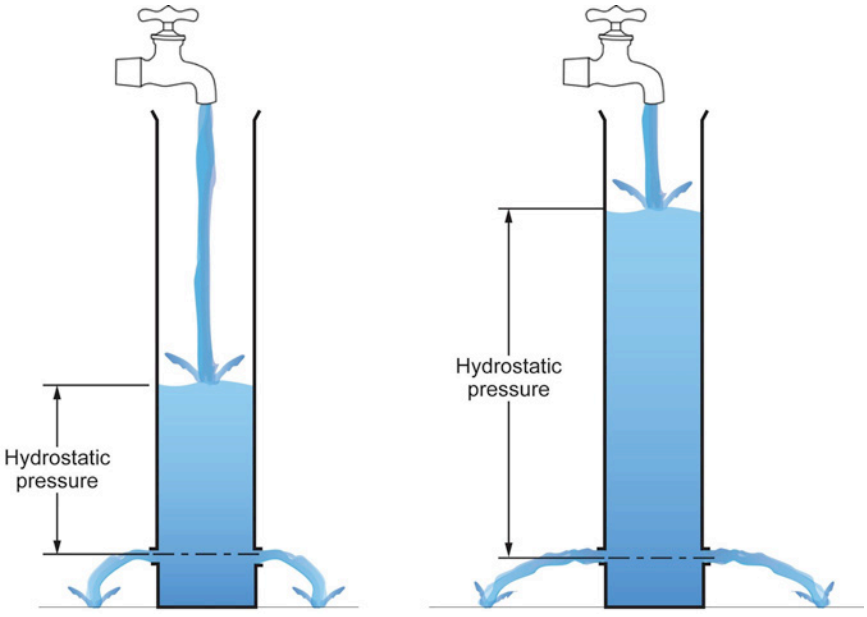
Joseph Lstiburek 41



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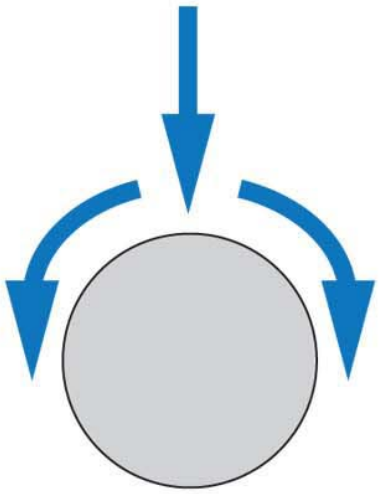

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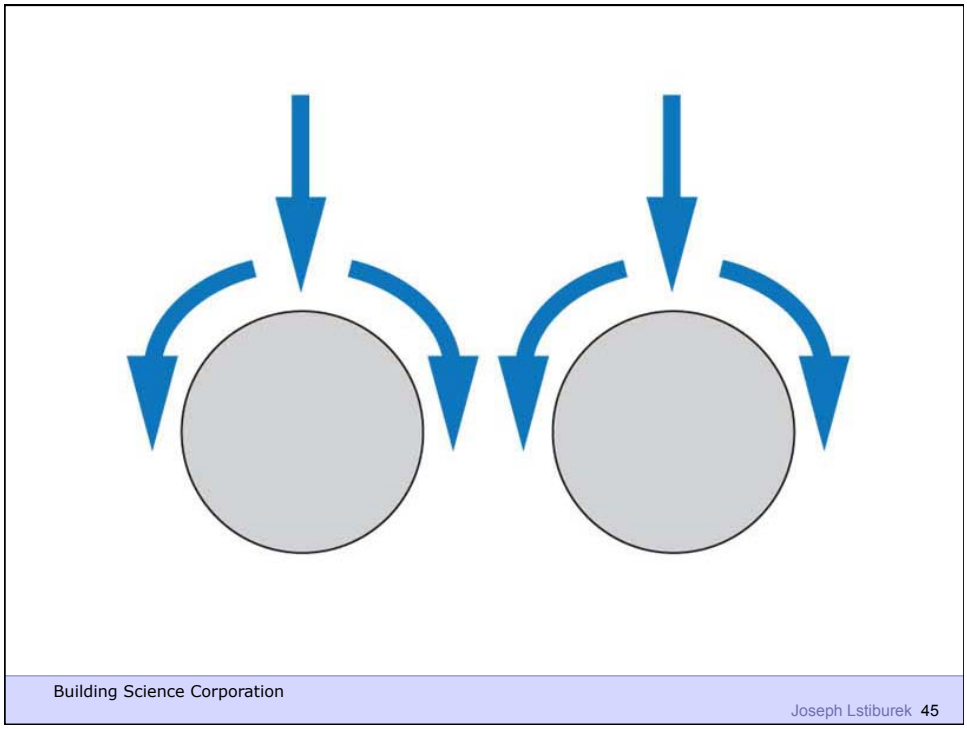

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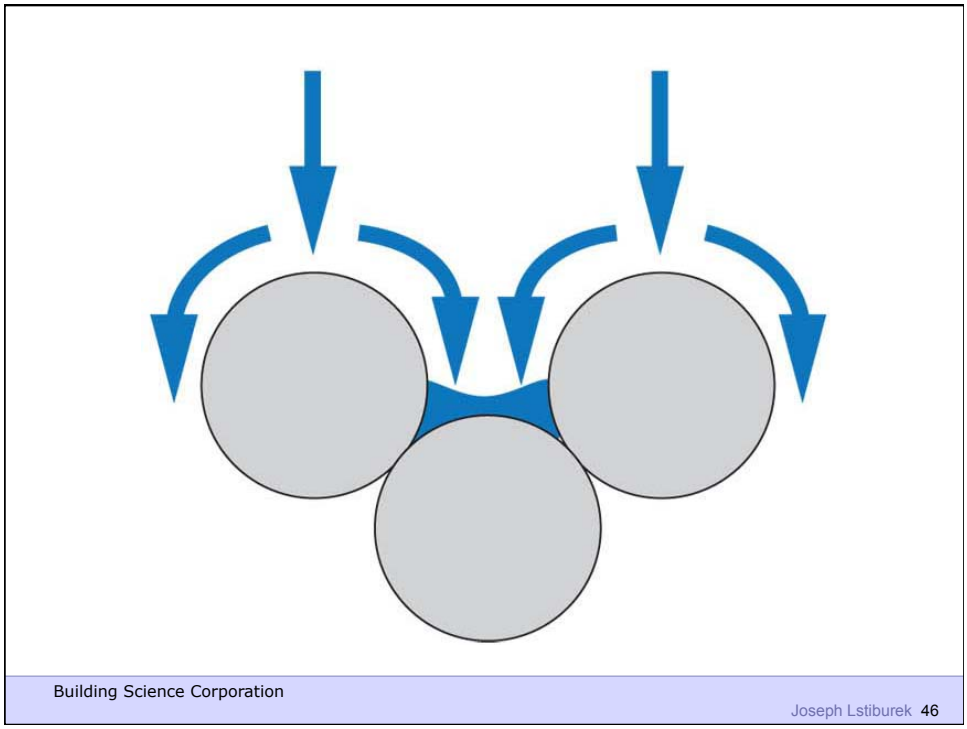

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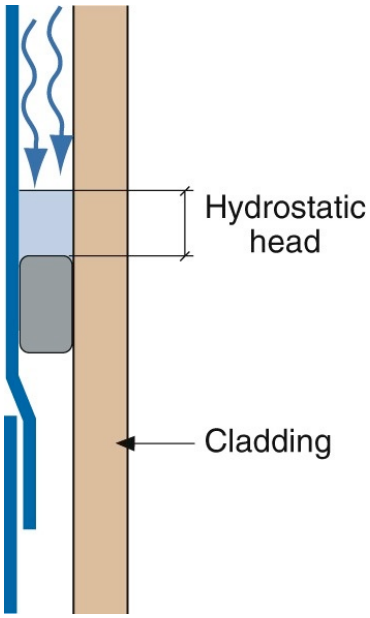
Joseph Lstiburek 47



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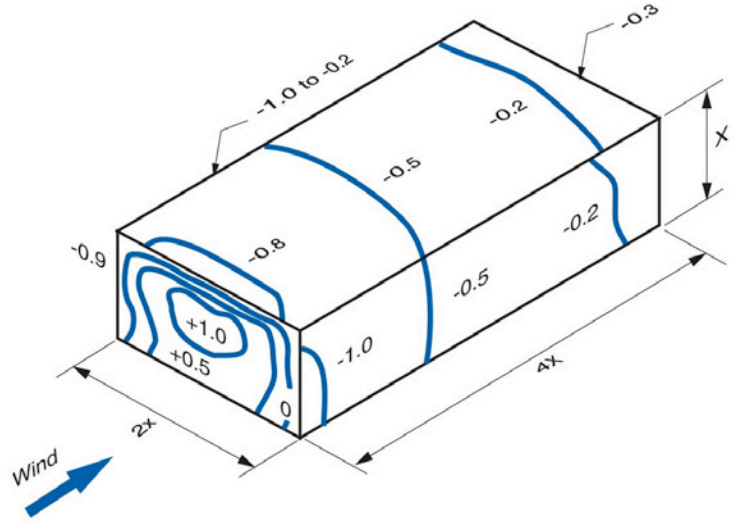

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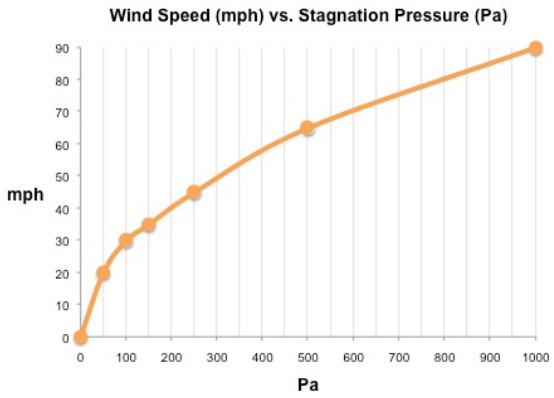
Pascals	mph
50 Pa =	20 mph
100 Pa =	30 mph
150 Pa =	35 mph
250 Pa =	45 mph
500 Pa =	65 mph
1,000 Pa =	90 mph



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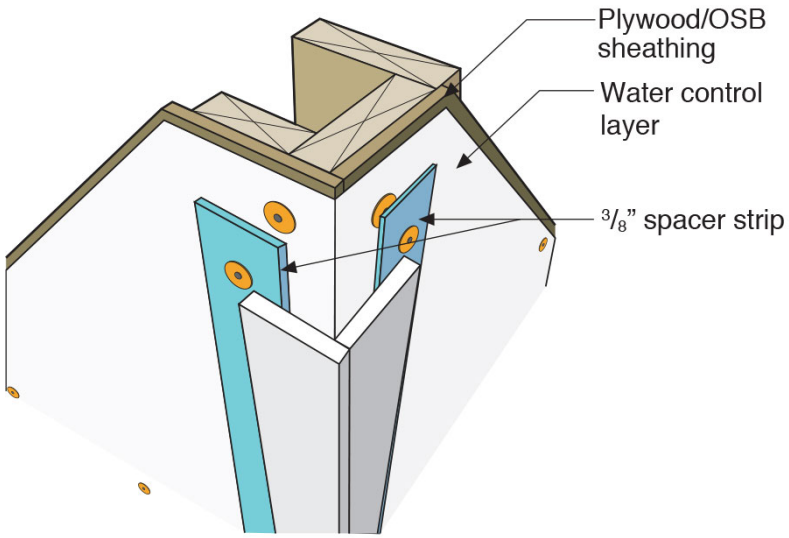

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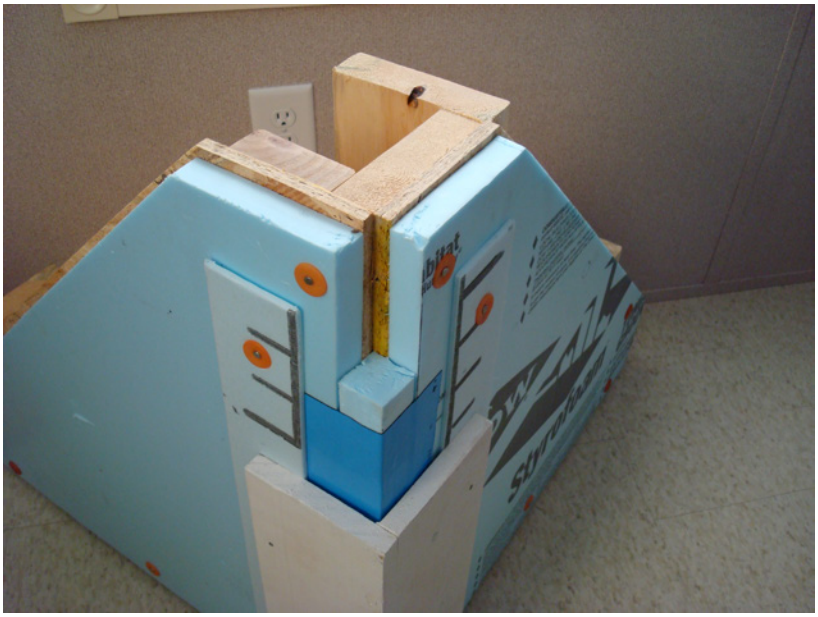

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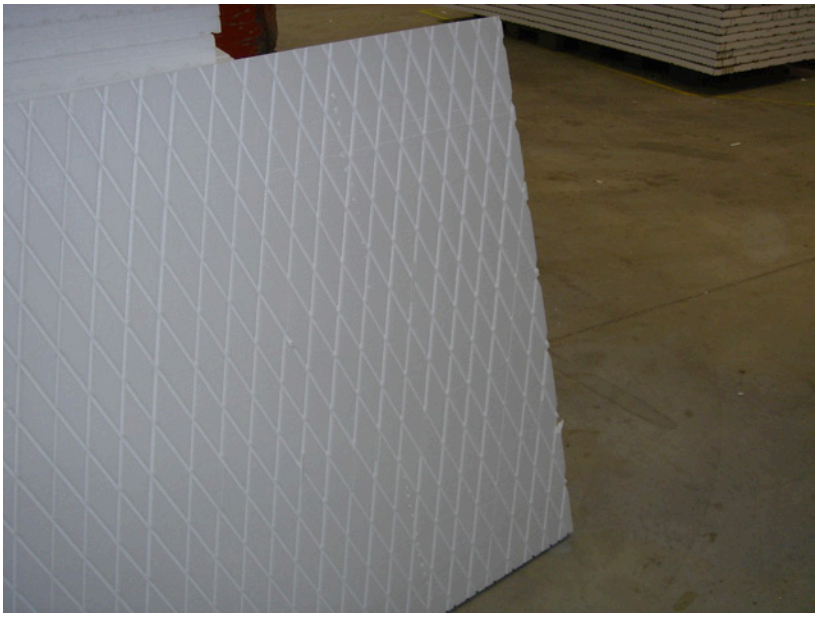

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Joseph Lstiburek 57

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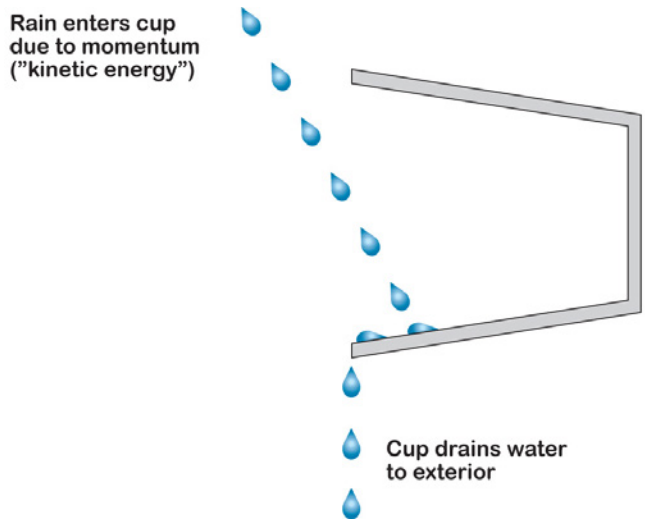
Joseph Lstiburek – Rain Control 59



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2011

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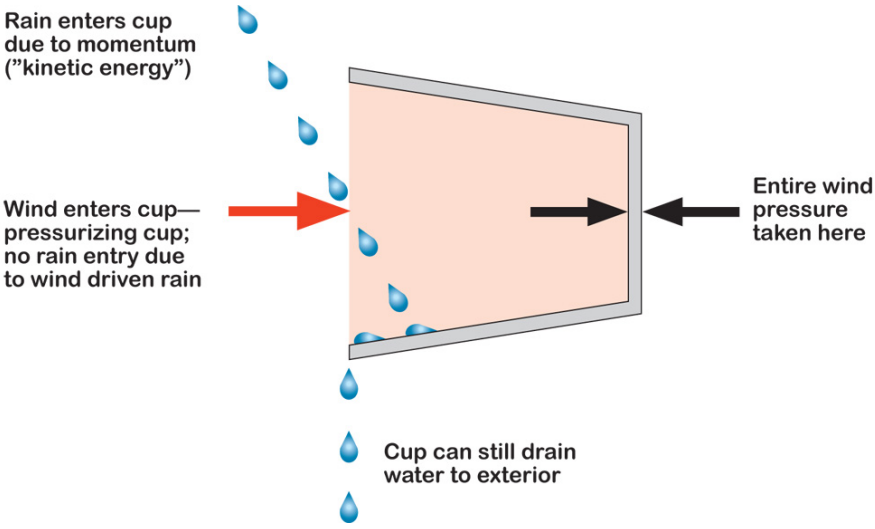

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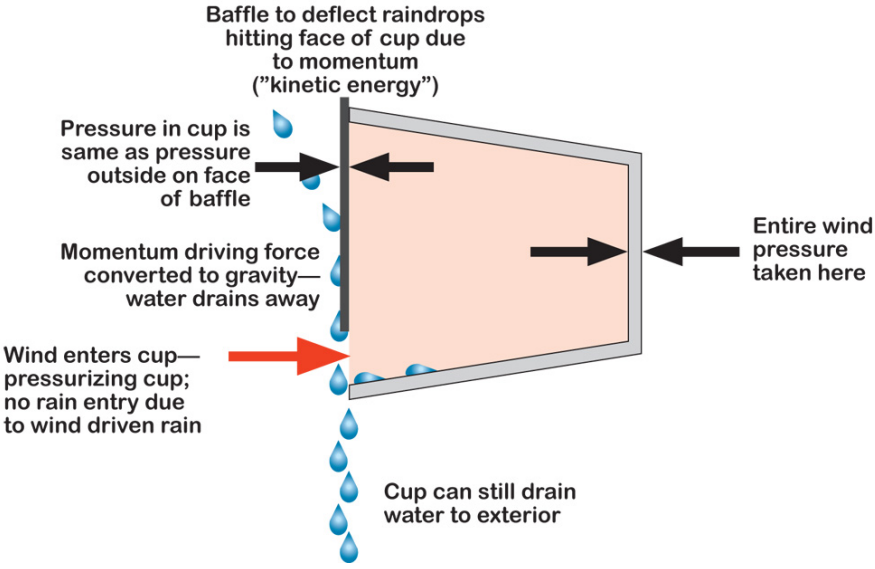
2011
Joseph Lstiburek 61



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2011
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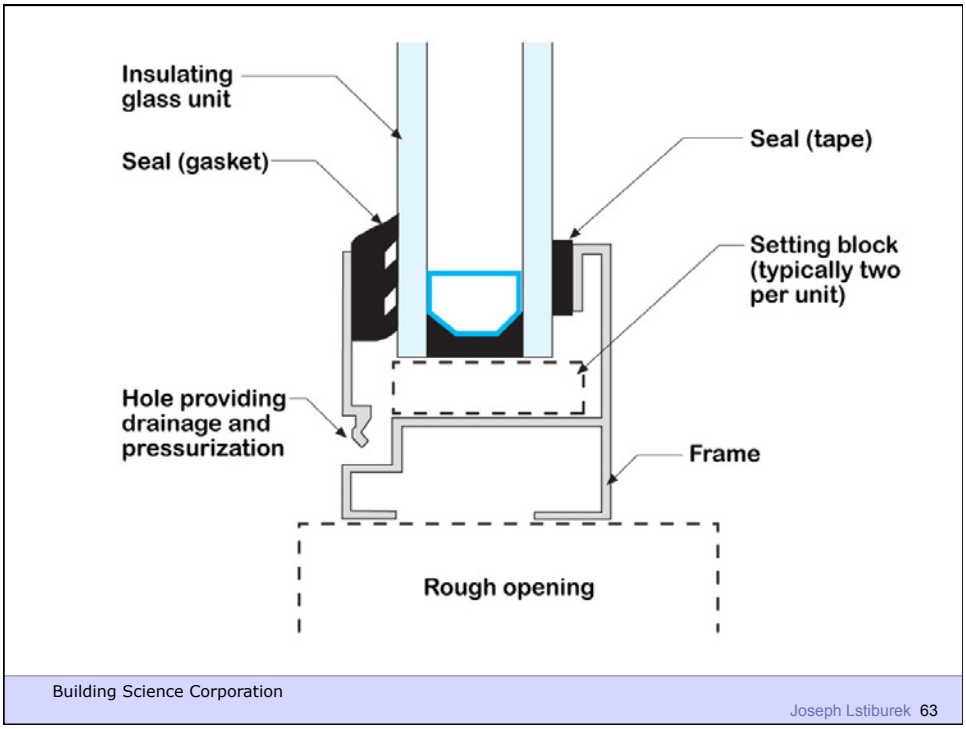
Insulating glass unit
Seal (gasket)
Seal (tape)
Setting block (typically two per unit)
Hole providing drainage and pressurization
Frame
Rough opening
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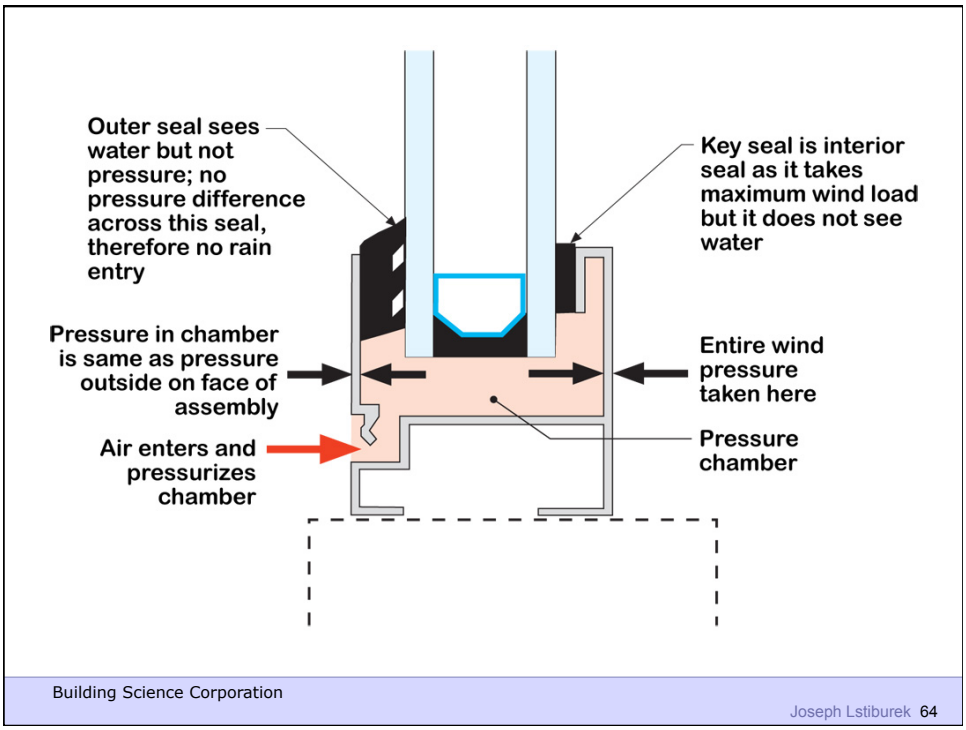
Outer seal sees water but not pressure; no pressure difference across this seal, therefore no rain entry
Key seal is interior seal as it takes maximum wind load but it does not see water
Pressure in chamber is same as pressure outside on face of assembly
Entire wind pressure taken here
Air enters and pressurizes chamber
Pressure chamber
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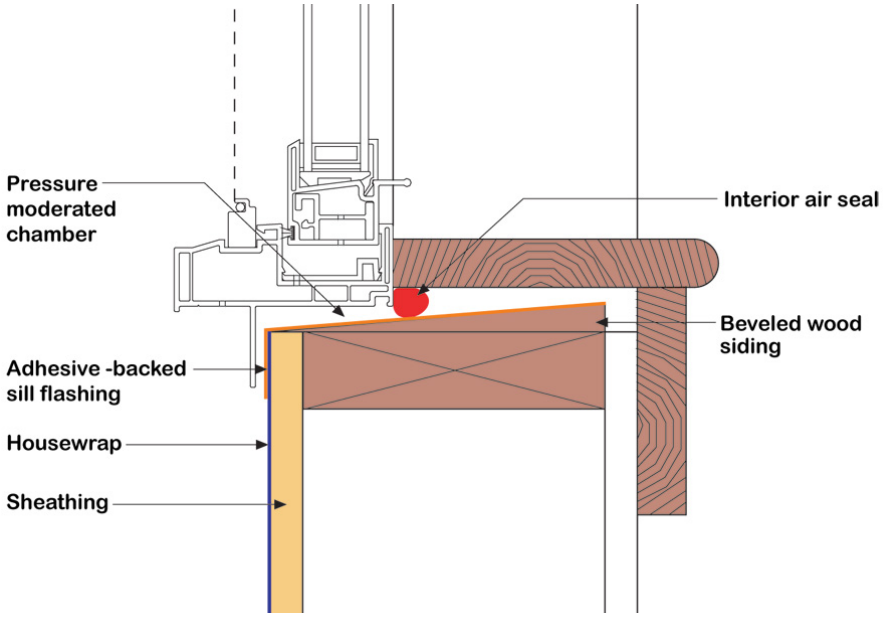

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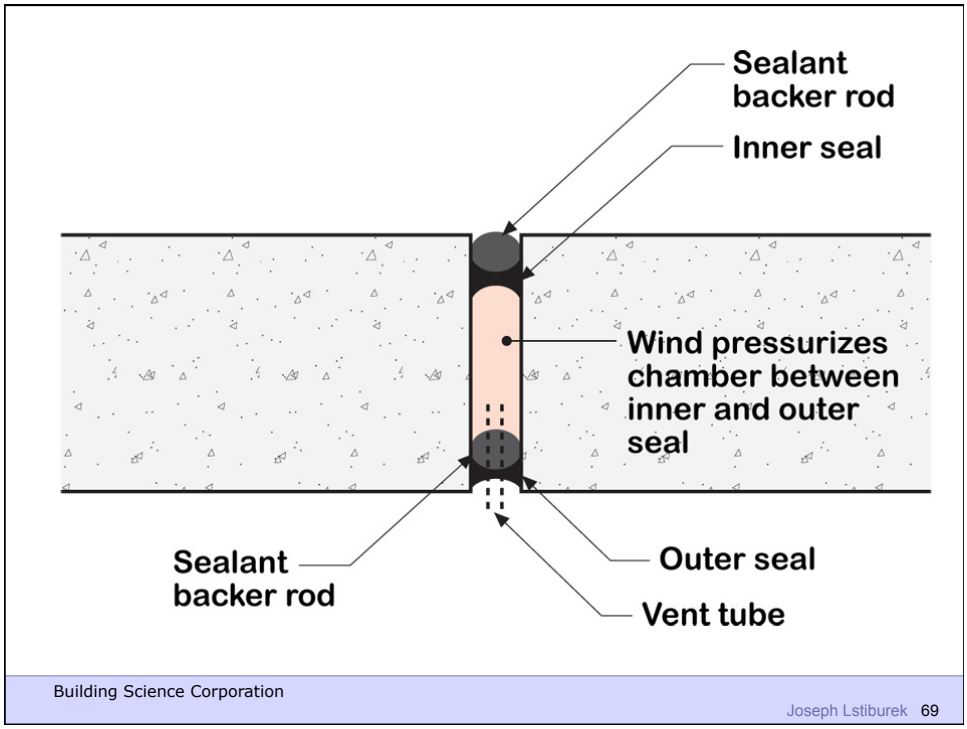
Joseph Lstiburek 68



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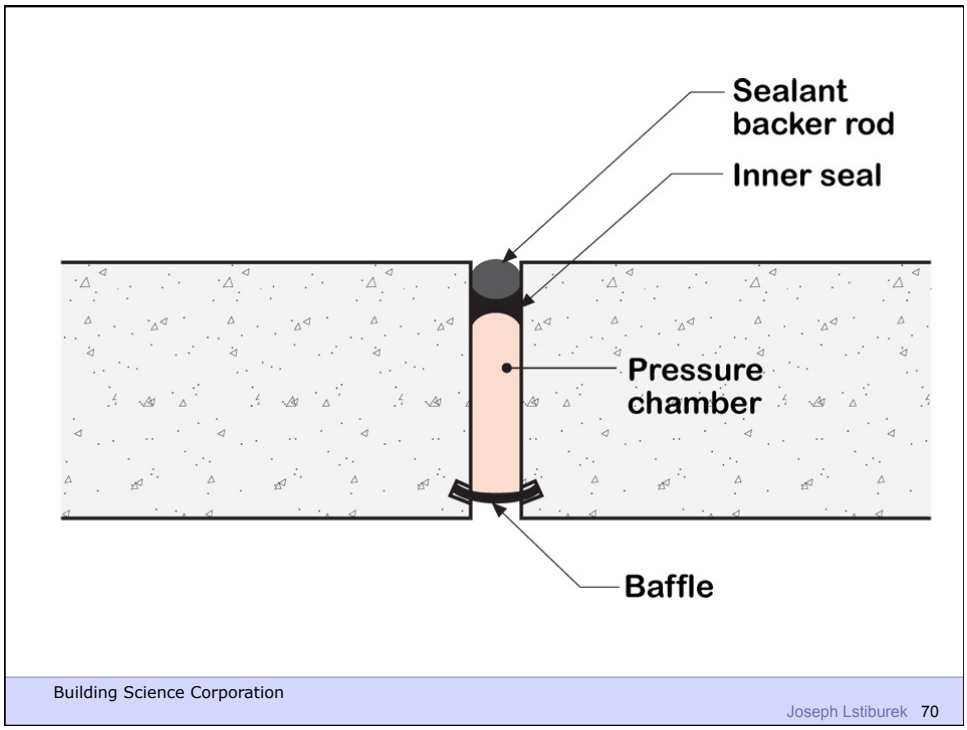

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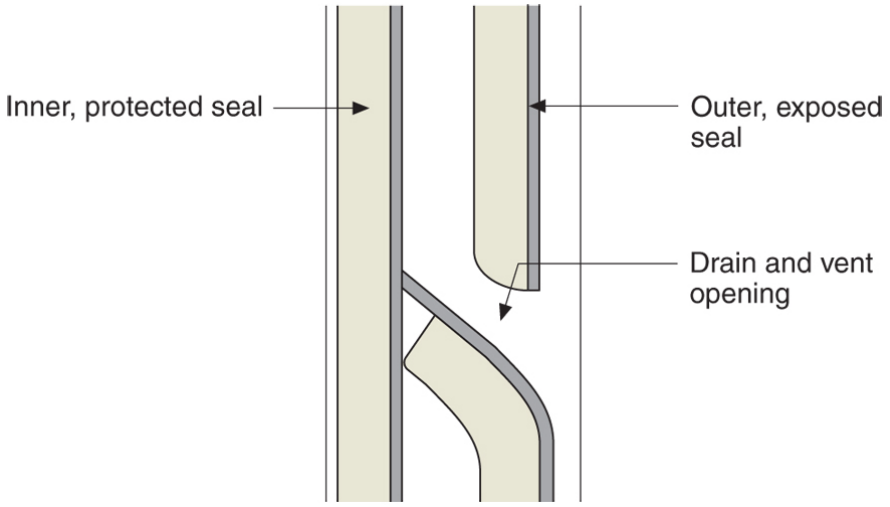

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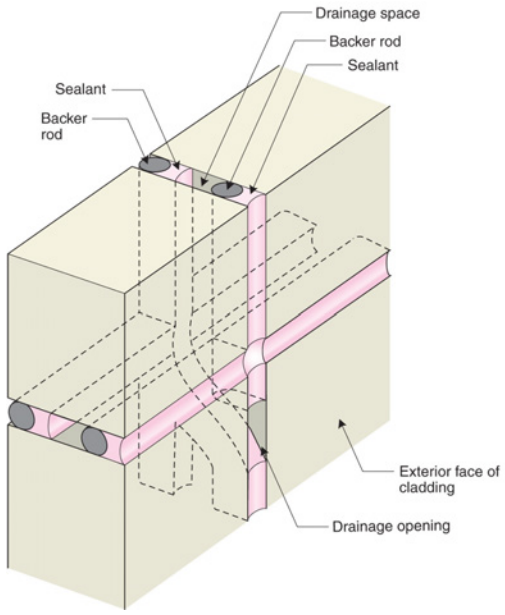

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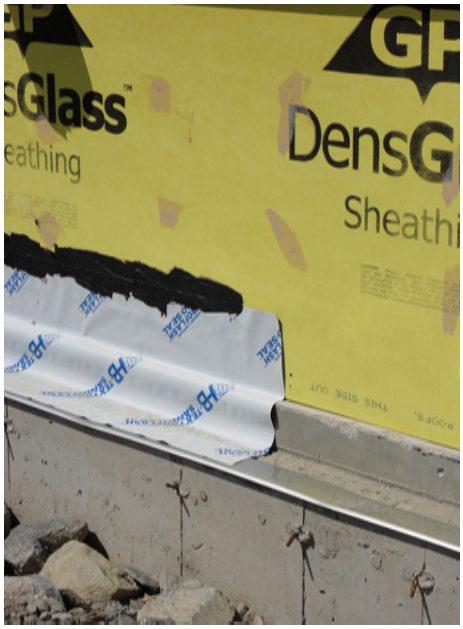

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Joseph Lstiburek 75

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Joseph Lstiburek 76

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Joseph Lstiburek 77

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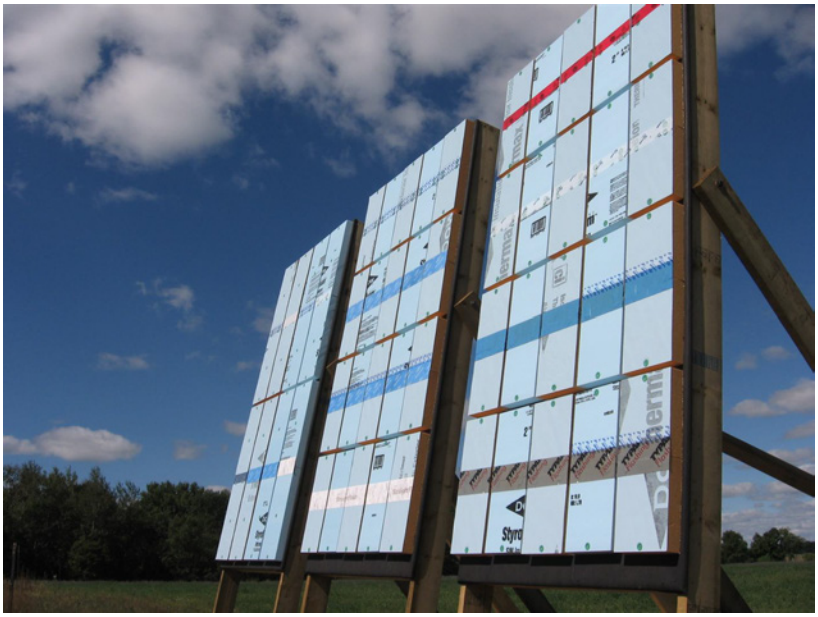
Joseph Lstiburek 78



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Joseph Lstiburek 80

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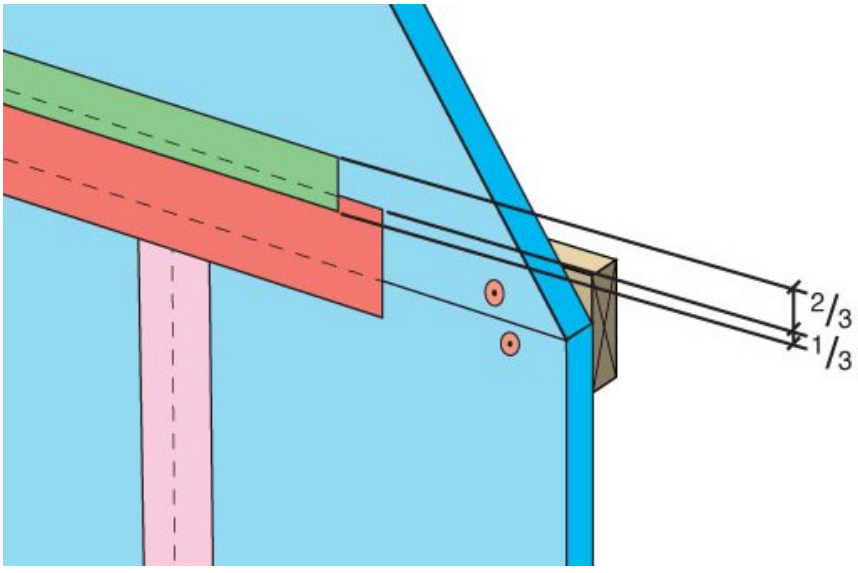
Joseph Lstiburek 81



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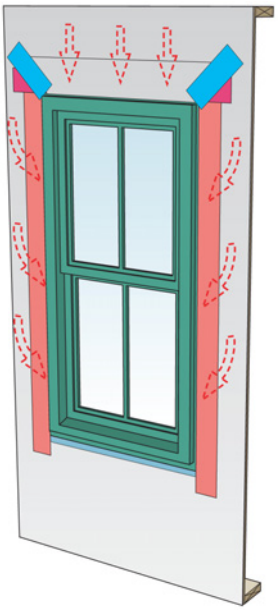

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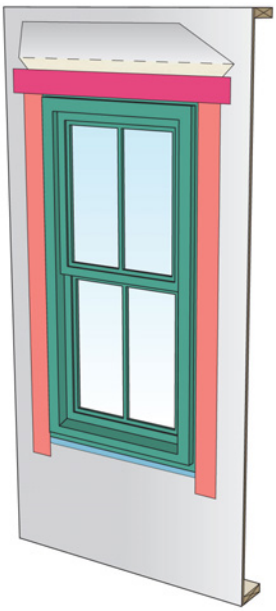

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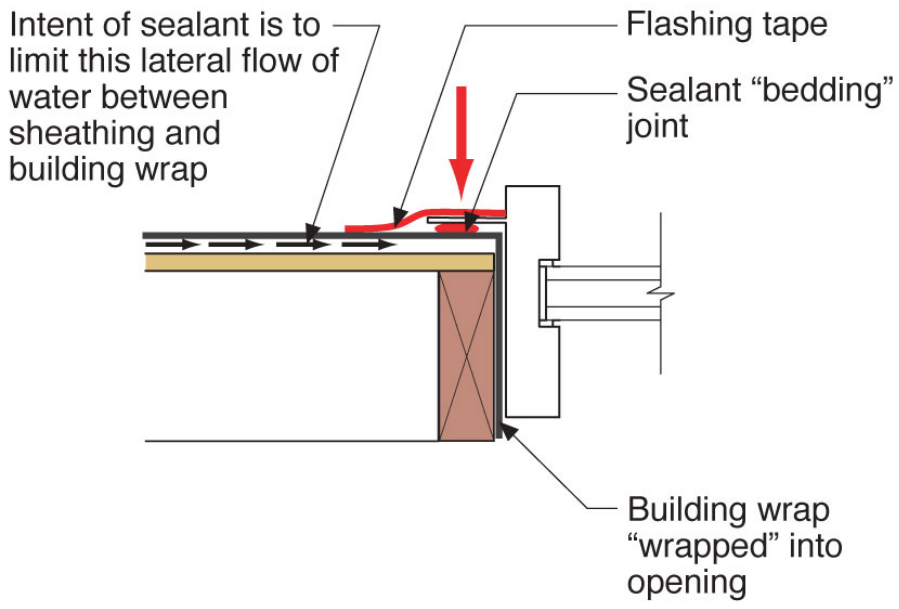

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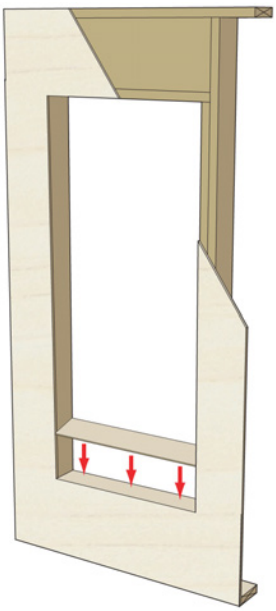

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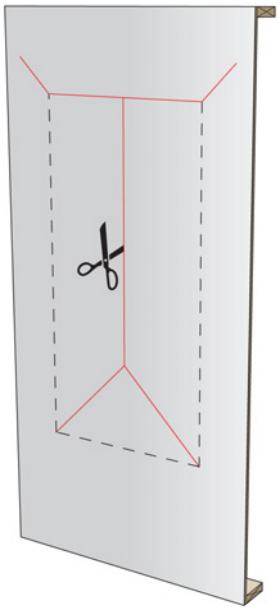

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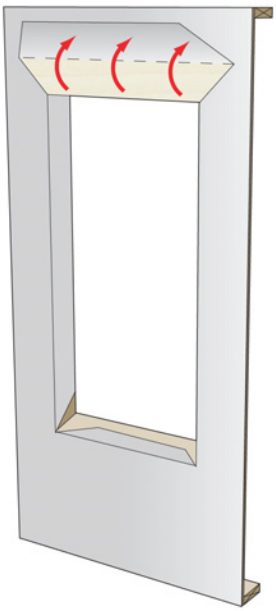

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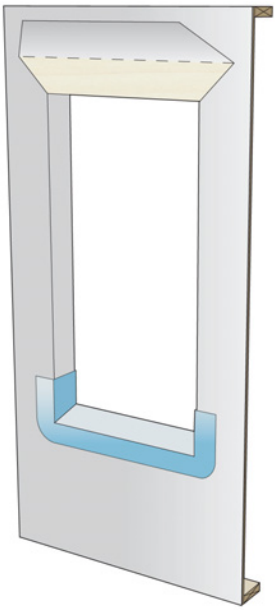

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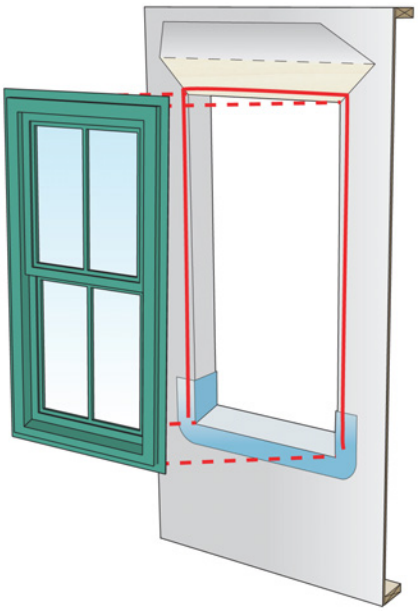

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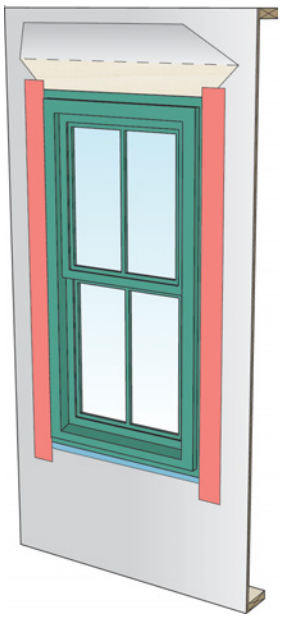

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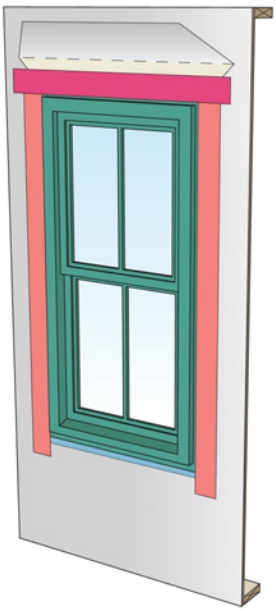

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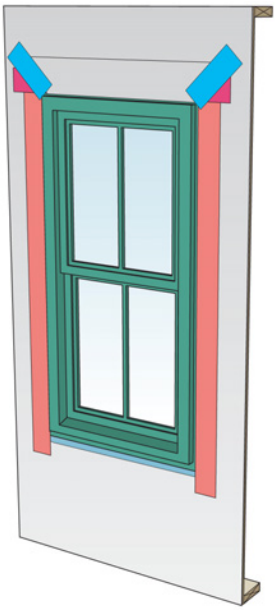

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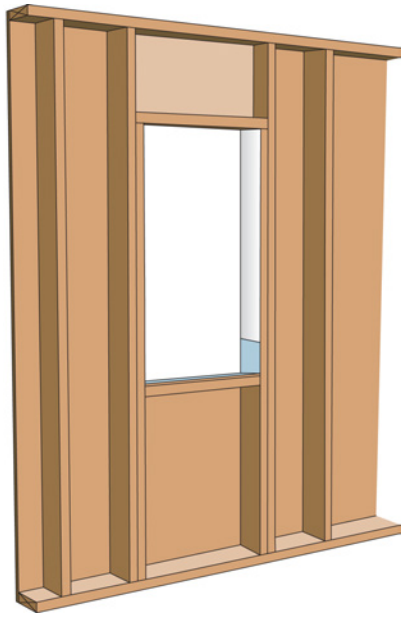

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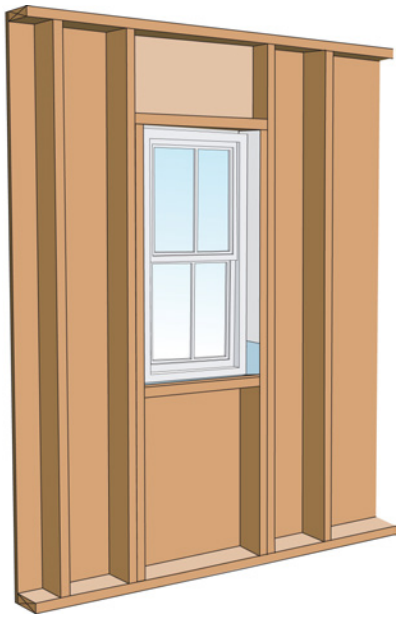

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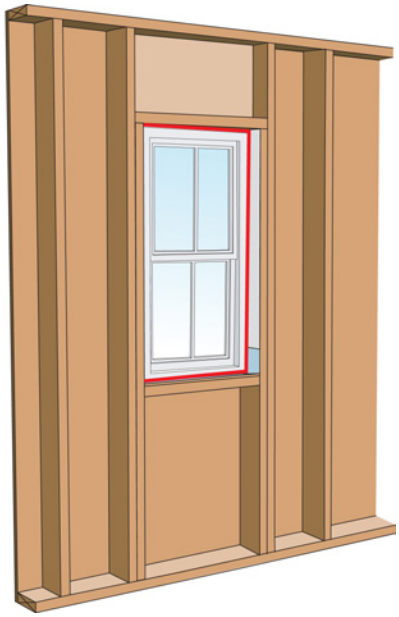

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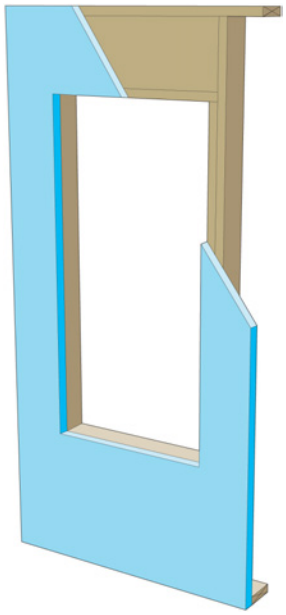

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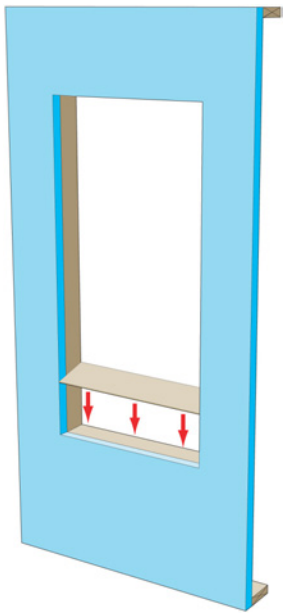

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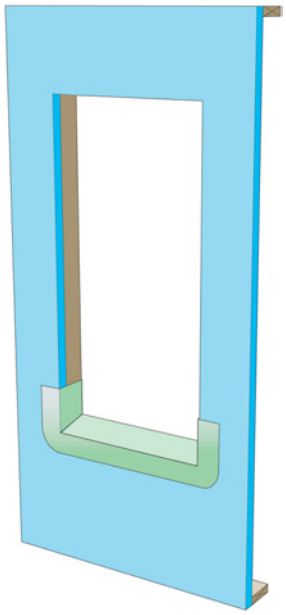

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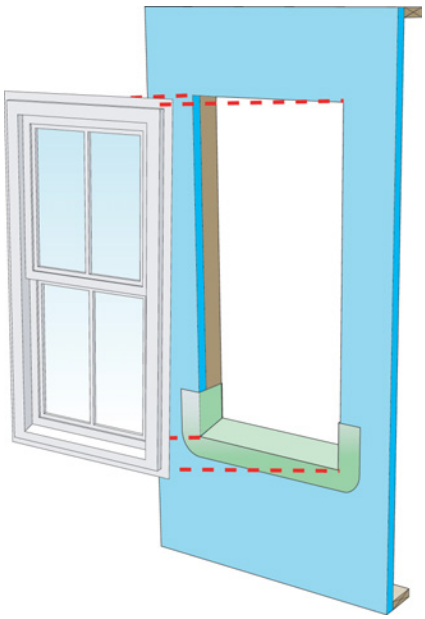
Joseph Lstiburek 100



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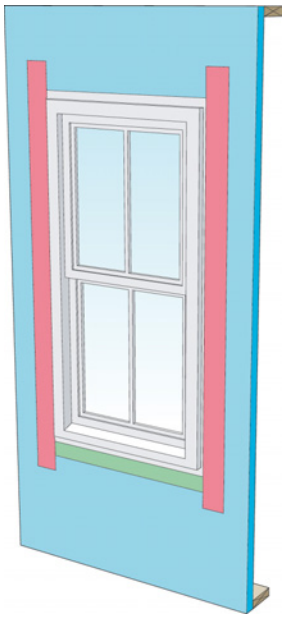

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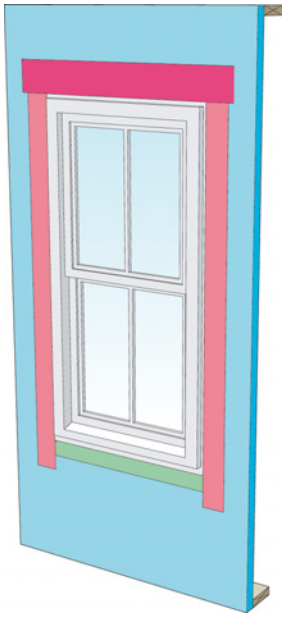

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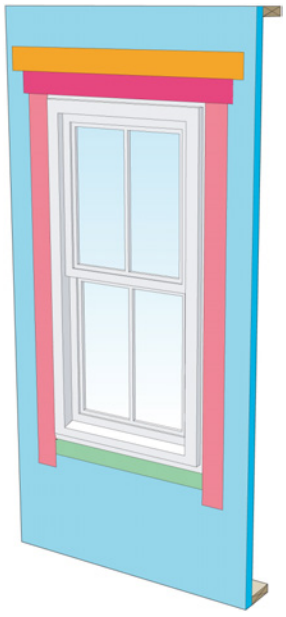

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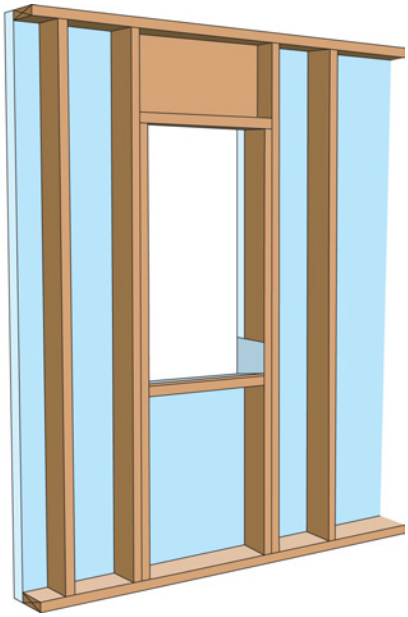

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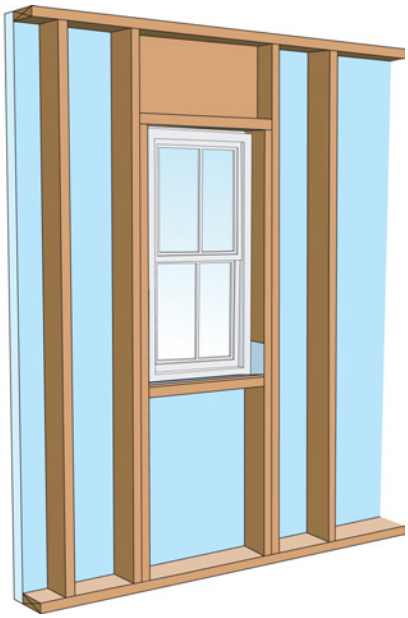

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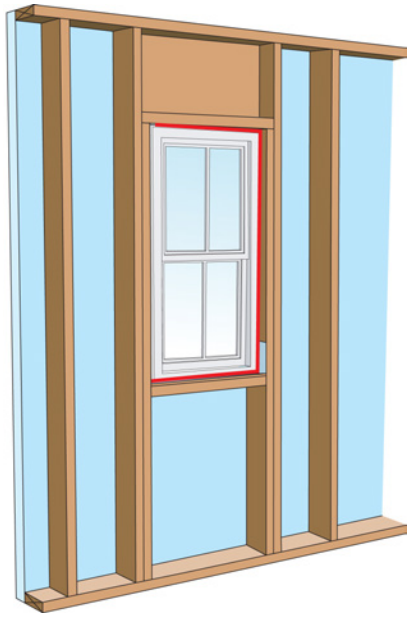

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Joseph Lstiburek 108

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

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Roofs

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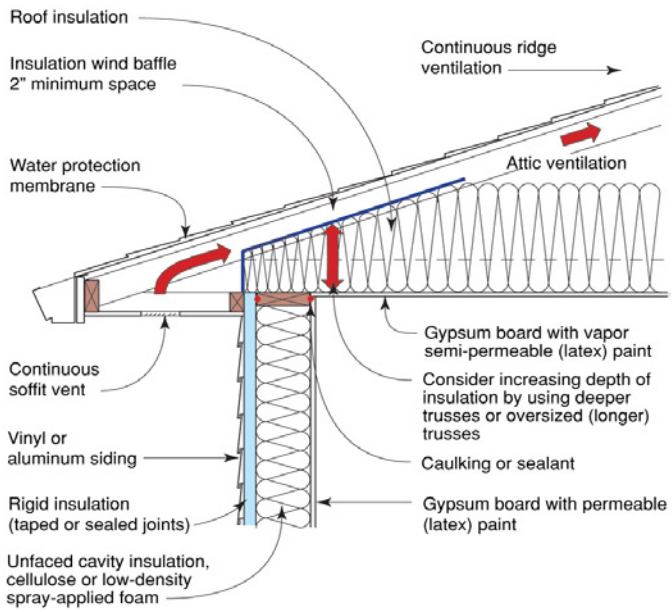

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Joseph Lstiburek 2

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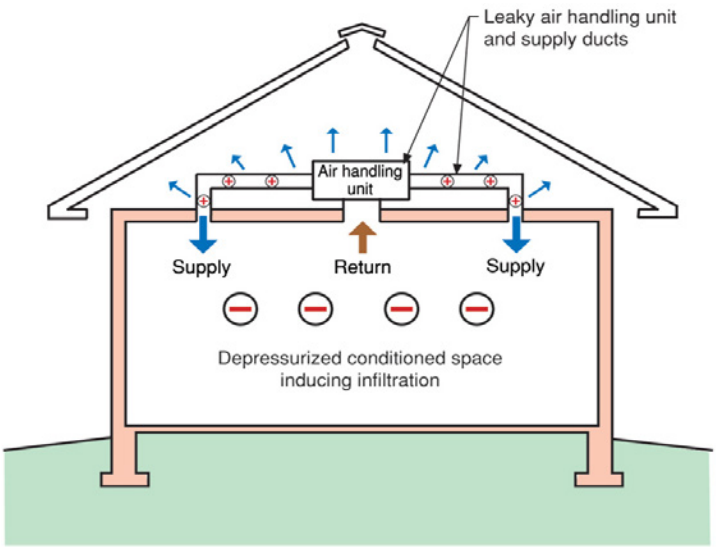
Joseph Lstiburek 3



Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

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Joseph Lstiburek 4

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Joseph Lstiburek 5

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Joseph Lstiburek 6

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Joseph Lstiburek 7

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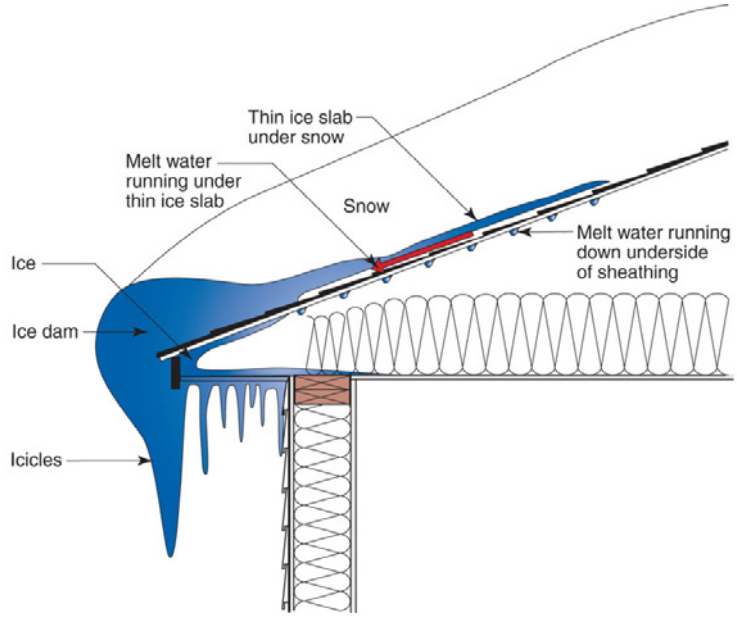
Joseph Lstiburek 8



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Joseph Lstiburek 9

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Joseph Lstiburek 10

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Joseph Lstiburek 11

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Joseph Lstiburek 15

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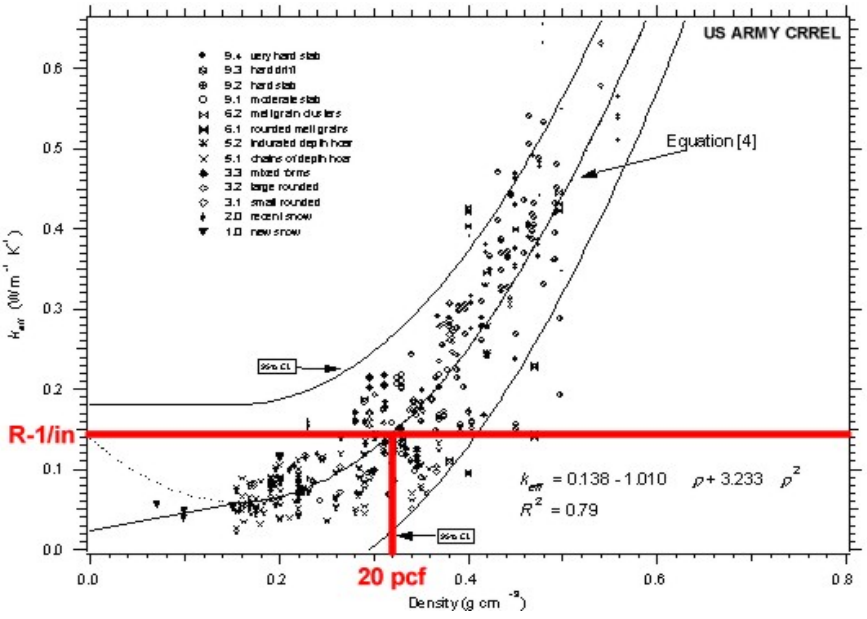
Joseph Lstiburek 16



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Joseph Lstiburek 17

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Joseph Lstiburek 18

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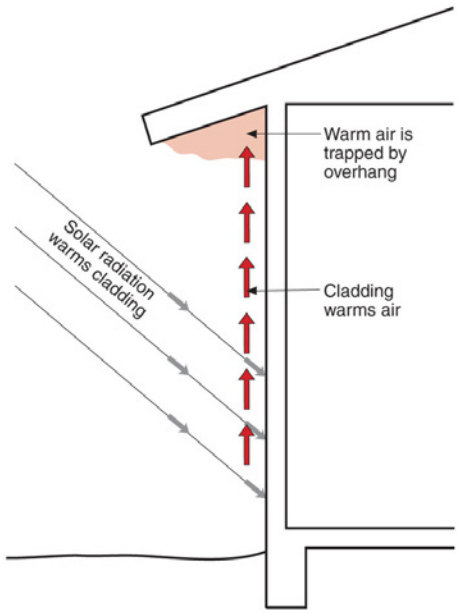
Joseph Lstiburek 19



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Joseph Lstiburek 20

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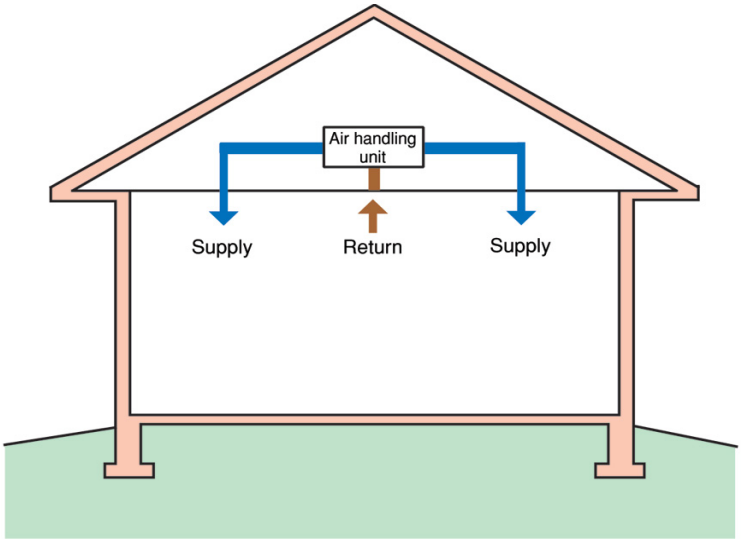
Joseph Lstiburek 24



Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

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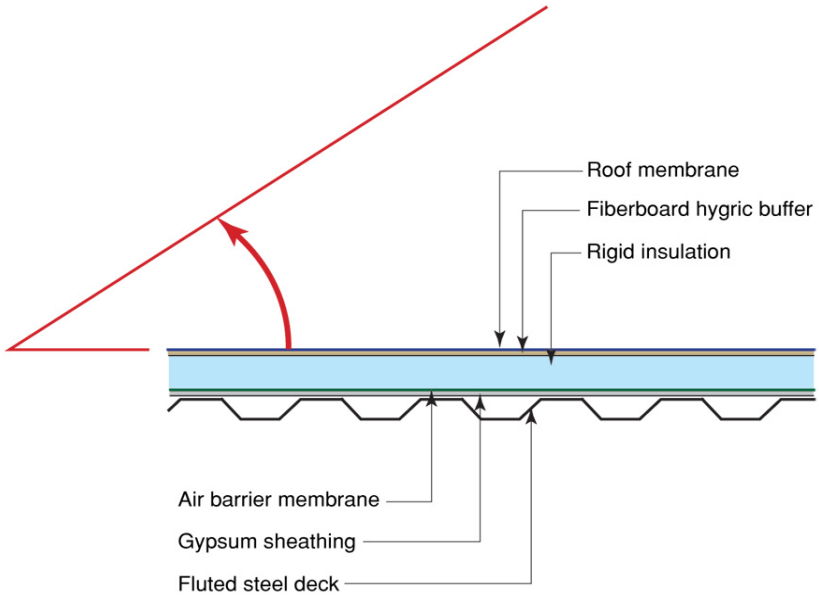
Joseph Lstiburek 25



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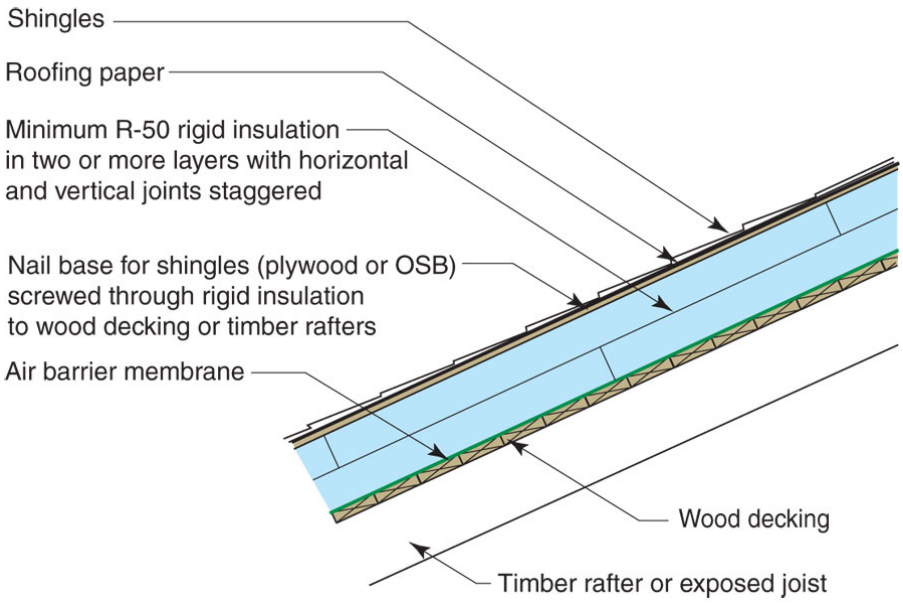
Joseph Lstiburek 26



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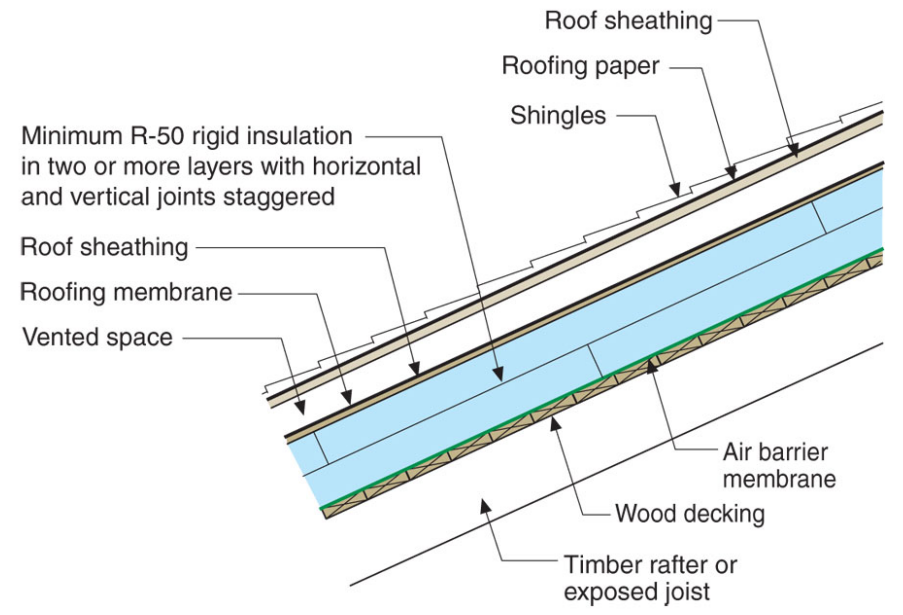

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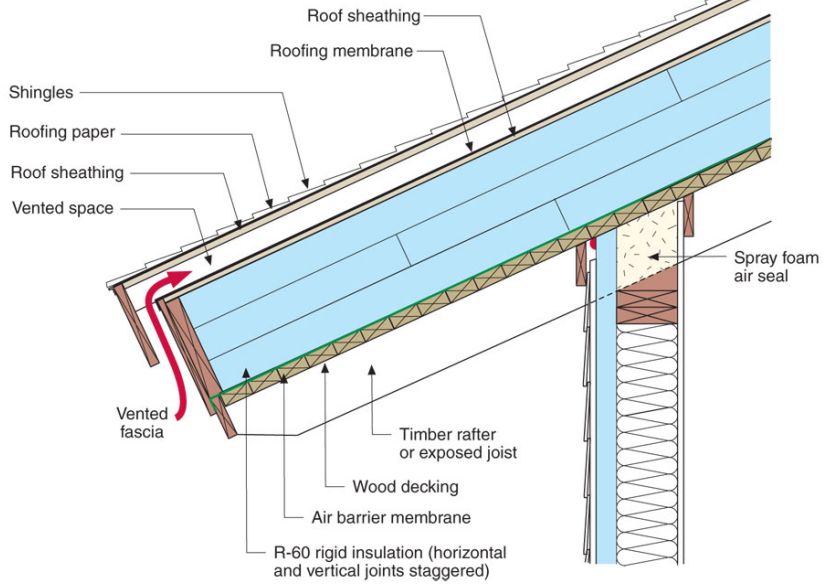

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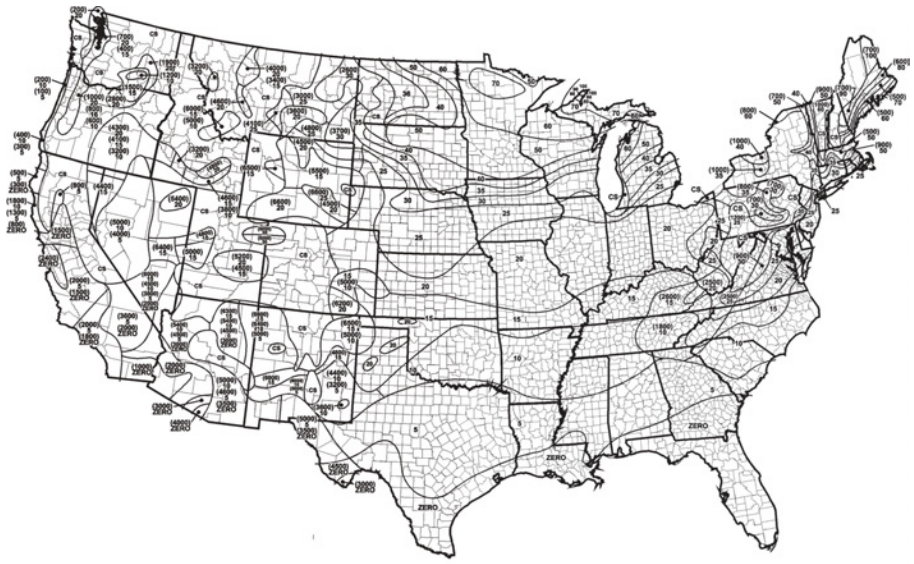

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Joseph Lstiburek 34

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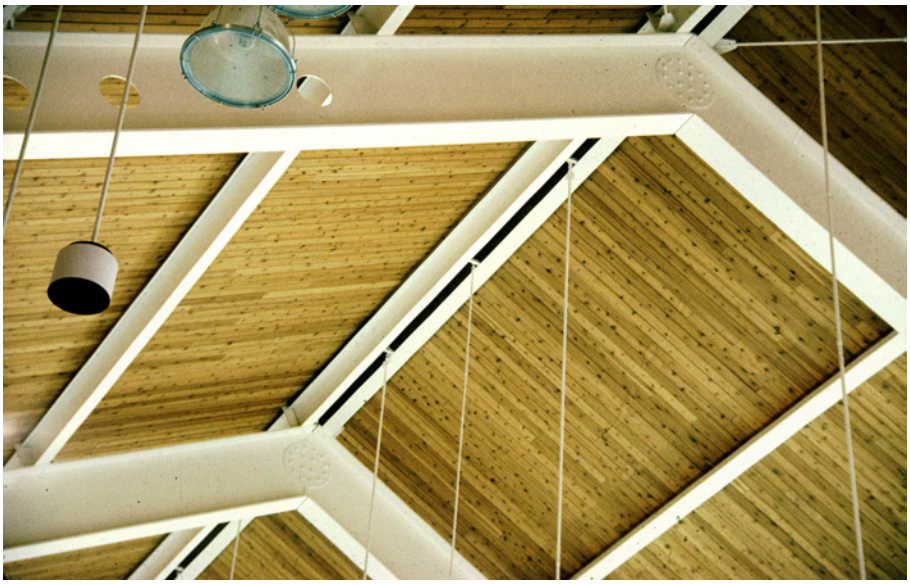
Joseph Lstiburek 35



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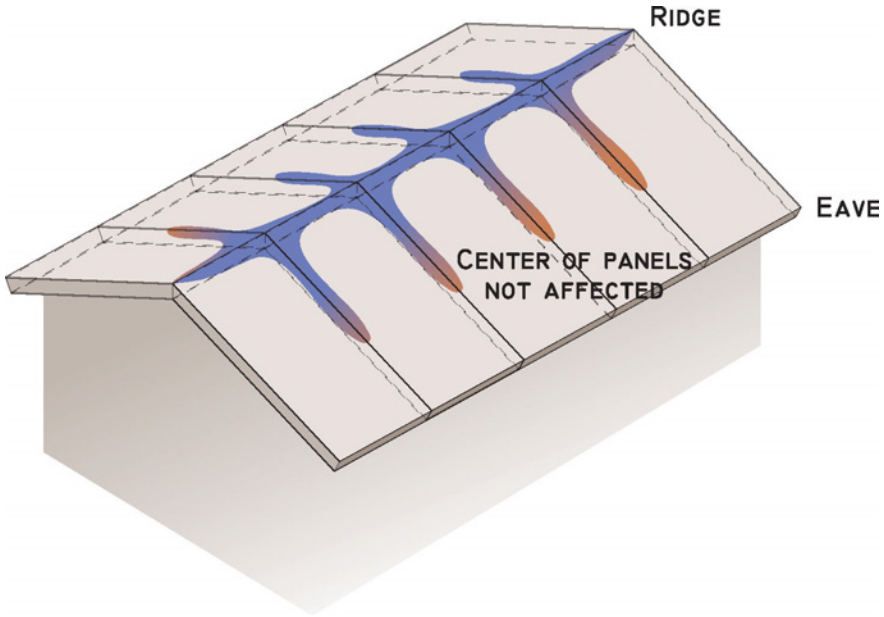
Joseph Lstiburek 46



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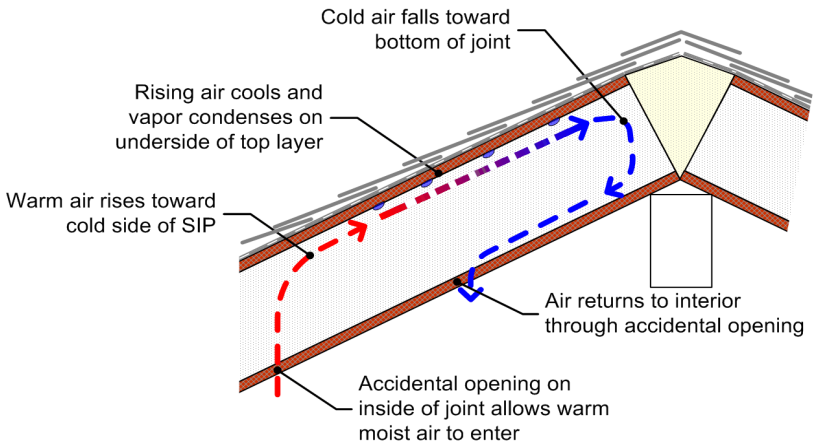

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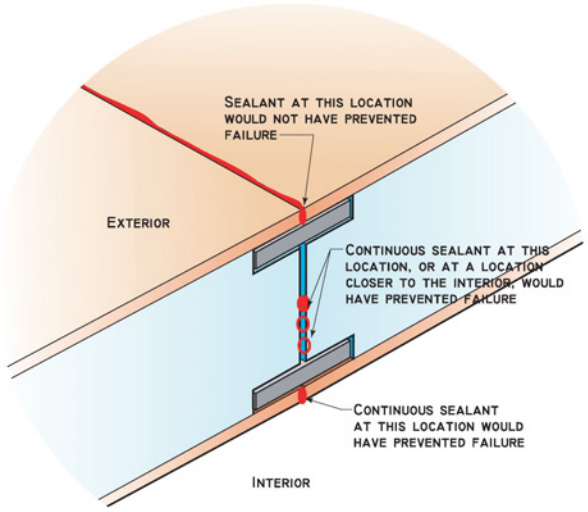

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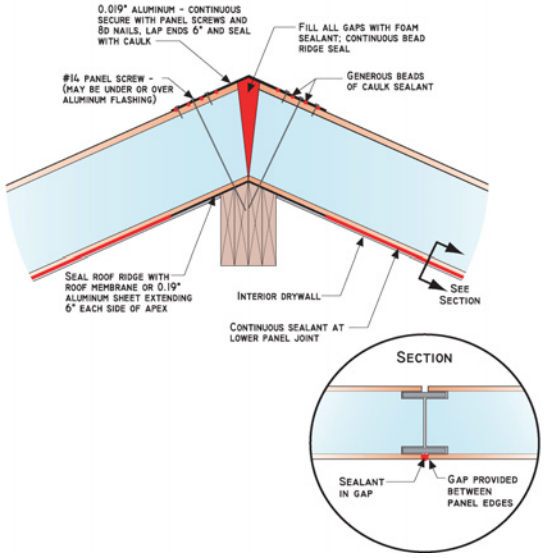

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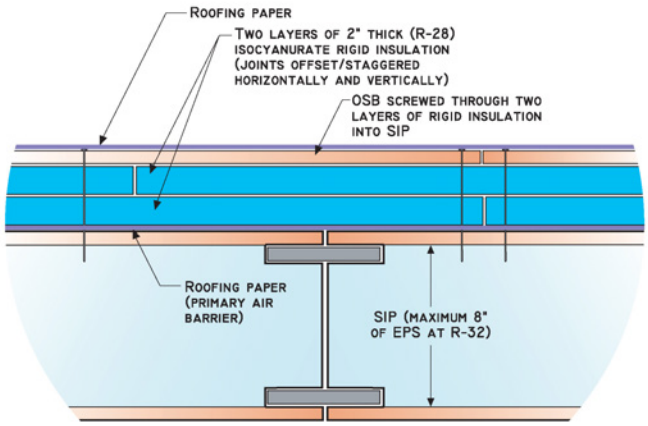

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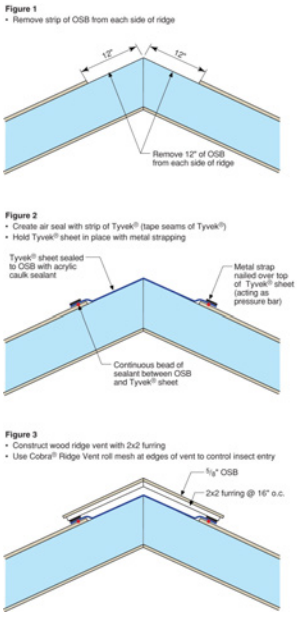

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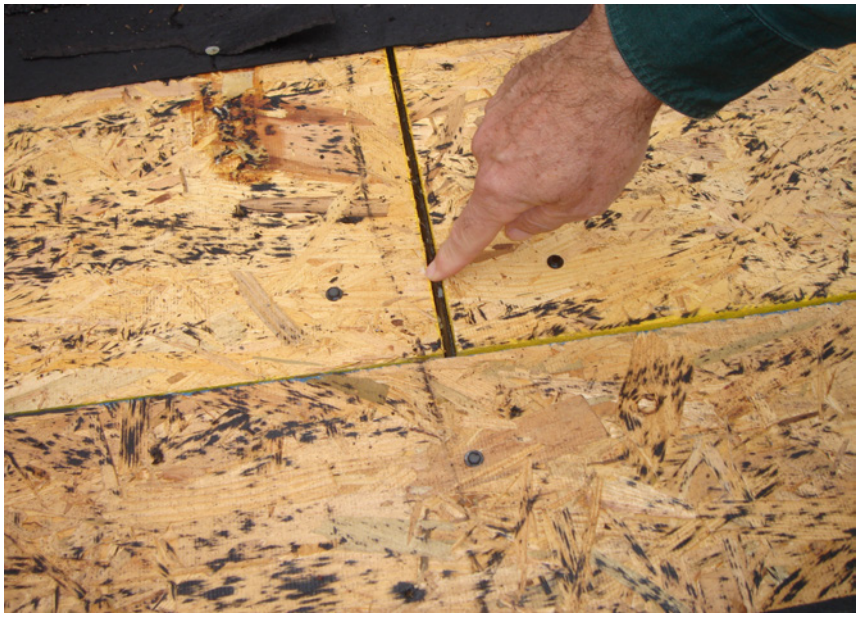

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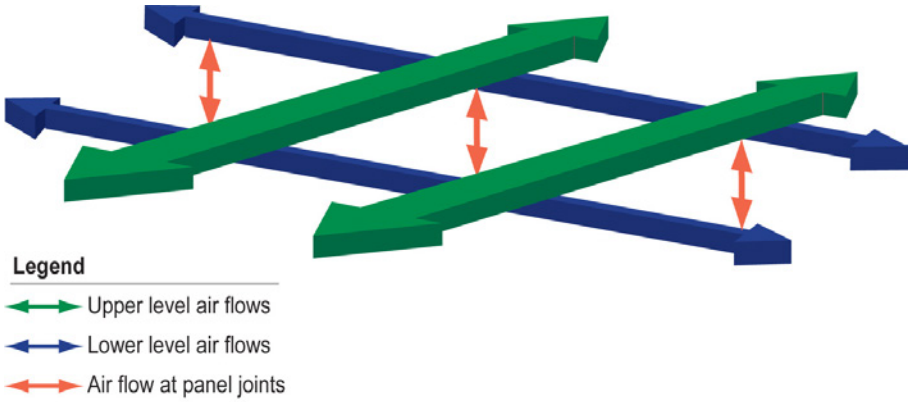
Joseph Lstiburek 76



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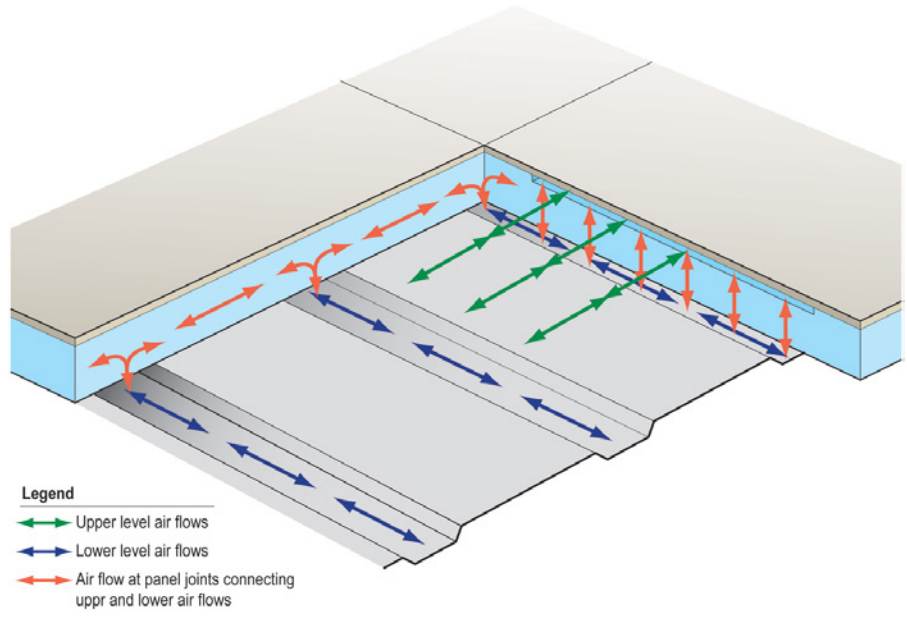

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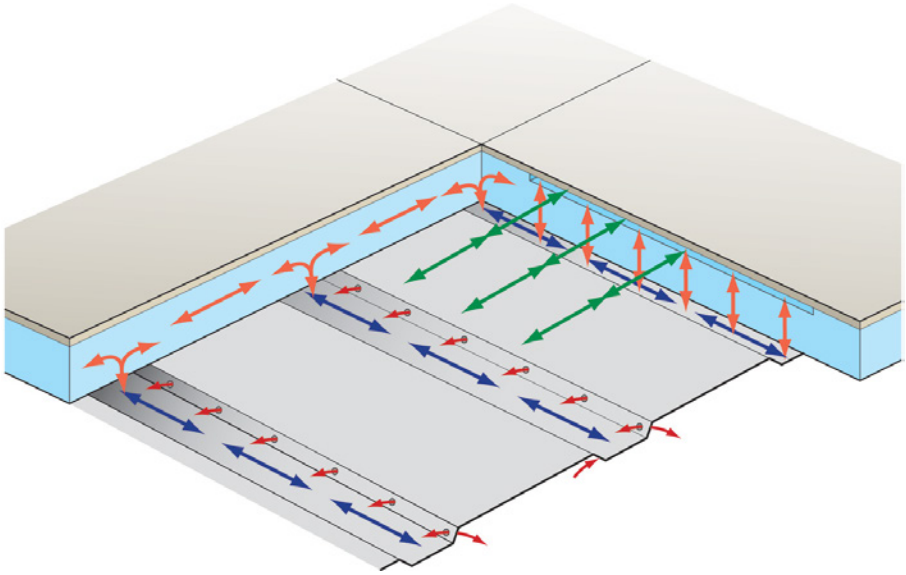

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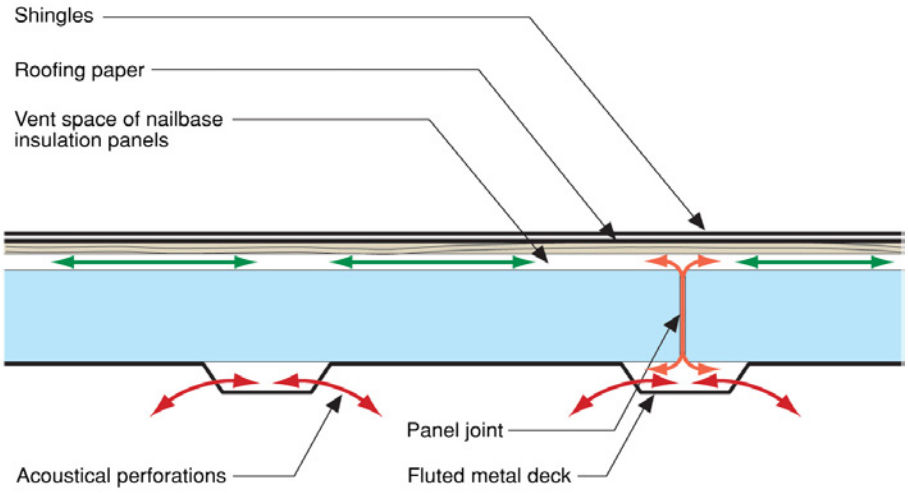
Joseph Lstiburek 80



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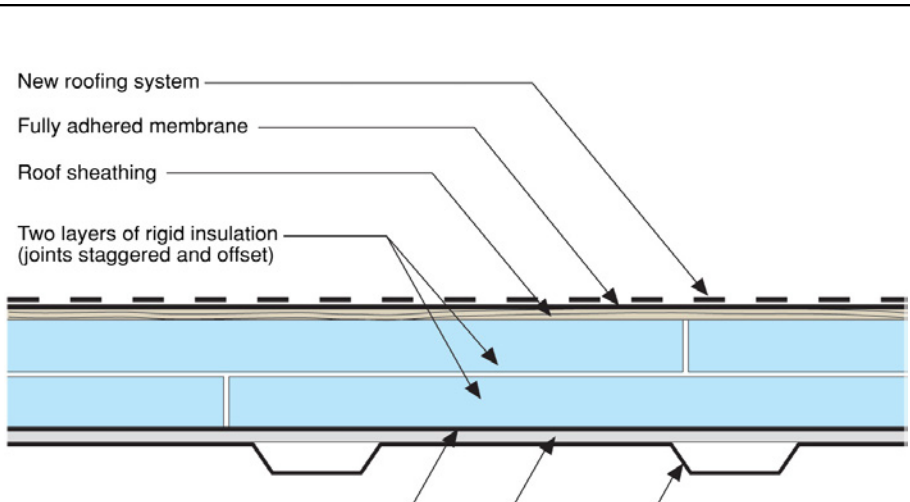

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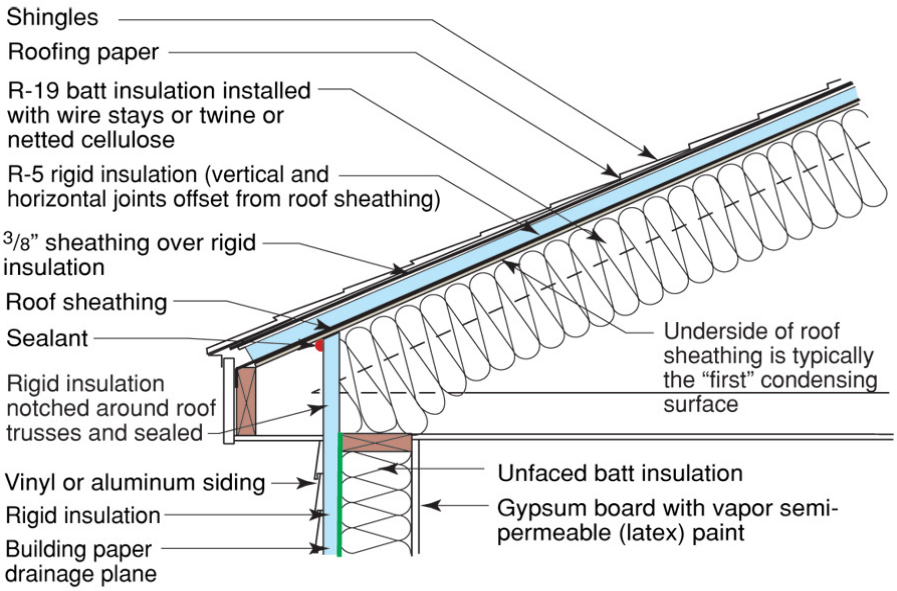

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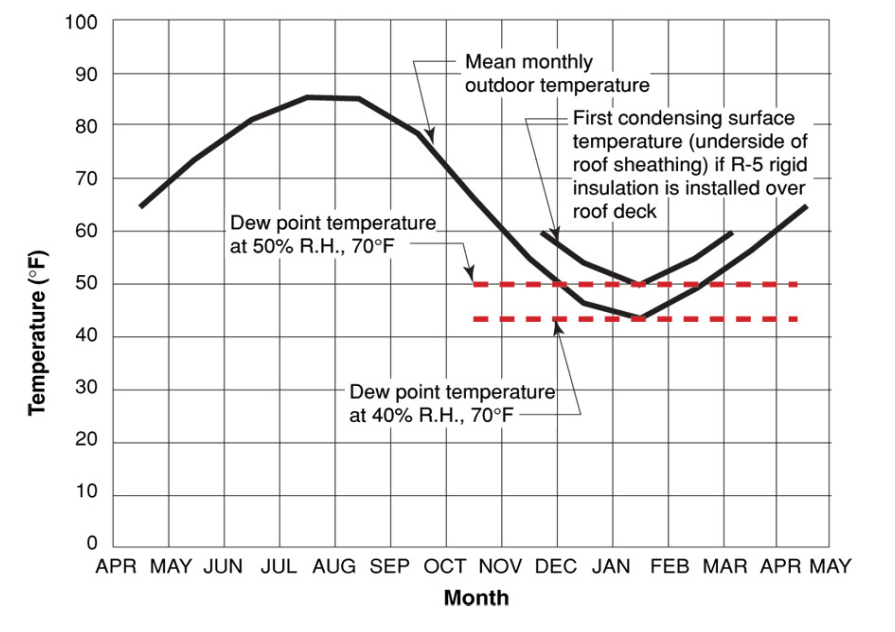

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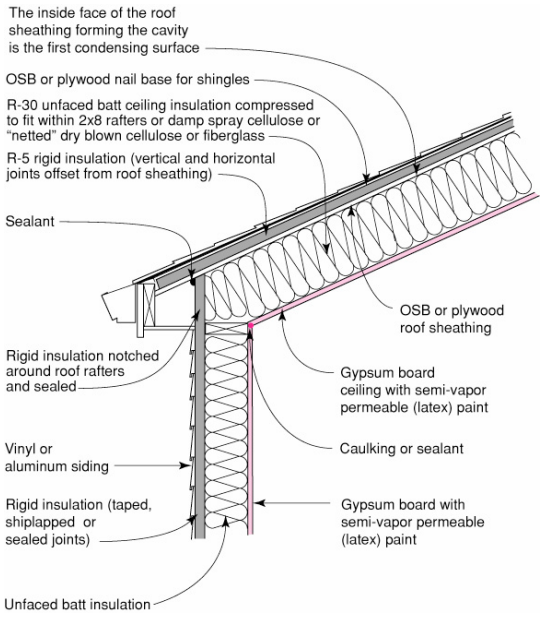

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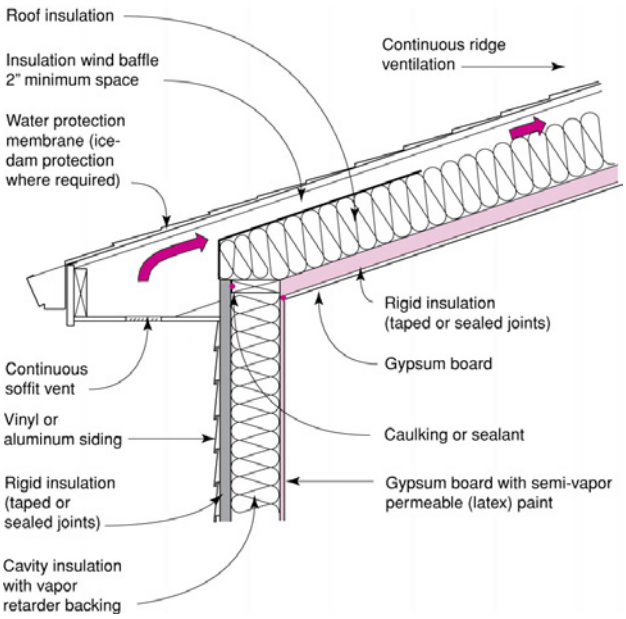

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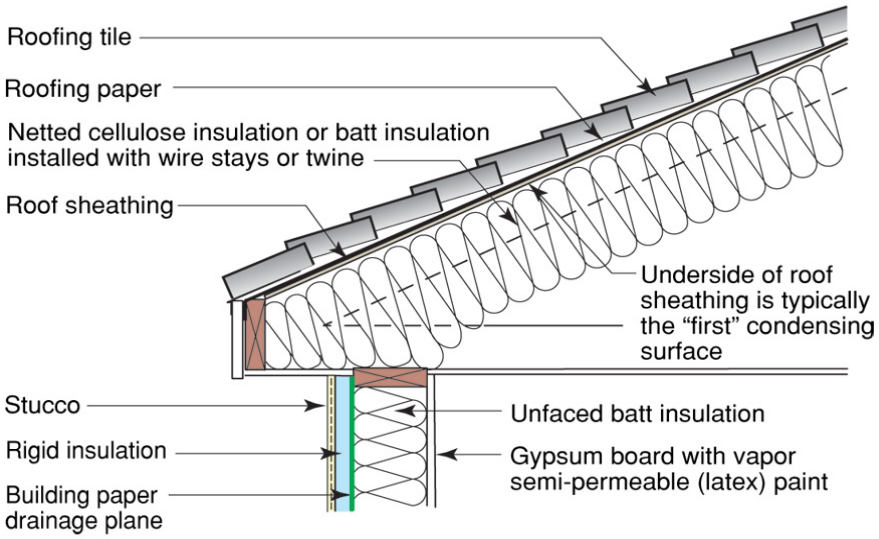

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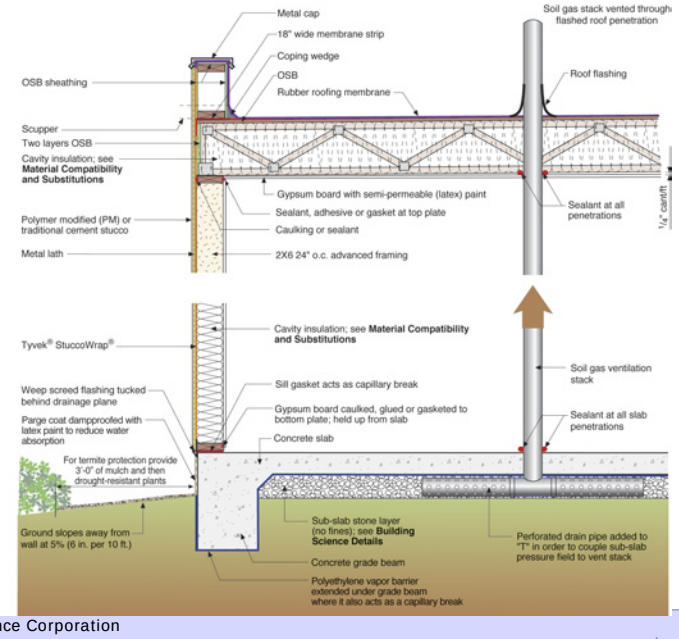
Joseph Lstiburek 90



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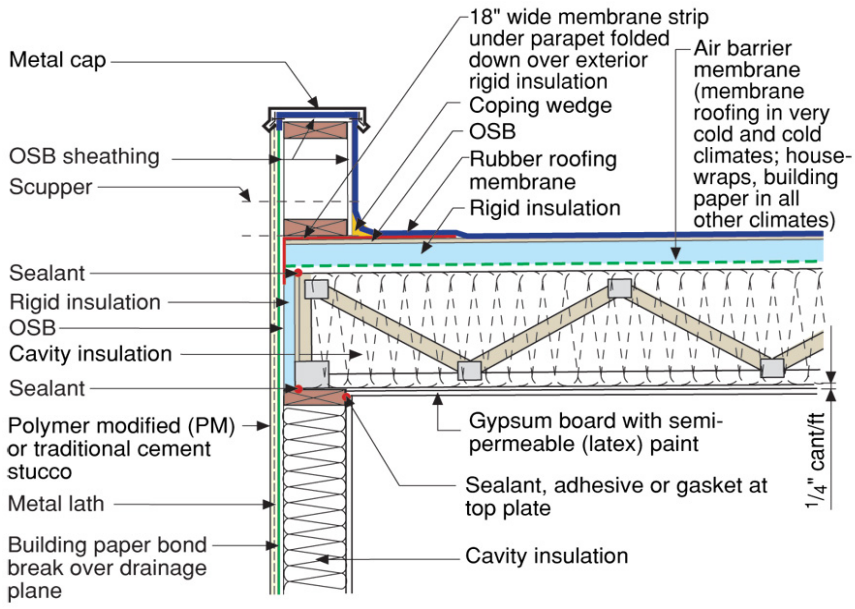

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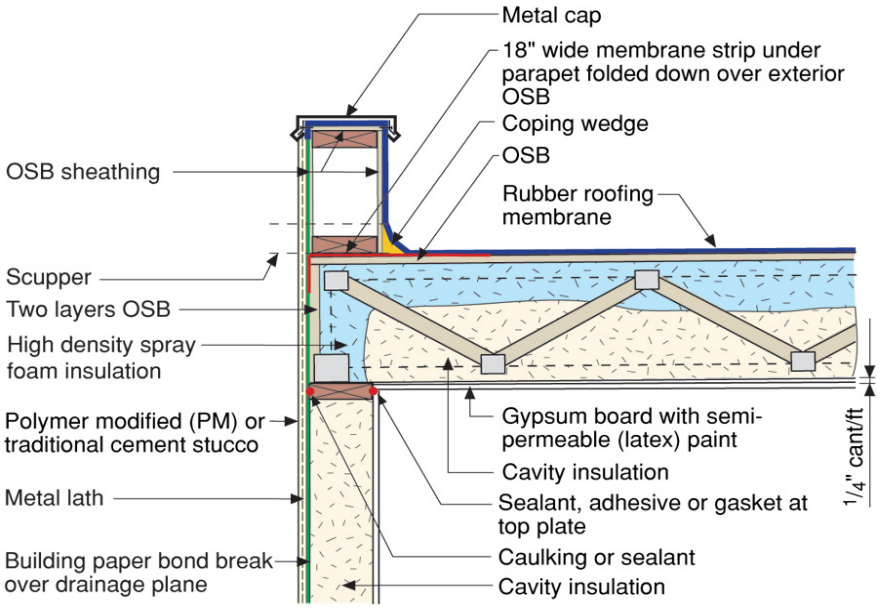

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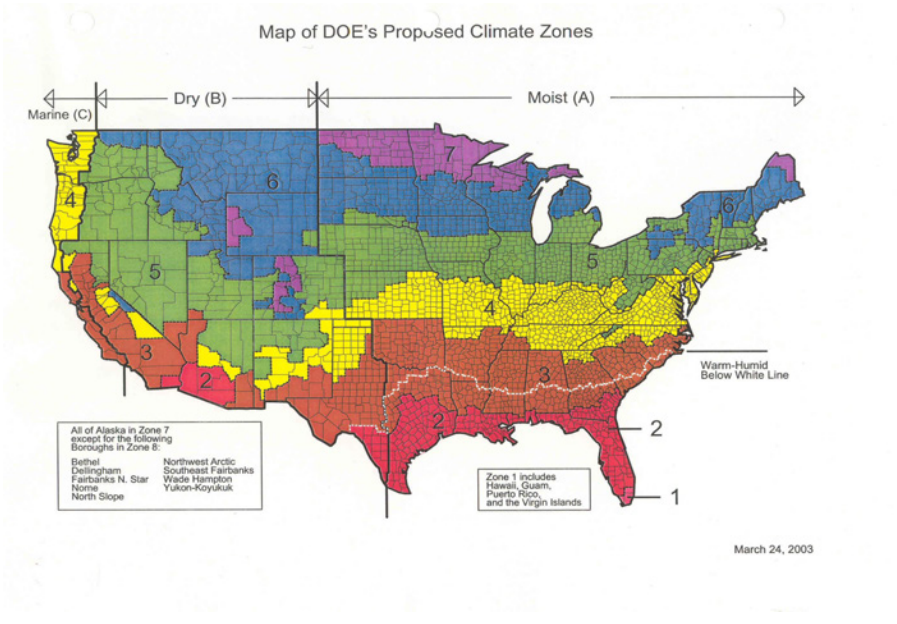

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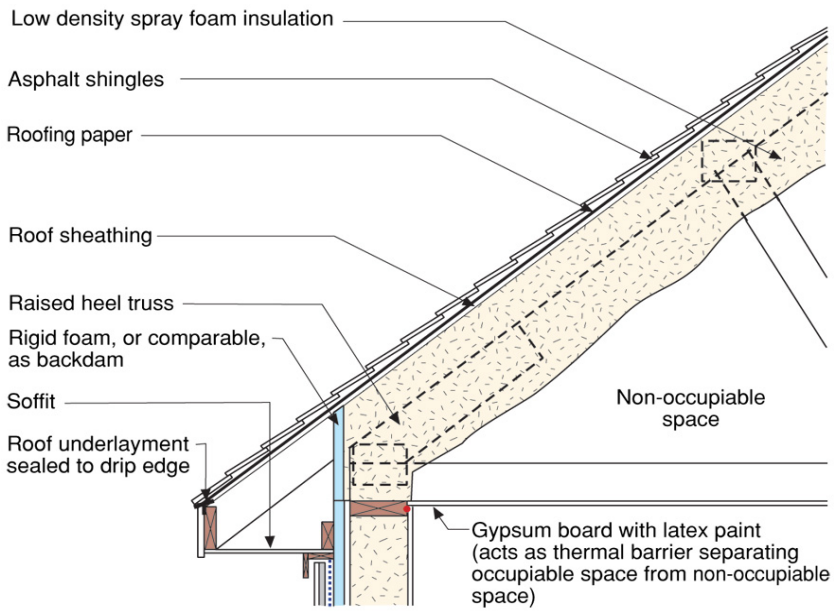

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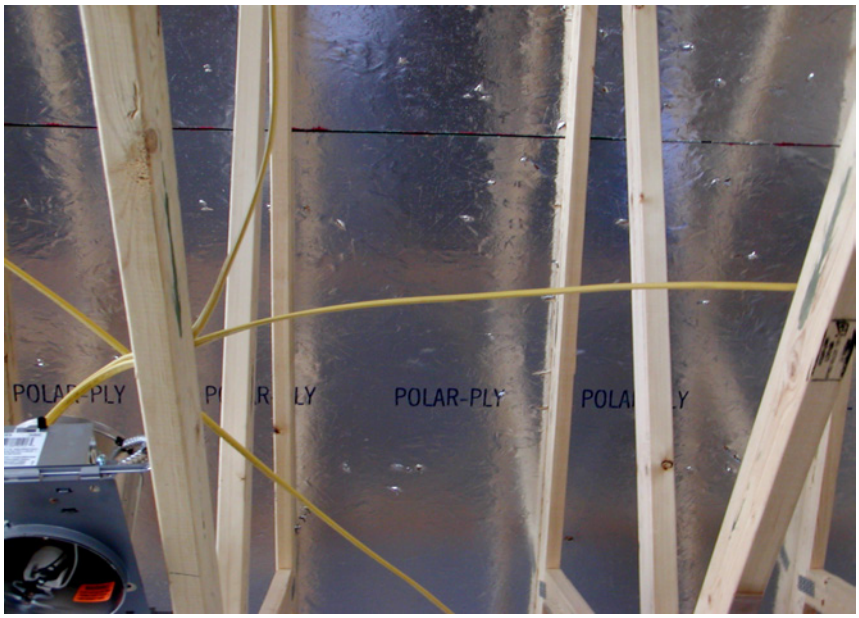

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