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

Building Science

Adventures In Building Science

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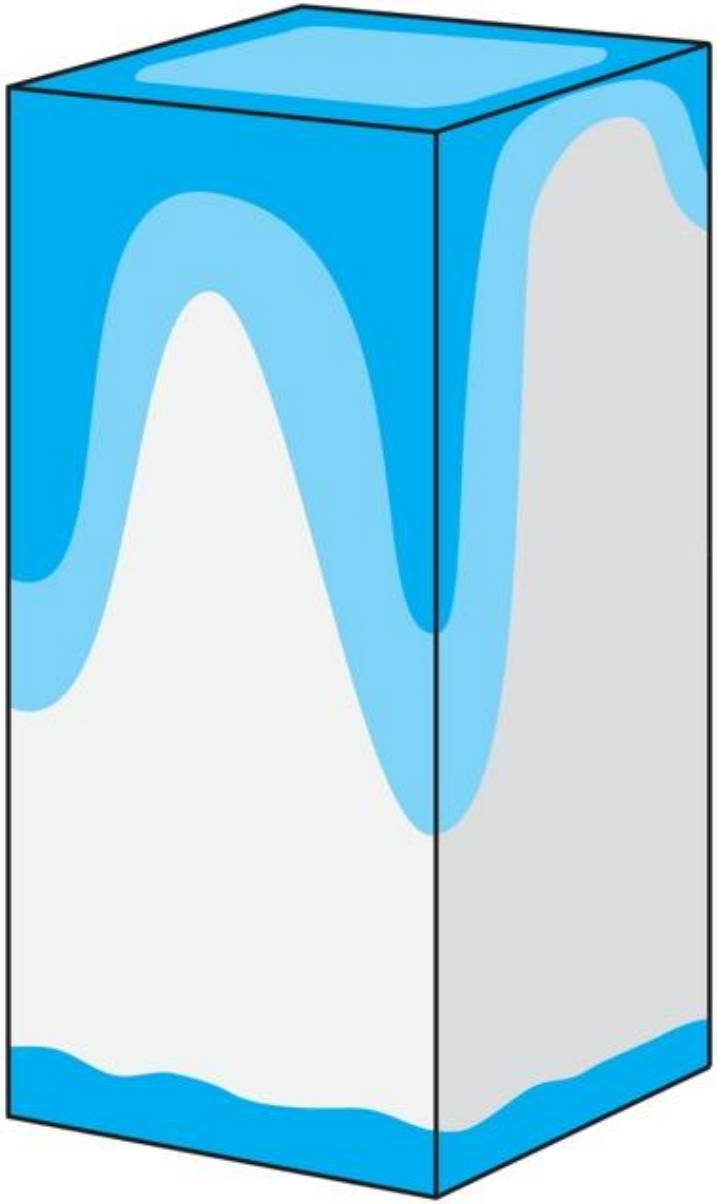
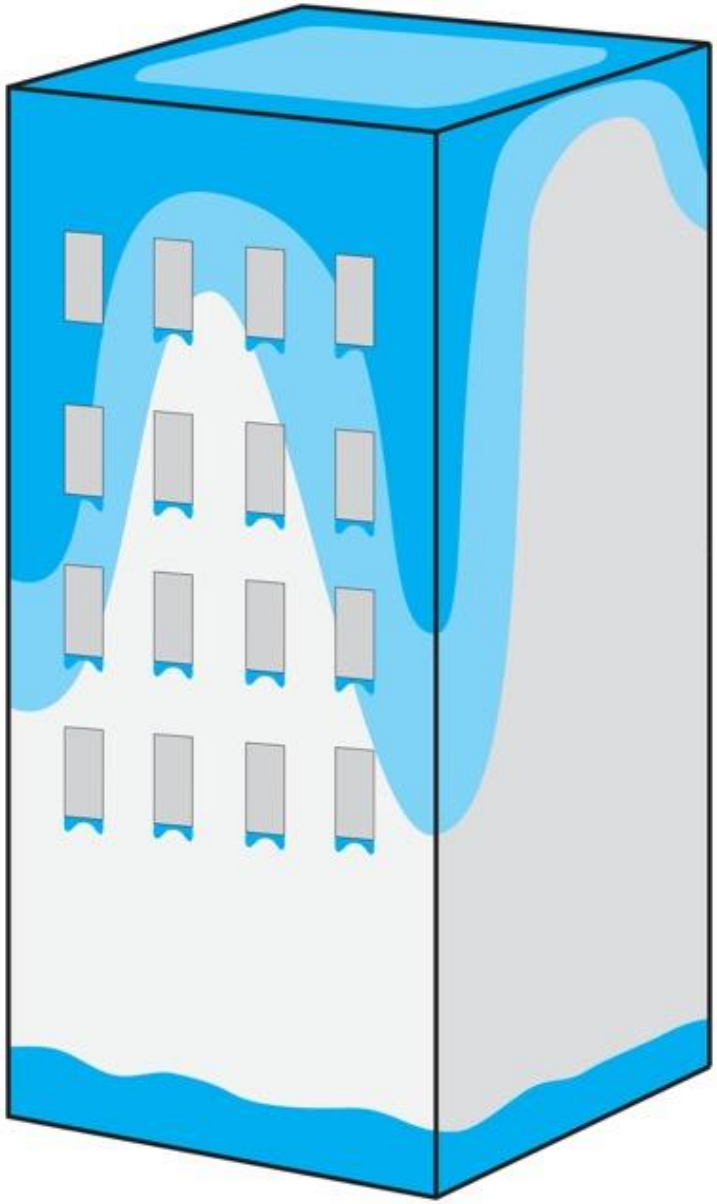
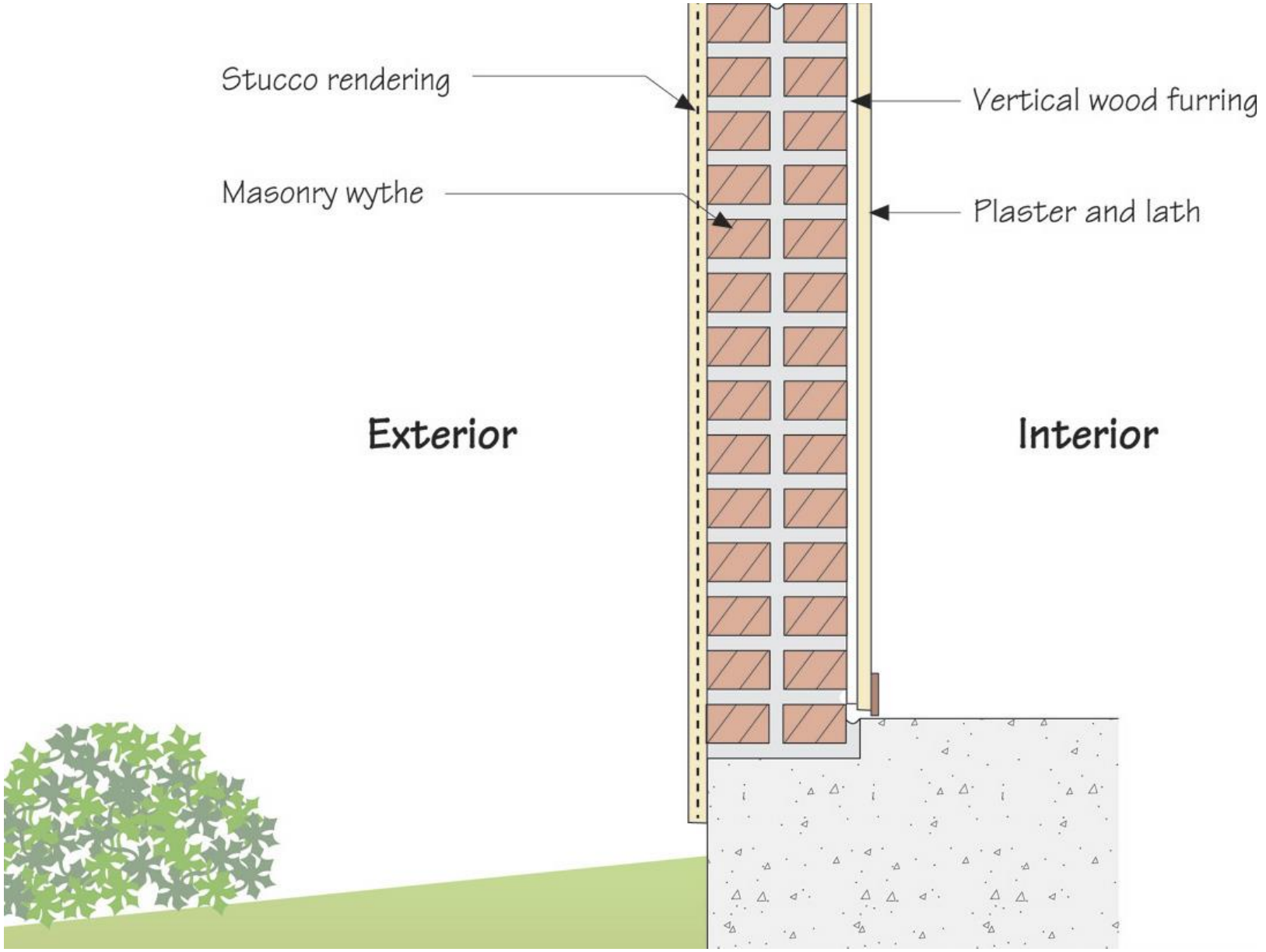
Context

Stucco Evolved As A Barrier System

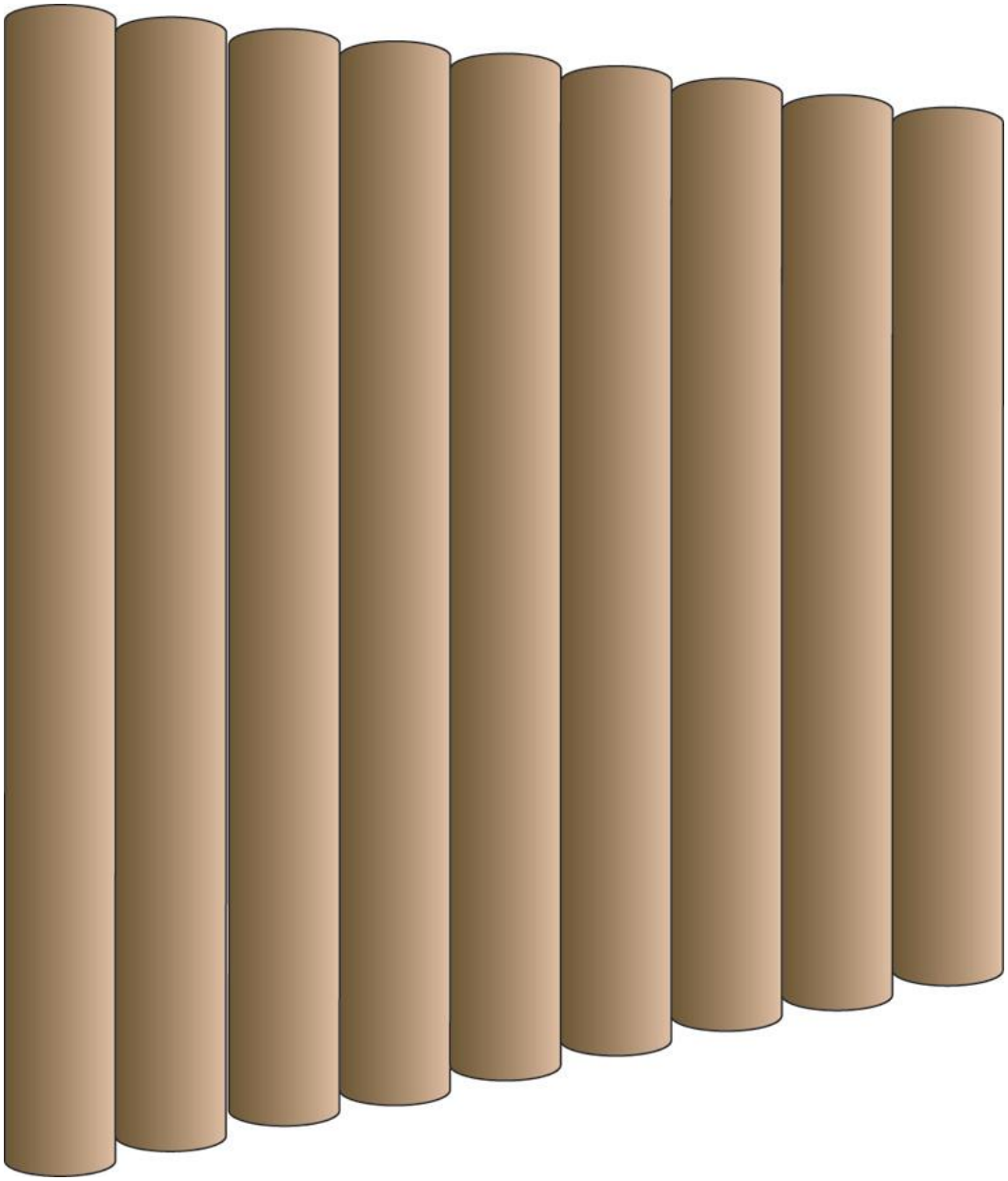
Mass Wall Evolution

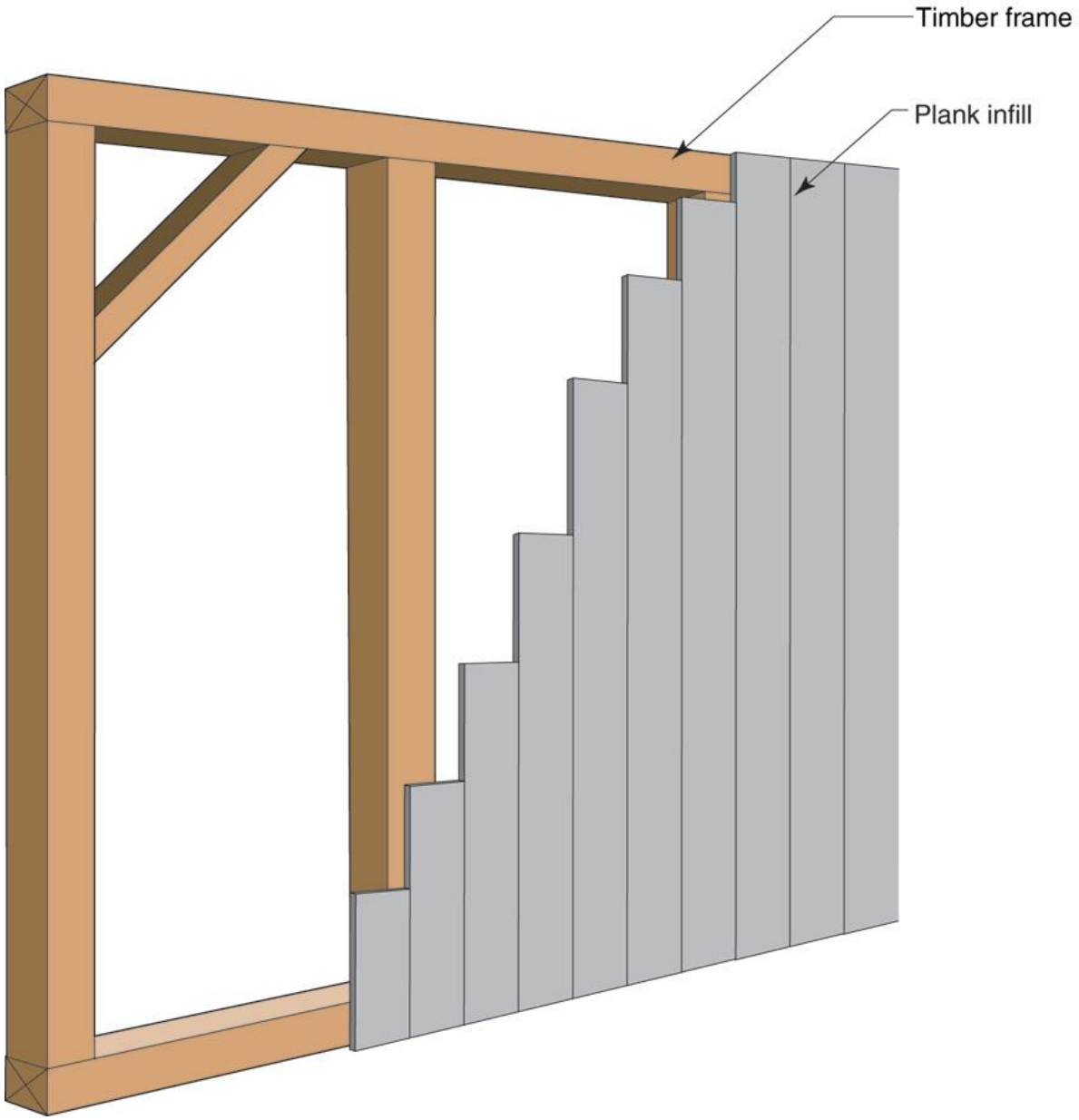


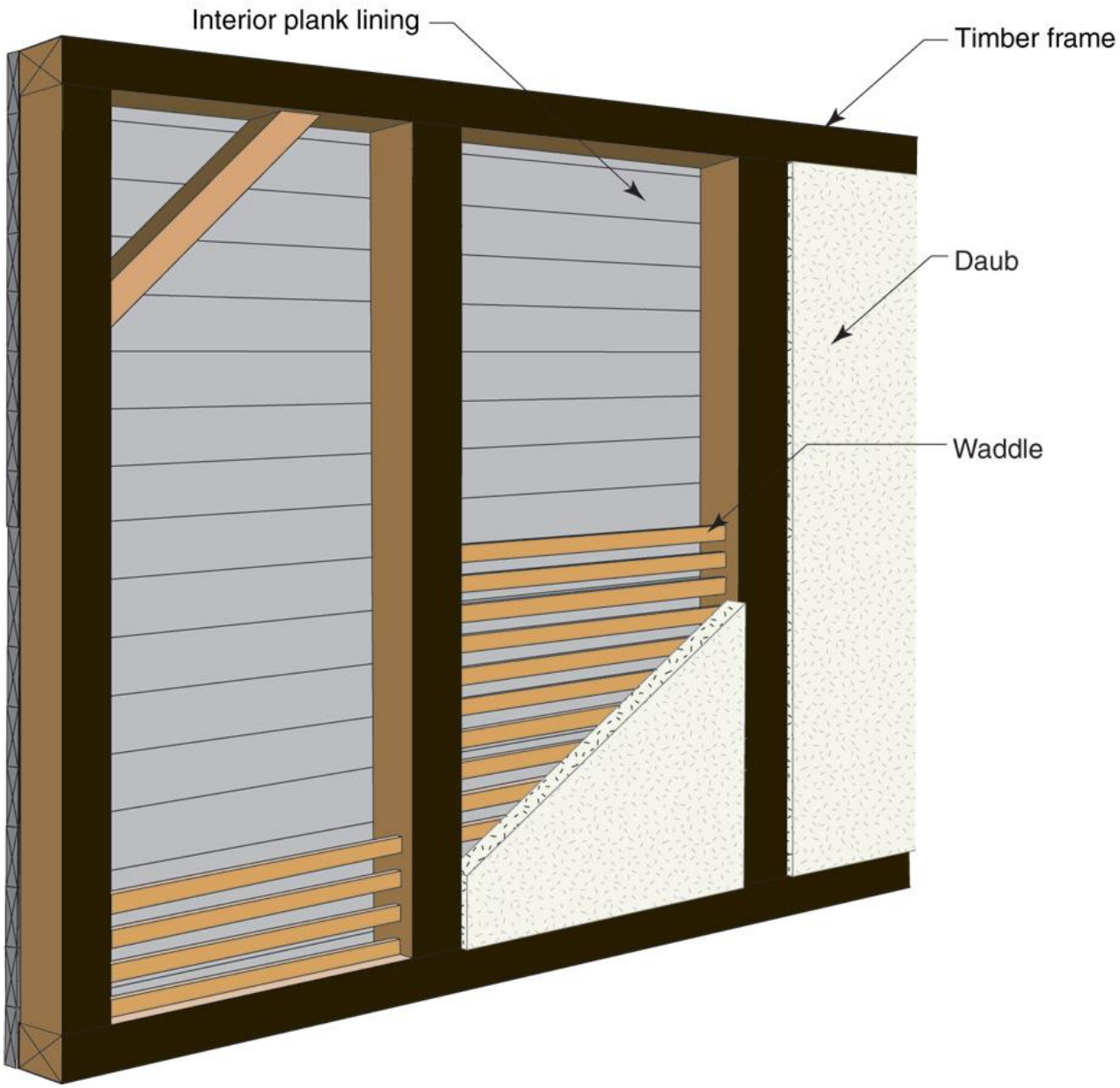


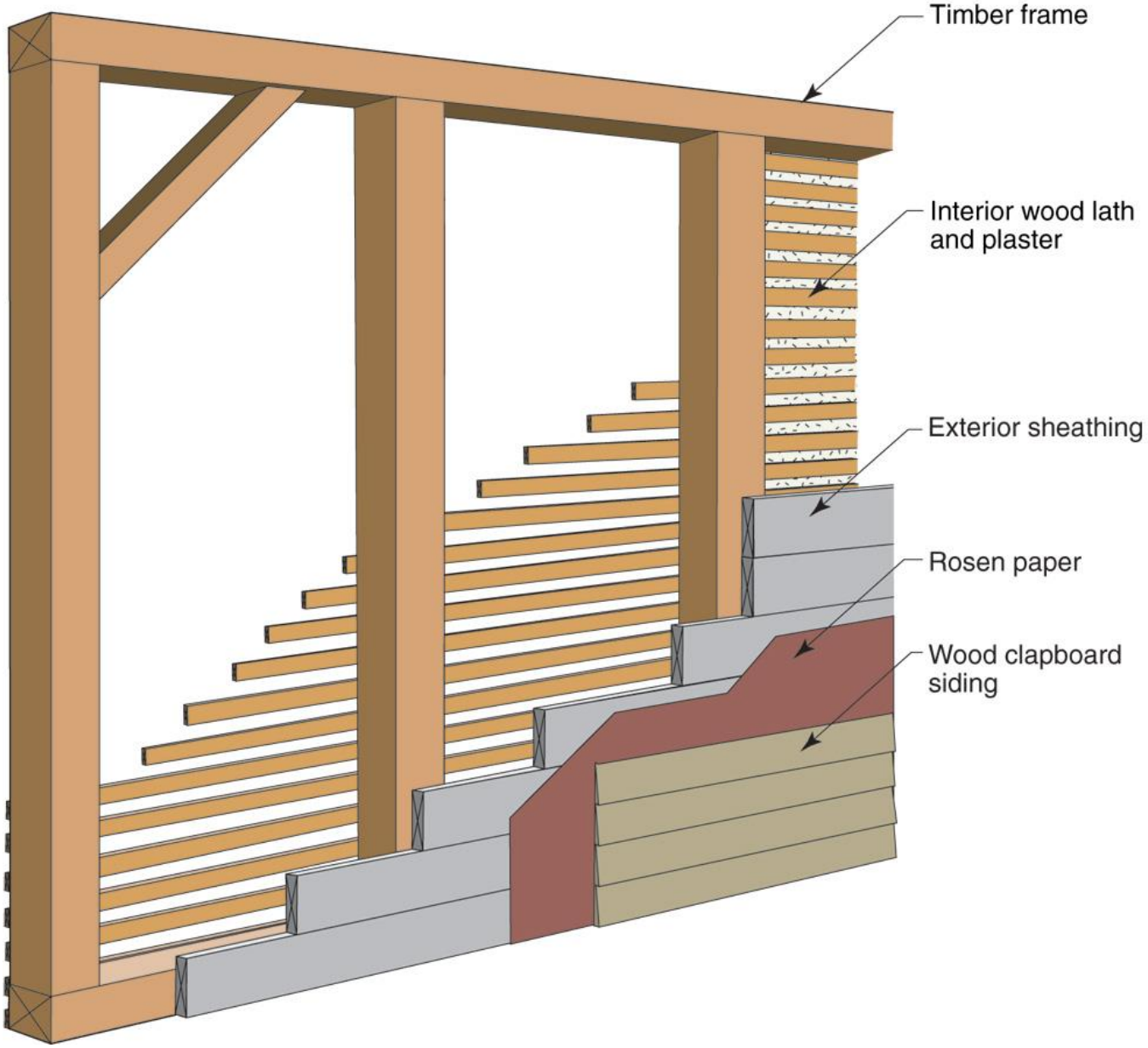

Stucco rendering
Masonry wythe
Vertical wood furring
Plaster and lath
Exterior
Interior

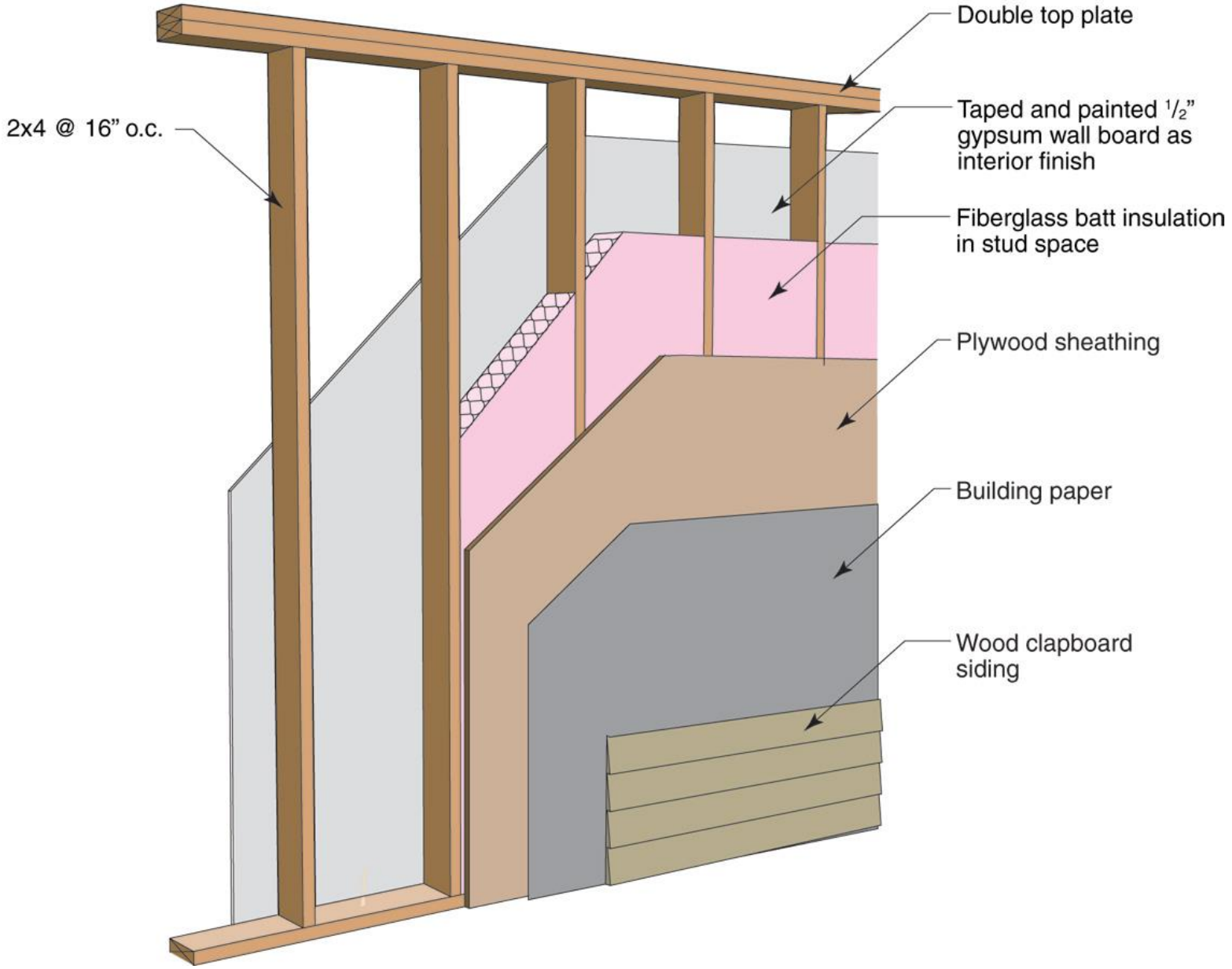
Frame Wall Evolution

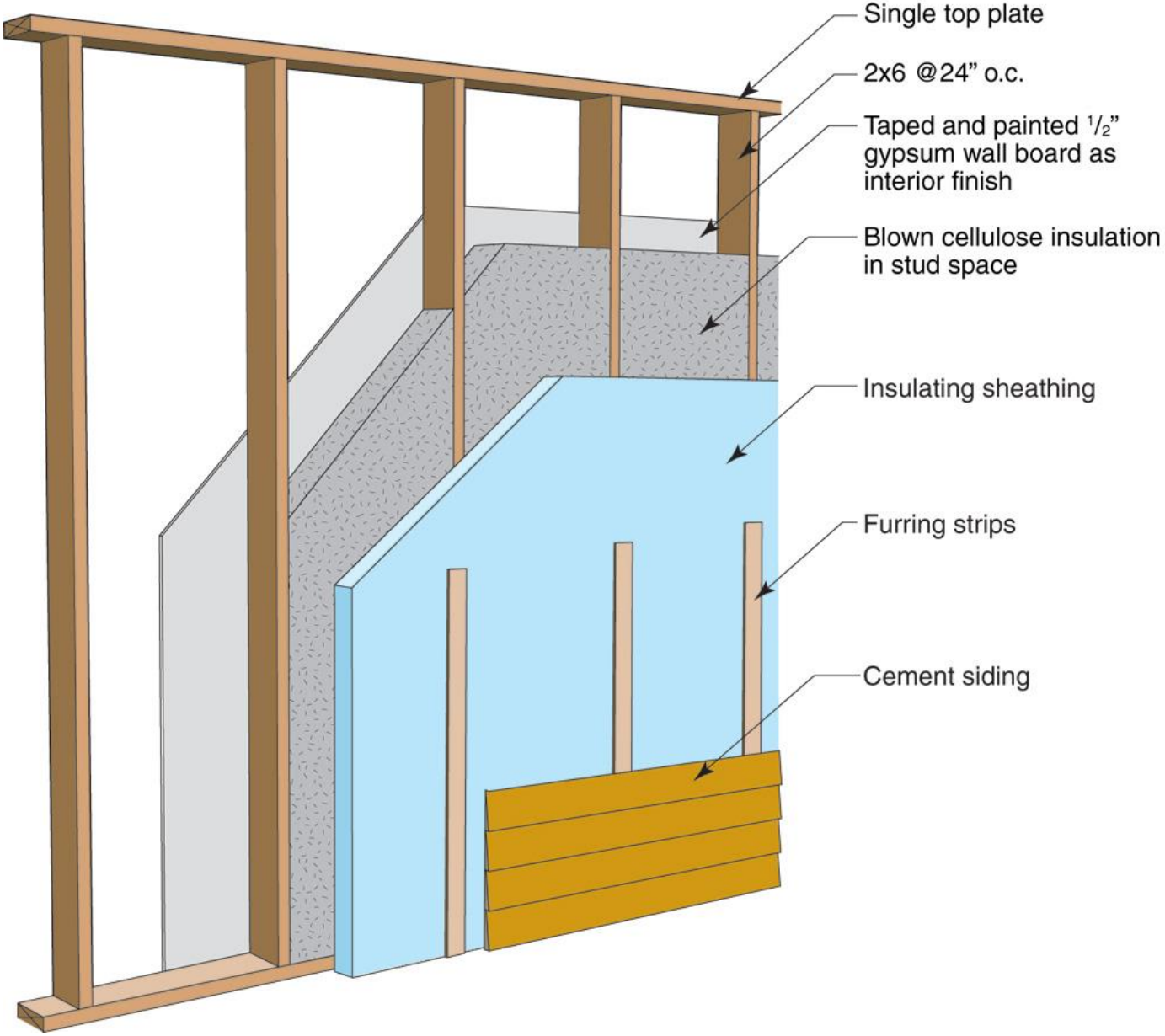



Timber frame
Plank infill


Interior plank lining
Timber frame
Daub
Waddle


Timber frame
Interior wood lath and plaster
Exterior sheathing
Rosen paper
Wood clapboard siding


Double top plate
2x4 @ 16" o.c.
Taped and painted 1/2" gypsum wall board as interior finish
Fiberglass batt insulation in stud space
Plywood sheathing
Building paper
Wood clapboard siding


Single top plate
2x6 @24" o.c.
Taped and painted 1/2" gypsum wall board as interior finish
Blown cellulose insulation in stud space
Insulating sheathing
Furring strips
Cement siding


T·C·1664
Bookland
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Books
Music
Maps


INSULATING SHEATHING
Celotex
INSULATING SHEATHING
Celotex

Recent History

Exterior Insulation Finish Systems

EIFS

Exterior Insulation Finish Systems

EIFS

Barrier System

Face-Sealed Not Water Managed


BUILT BY
EDDIE EVANS
CONSTRUCTION
1994

Life Is Hard Enough As It Is

It’s Harder When You Are Stupid

Don’t Do Stupid Things


Holiday Inn

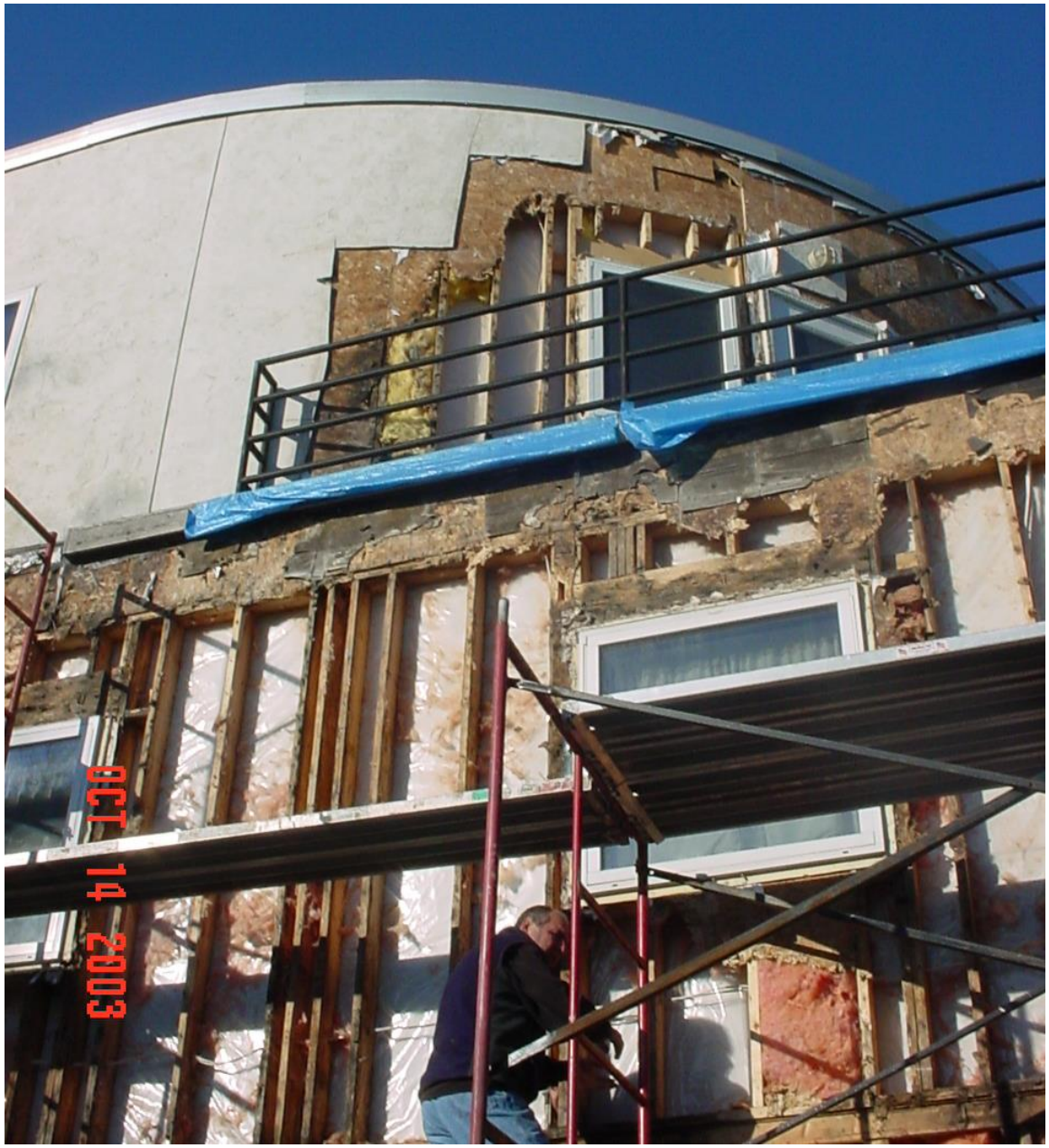
Side Trip To Vancouver….

Side Trip To Vancouver….

Vancouver Condo Crisis….

Should Have Put Everyone on Notice


6'8" CLEARANCE 2.0m


OCT 14 2003


OCT 14 2003


OCT 14 2003

What Happened In Vancouver?

OSB Instead of Plywood

Non Traditional Building Wraps

Interior Vapor Barriers

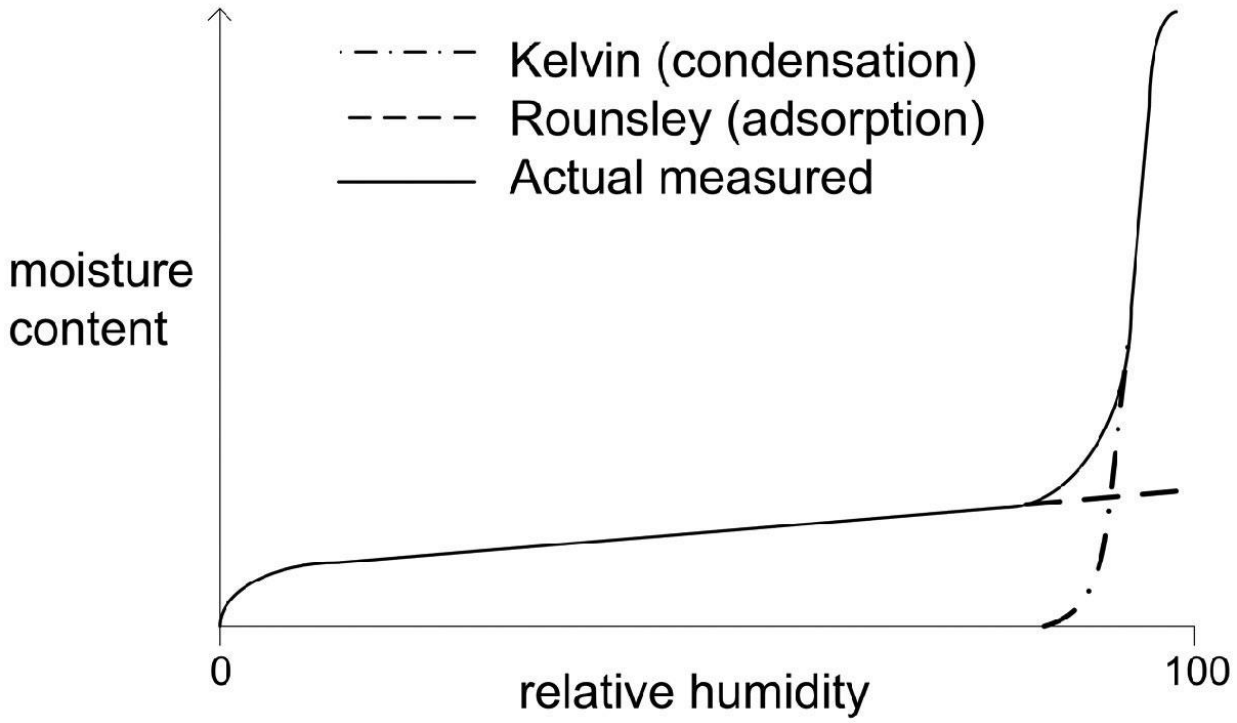
Increased Thermal Resistance

Portland Cement Instead of Lime

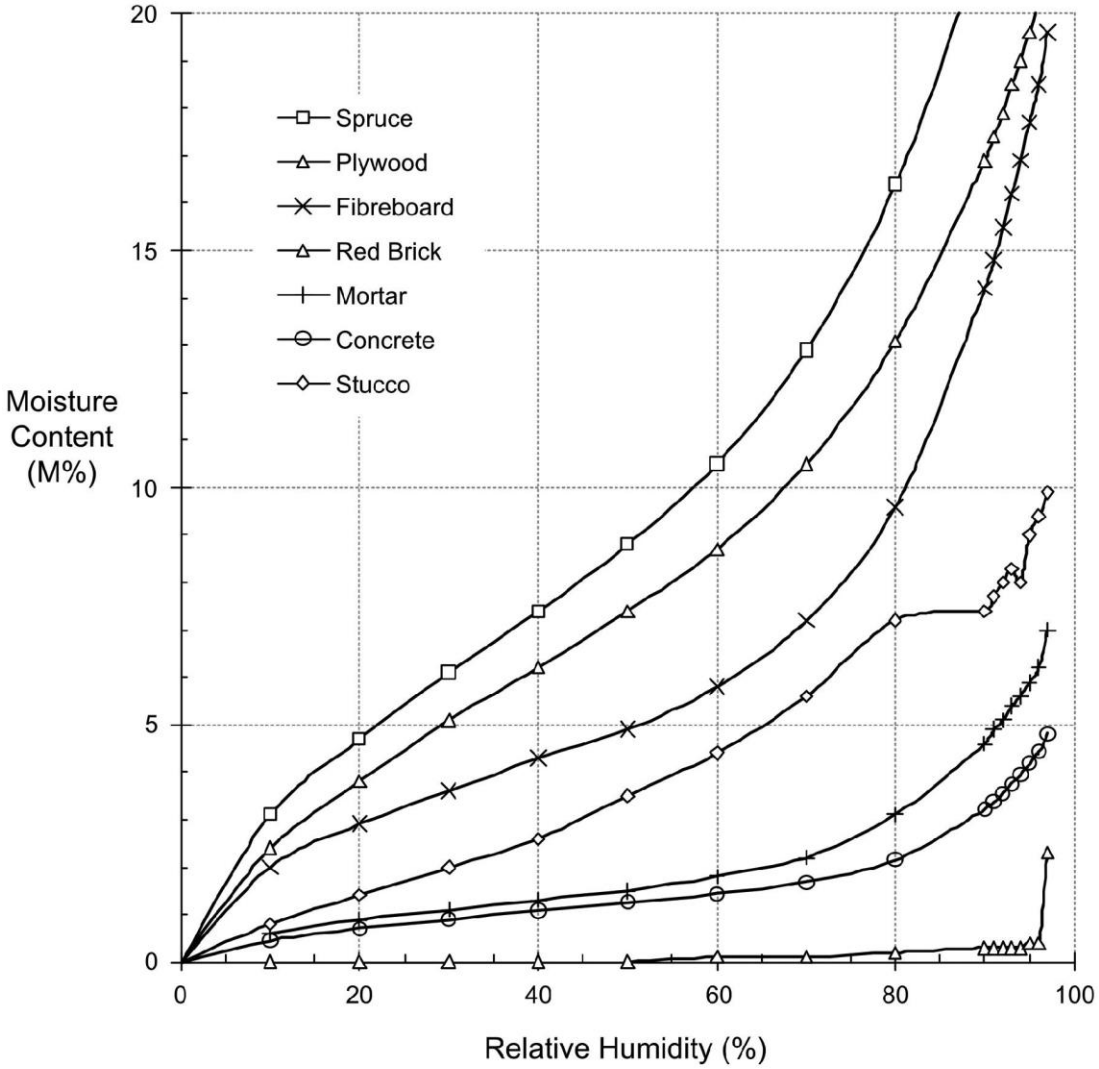
Materials

Inward Drive

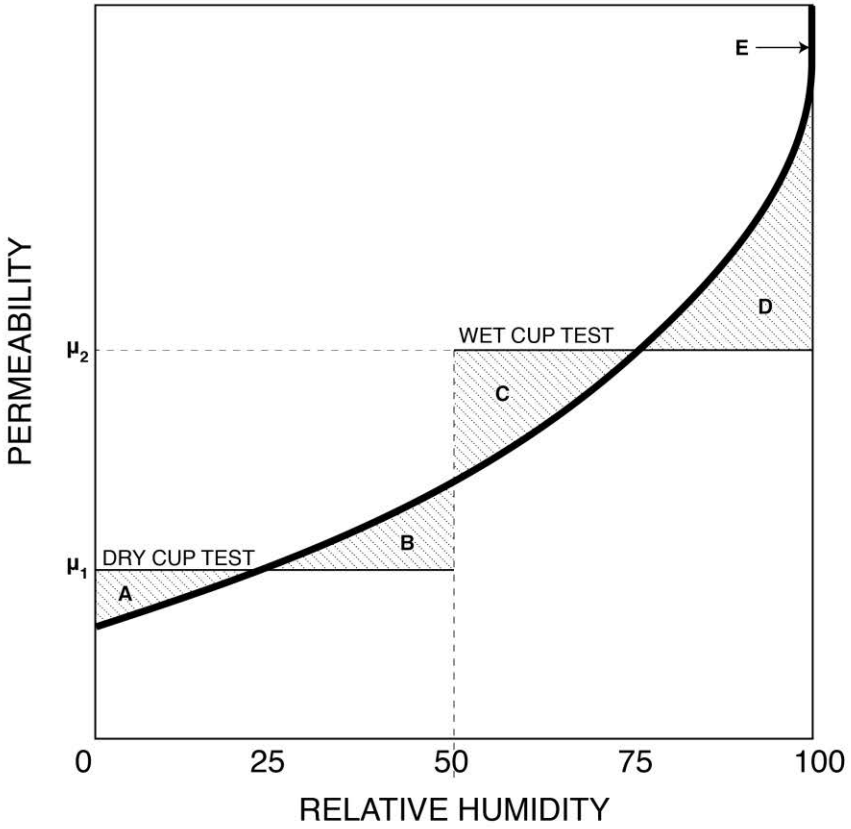
Energy



Typical predicted sorption isotherm according to Kelvin equation and modified BET theory
From Straube & Burnett, 2005



Sorption isotherm for several building materials [Kumaran 2002]
From Straube & Burnett, 2005



A - Single-layer of absorbed molecules
B - Multiple layers of absorbed molecules
C - Interconnected layers (internal capillary condensation)
D - Free water in pores, capillary suction
E - Supersaturated regime

Relationship between Dry Cup and Wet Cup
Adapted from Joy & Wilson, 1963


R-11 3½
OWENS-CORNING
Fiberglas
Building
Insulation
FIBERGLAS
ASSURED THERMAL
PERFORMANCE
R-11 3½
OWENS-CORNING
Fiberglas
Building
Insulation
R-11 3½
OWENS-CORNING
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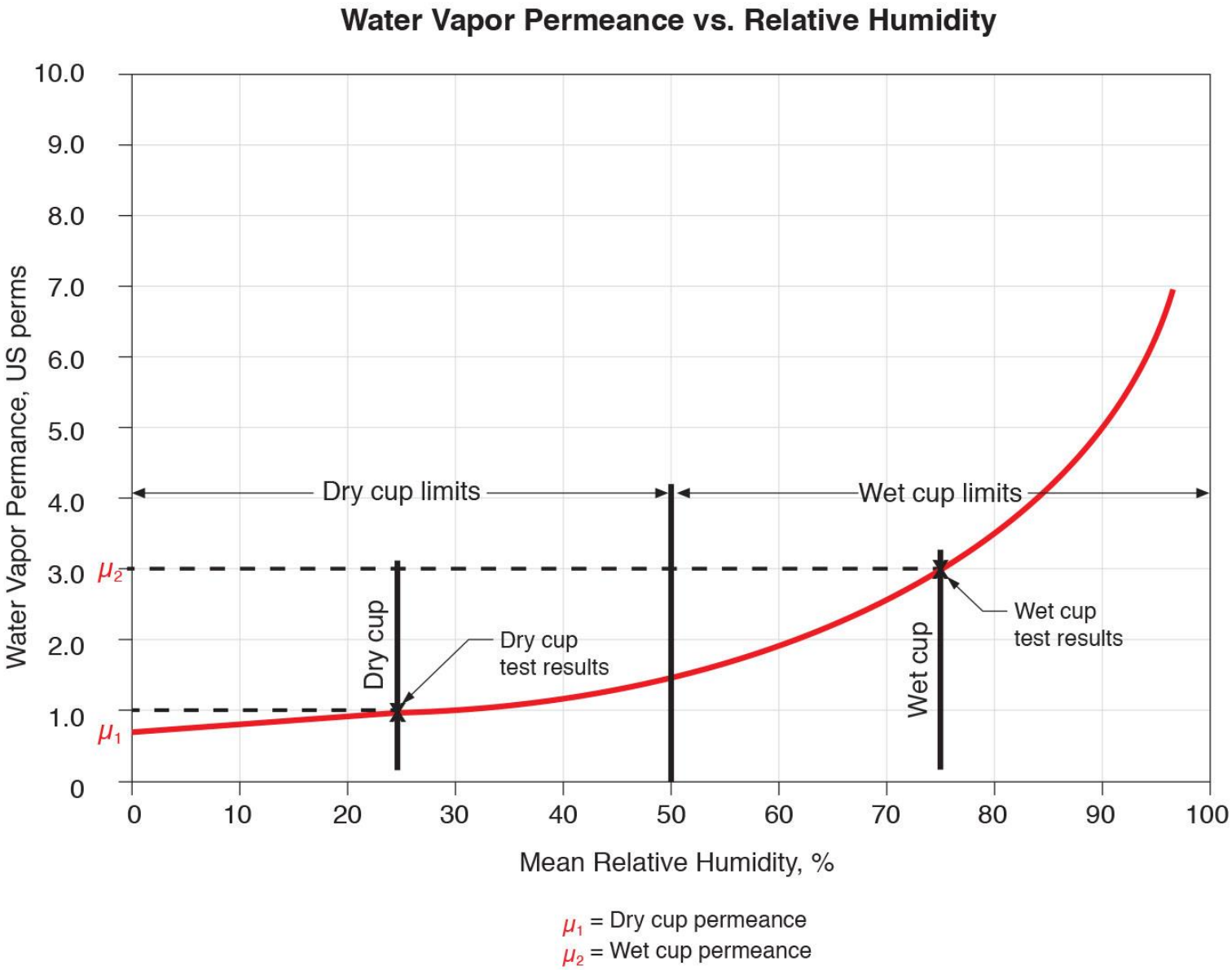
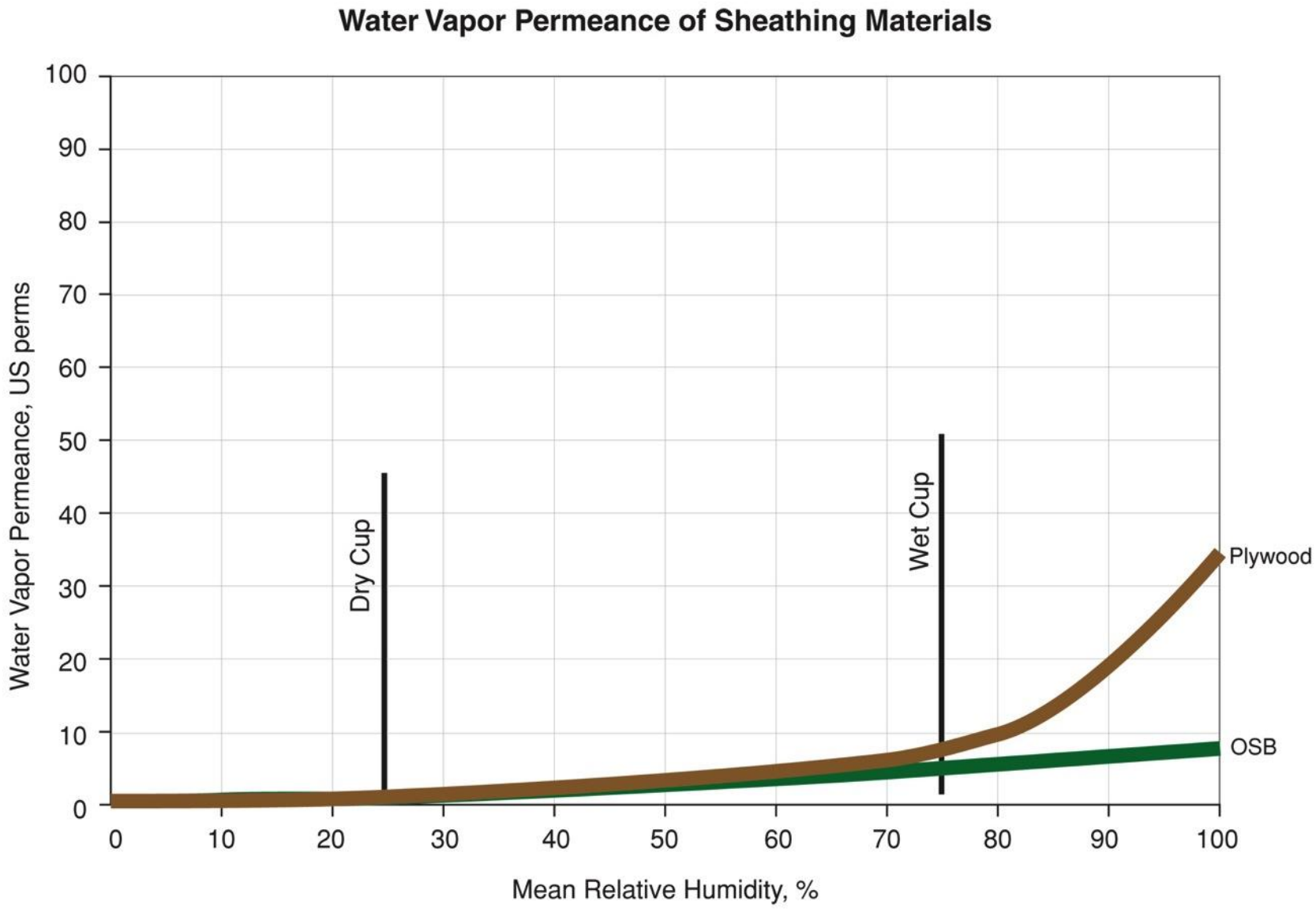
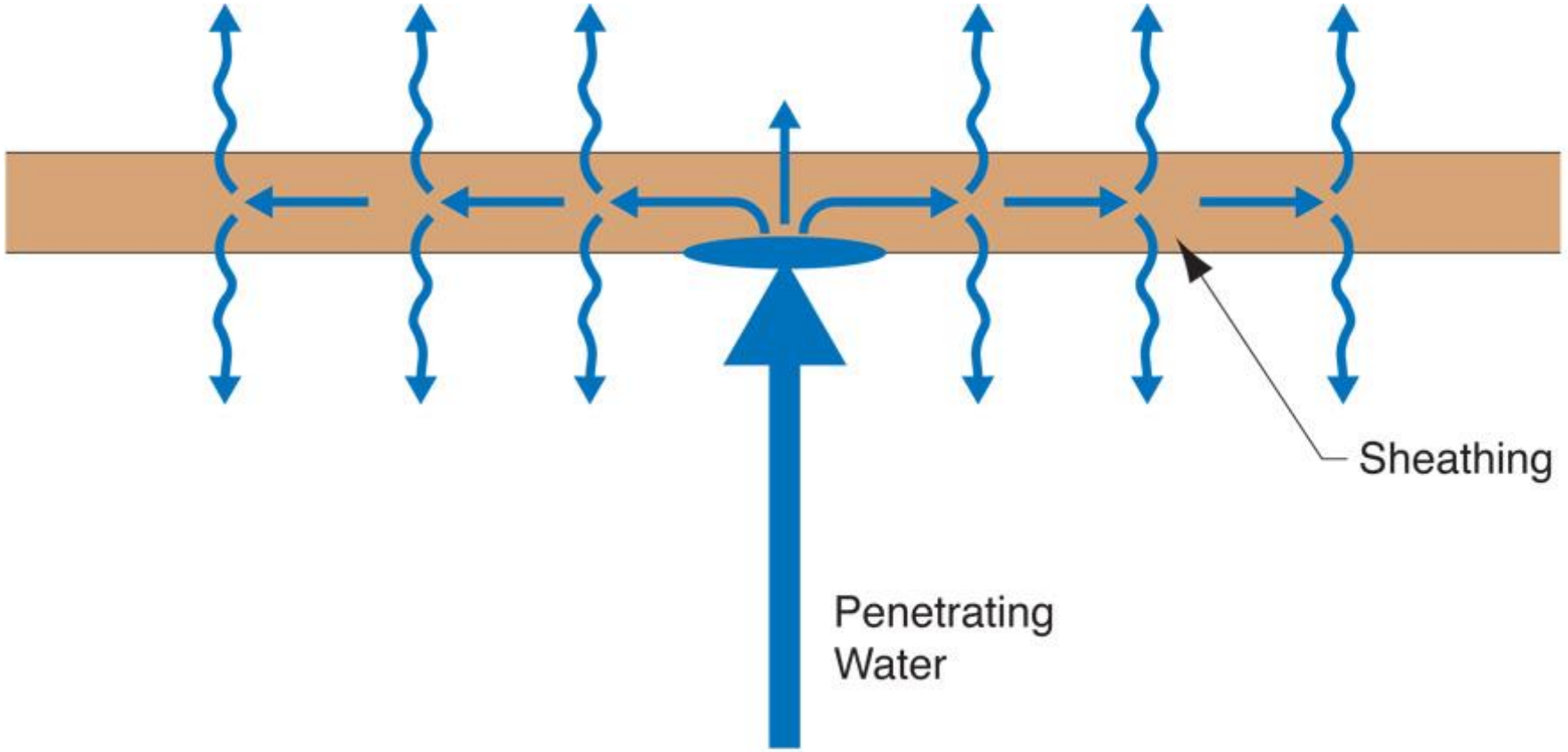
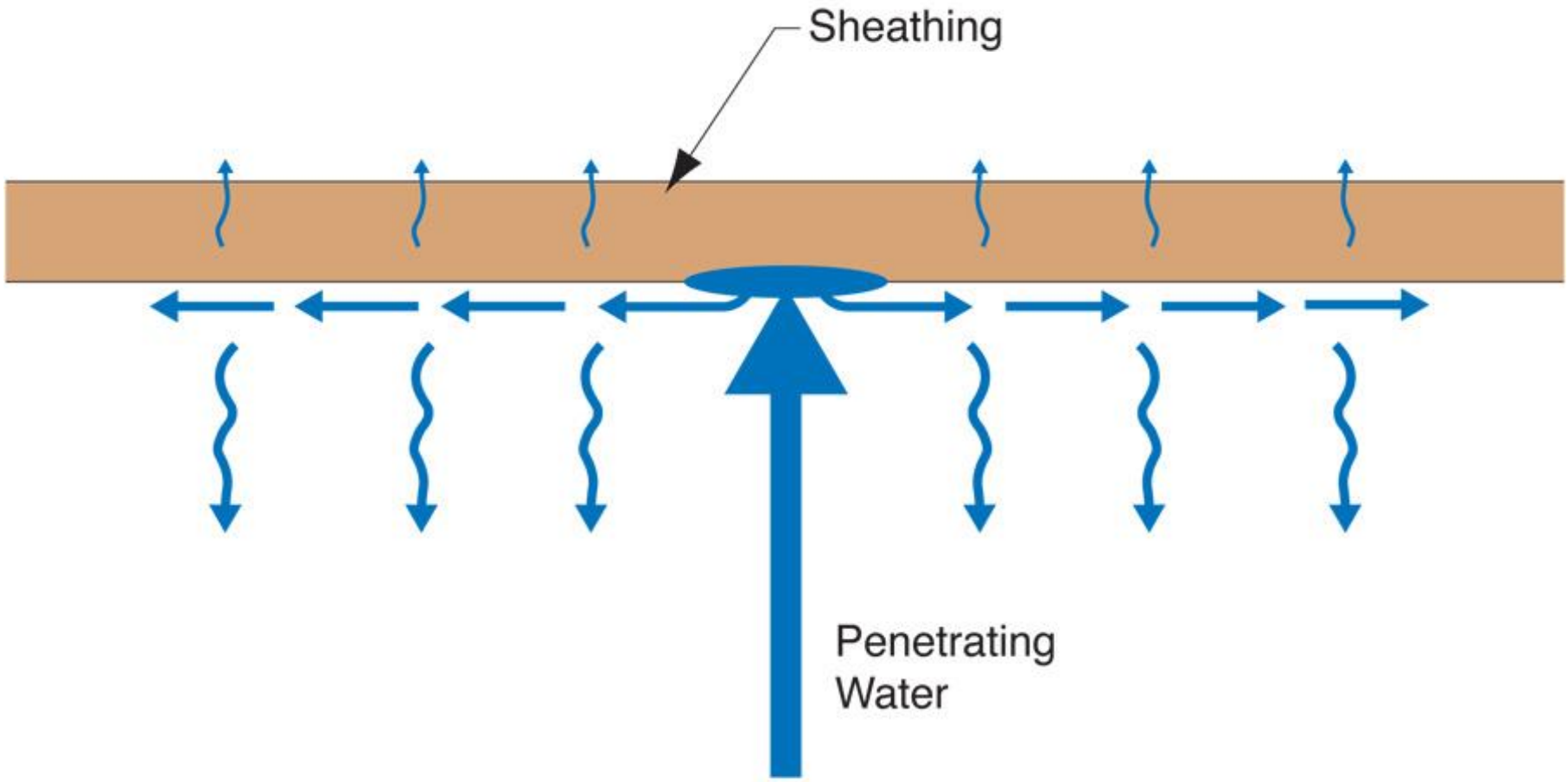
Building
Insulation


Water Vapor Permeance vs. Relative Humidity
Water Vapor Permance, US perms
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
μ_2
μ_1
Dry cup limits
Wet cup limits
Dry cup
Dry cup
test results
Wet cup
Wet cup
test results
0
10
20
30
40
50
60
70
80
90
100
Mean Relative Humidity, %
μ_1 = Dry cup permeance
μ_2 = Wet cup permeance

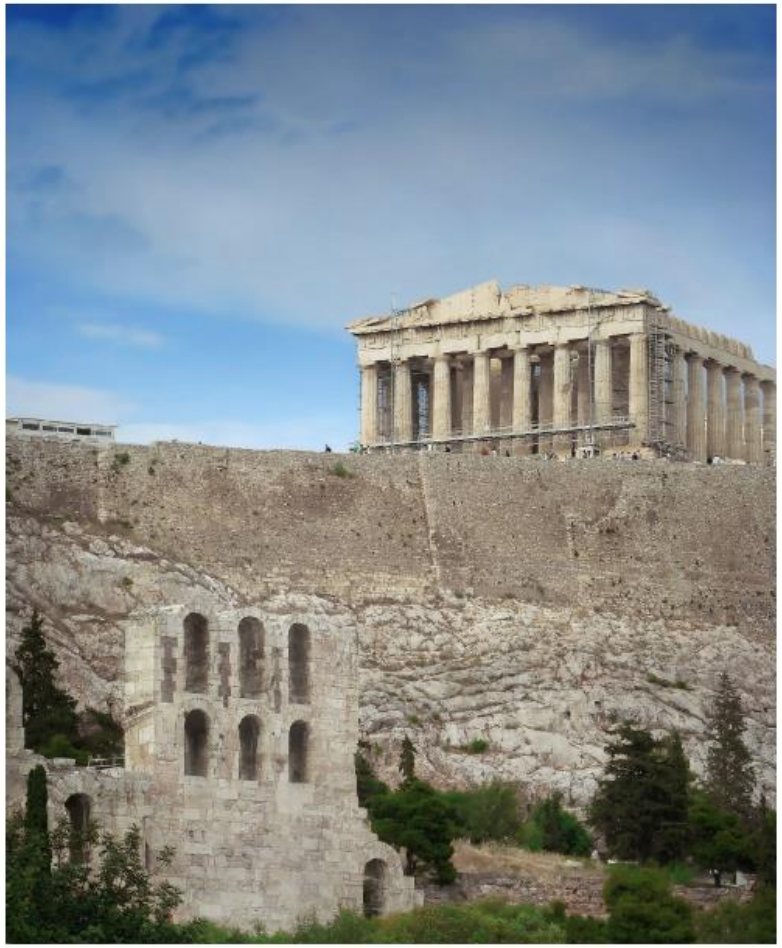

Water Vapor Permeance of Sheathing Materials
Water Vapor Permeance, US perms
100
90
80
70
60
50
40
30
20
10
0
Dry Cup
Wet Cup
Plywood
OSB
0
10
20
30
40
50
60
70
80
90
100
Mean Relative Humidity, %


Sheathing
Penetrating
Water


Sheathing
Penetrating
Water


panago
QUILTED TREASURES


panago
QUILTED TREASURES

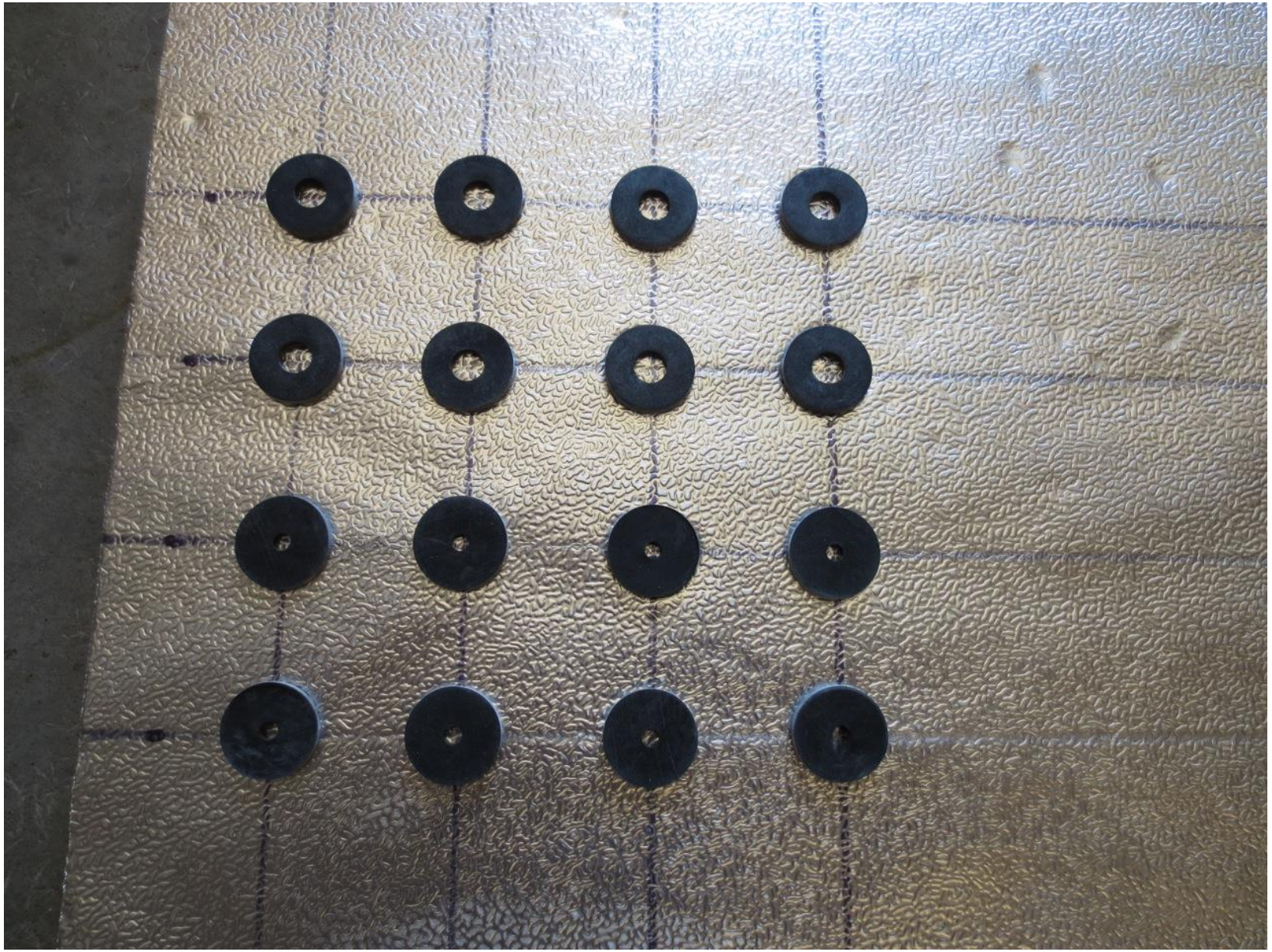



W1
W3

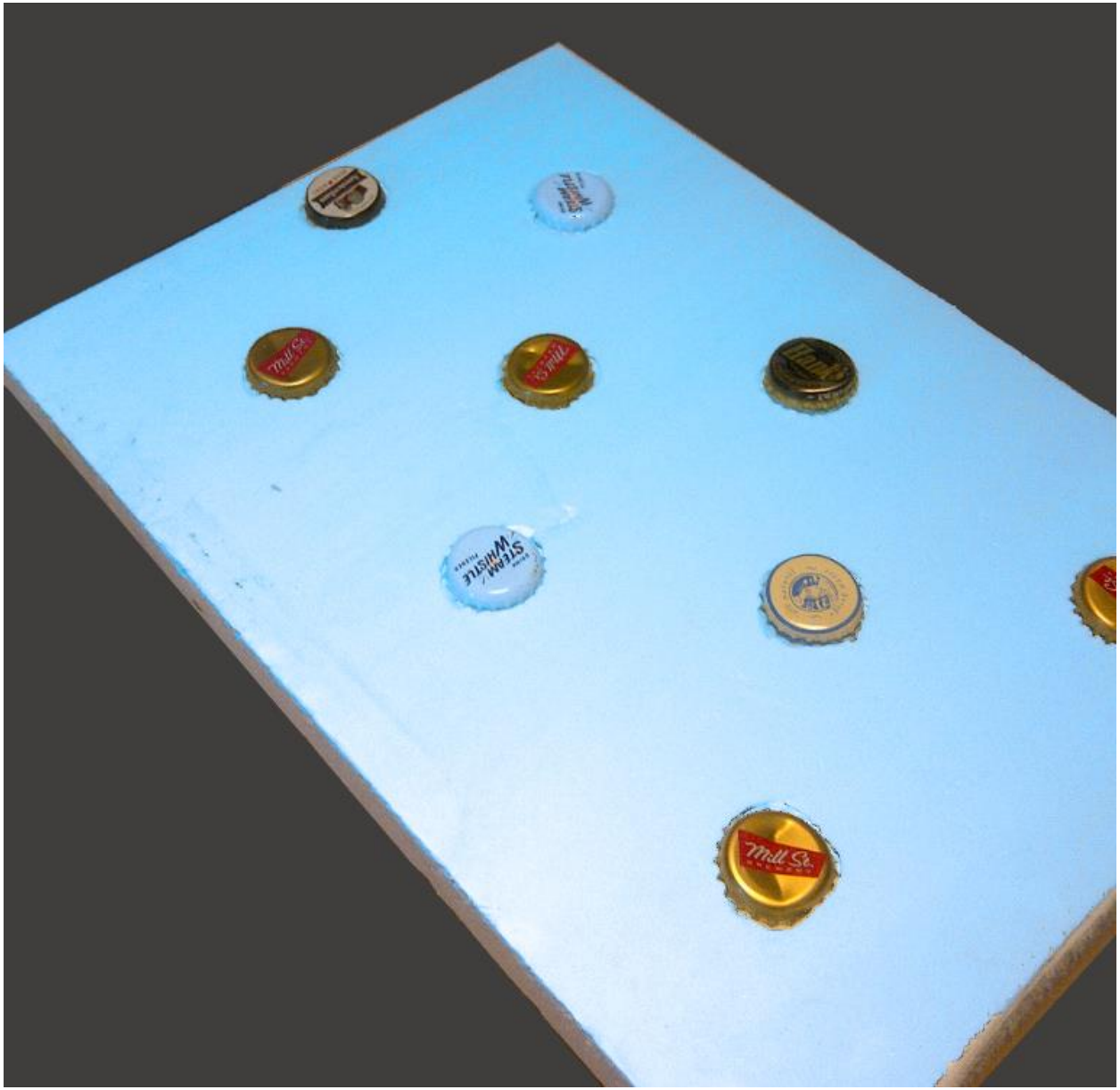

LOWER
N-2

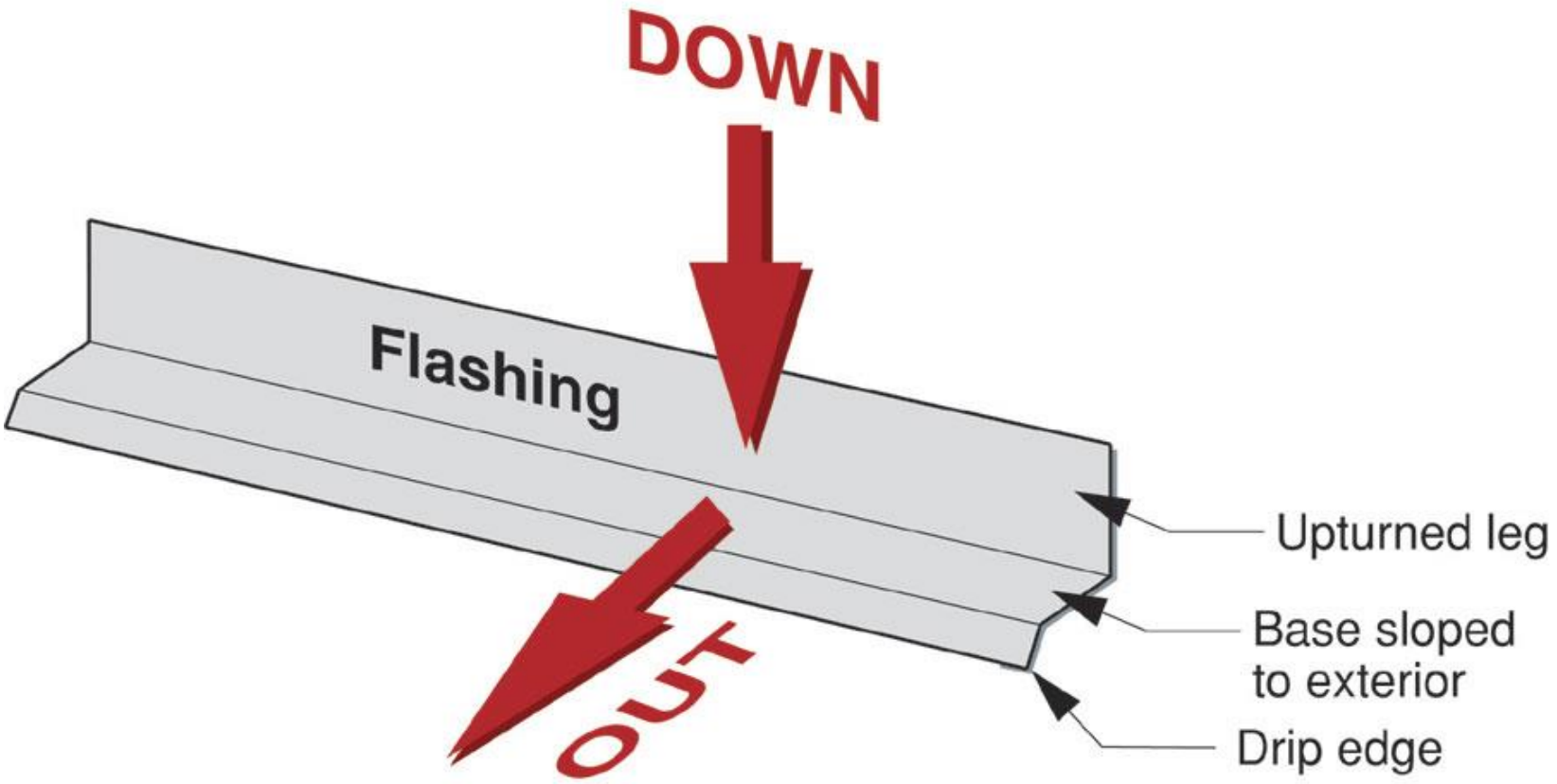

yvek
omeWrap
Tyve
HomeWra

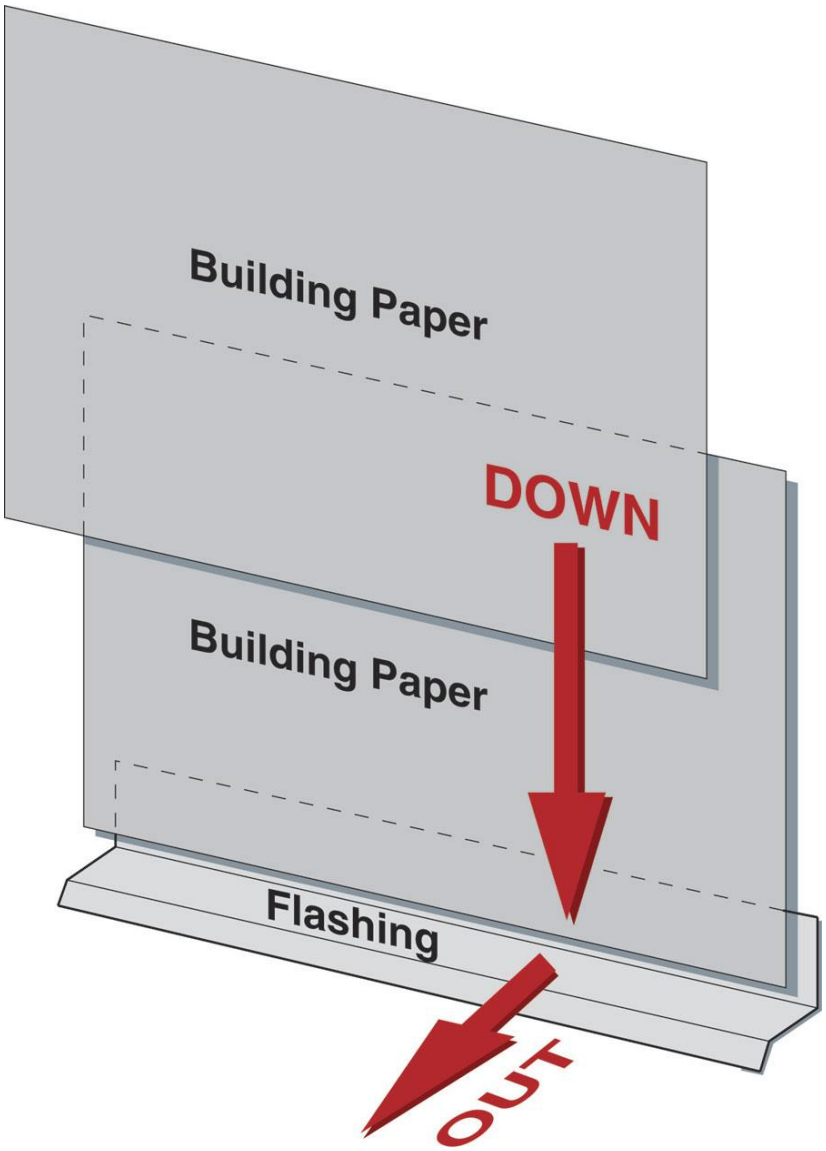
Rain Screen

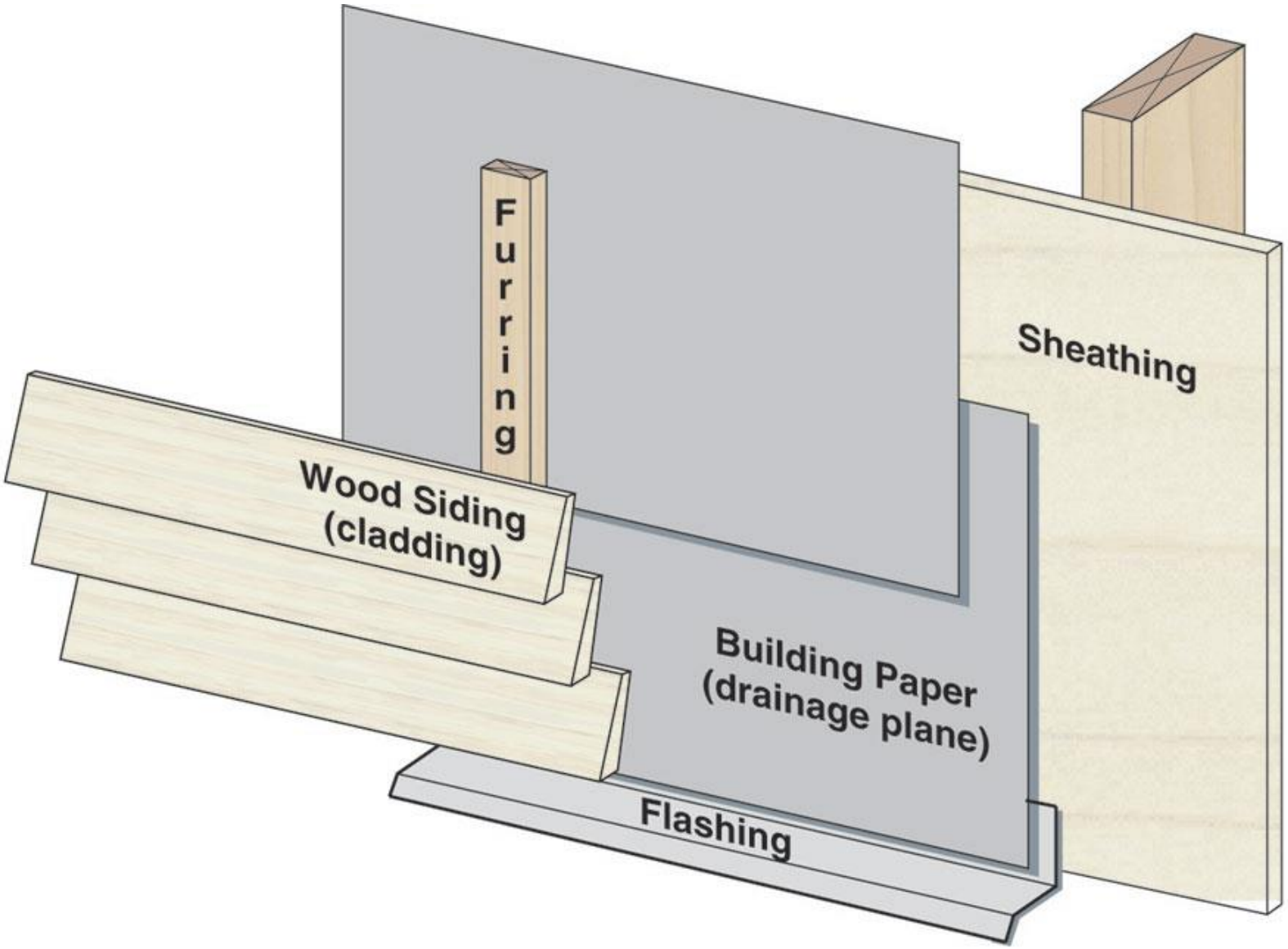


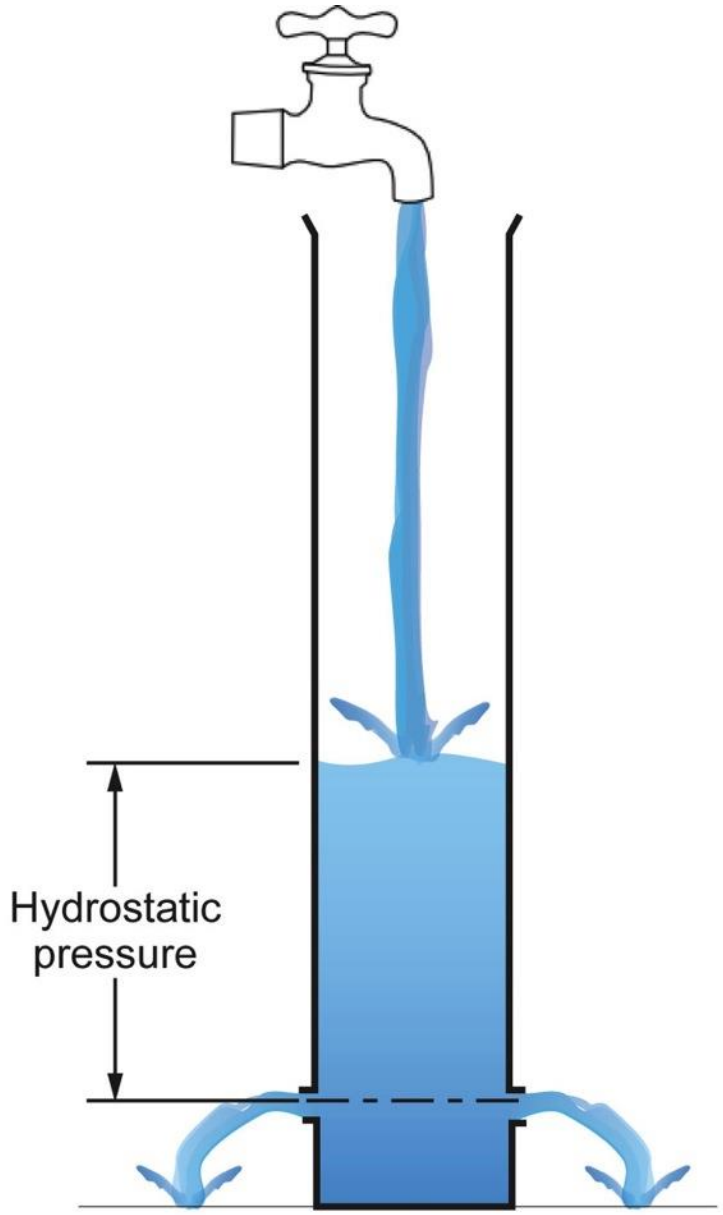
Beer Screen?

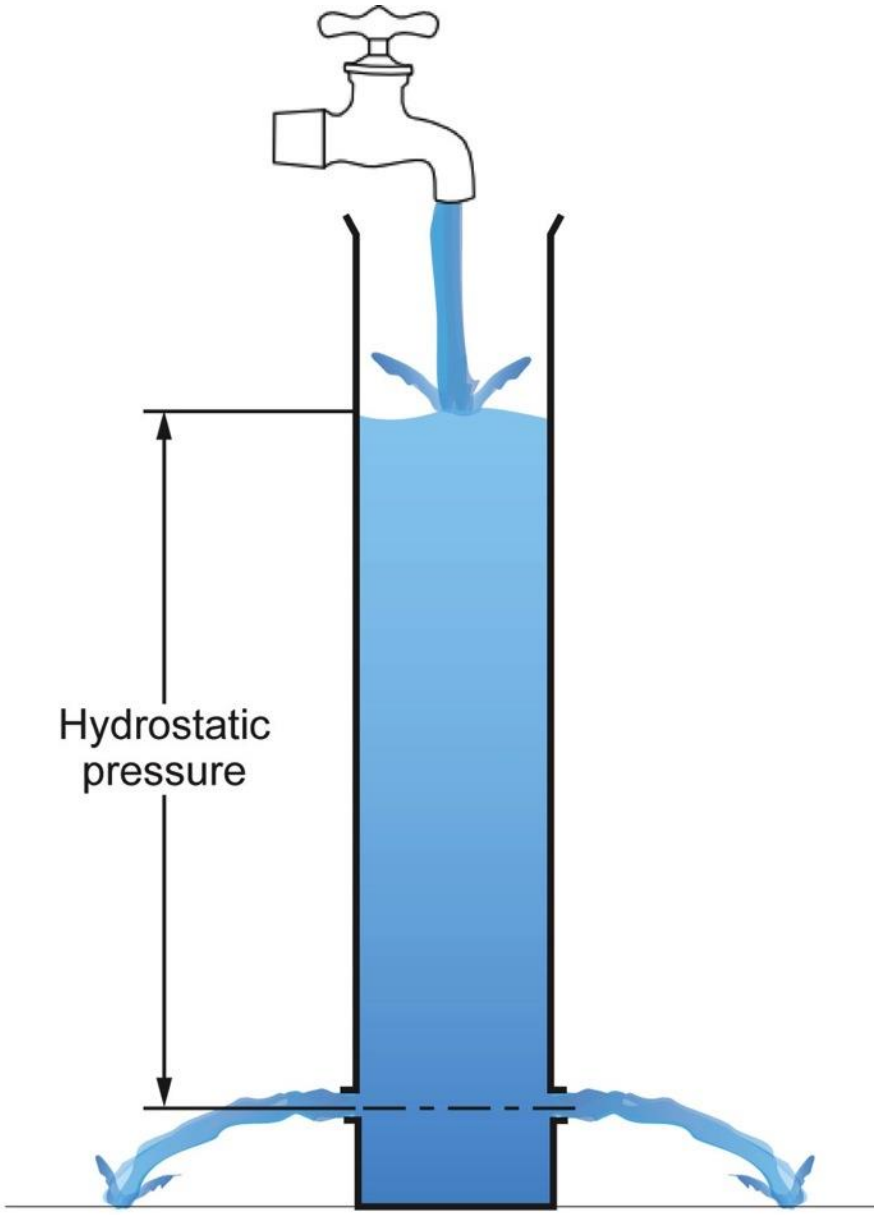

Mill St.
Steam Whistle

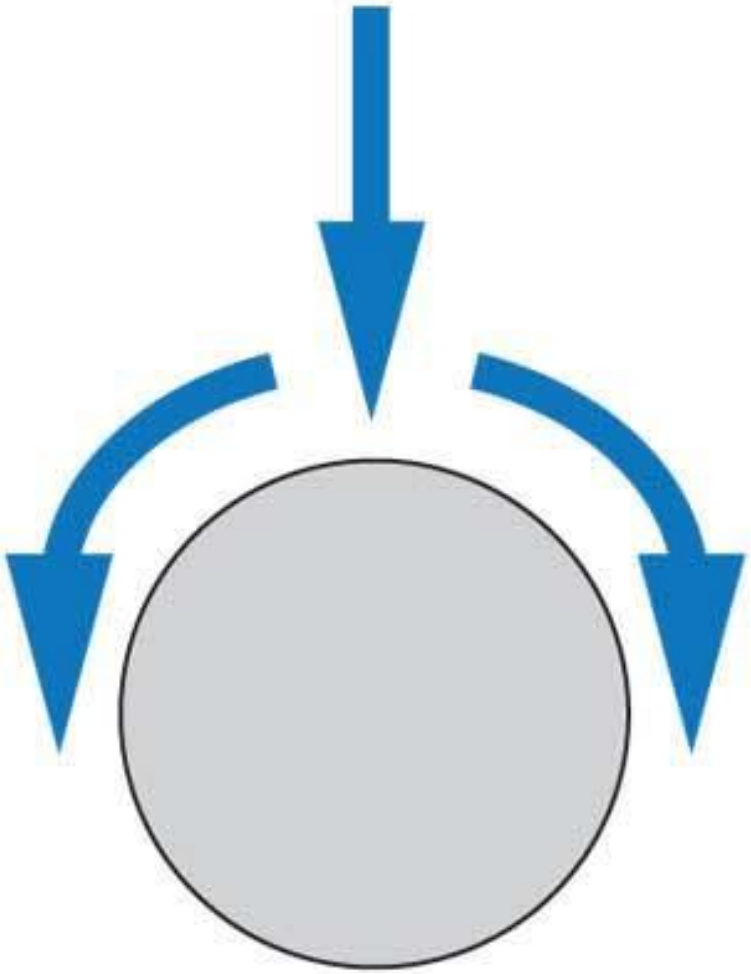

DOWN
Flashing
OUT
Upturned leg
Base sloped
to exterior
Drip edge

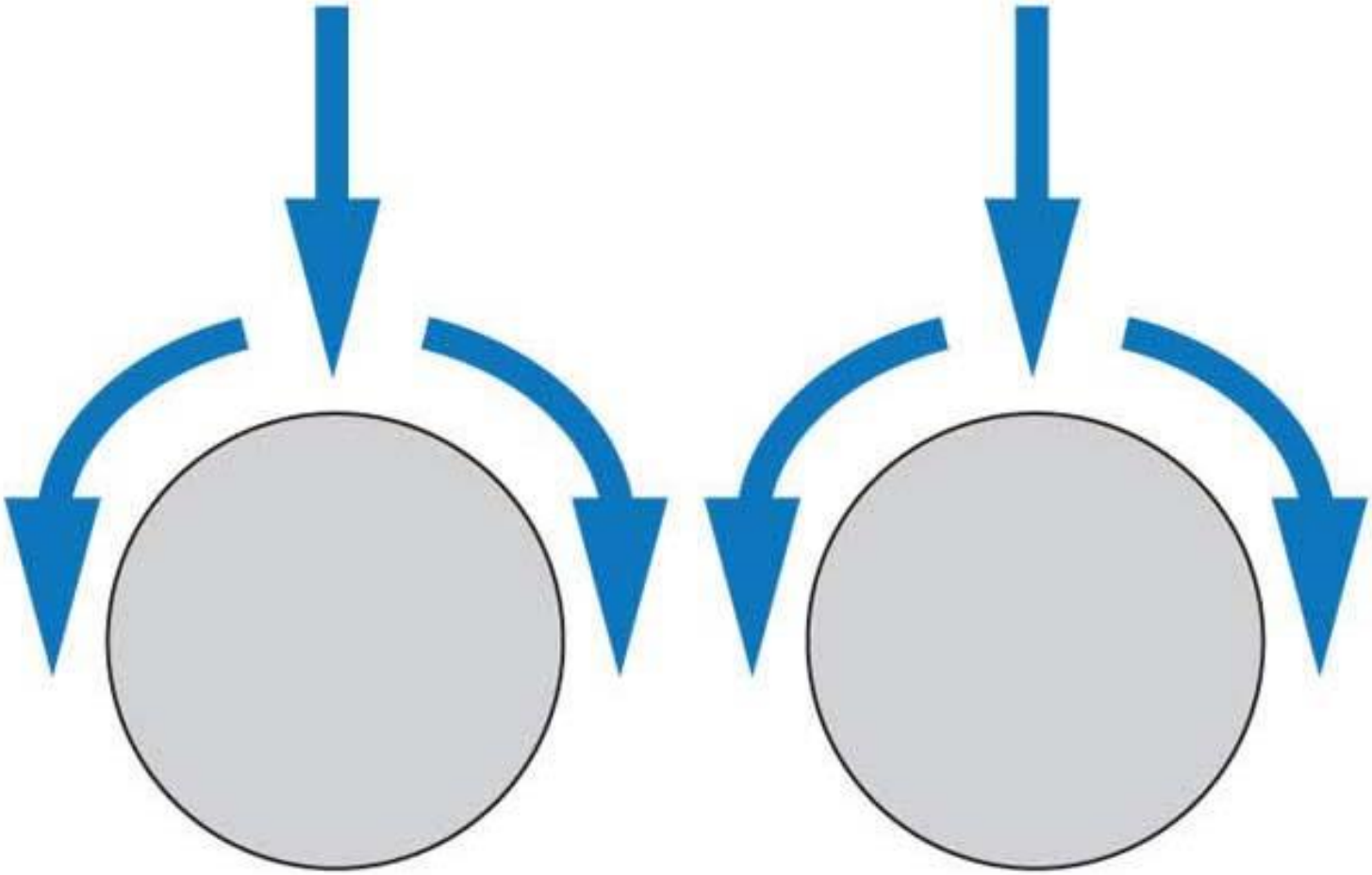

Building Paper
DOWN
Building Paper
Flashing
OUT

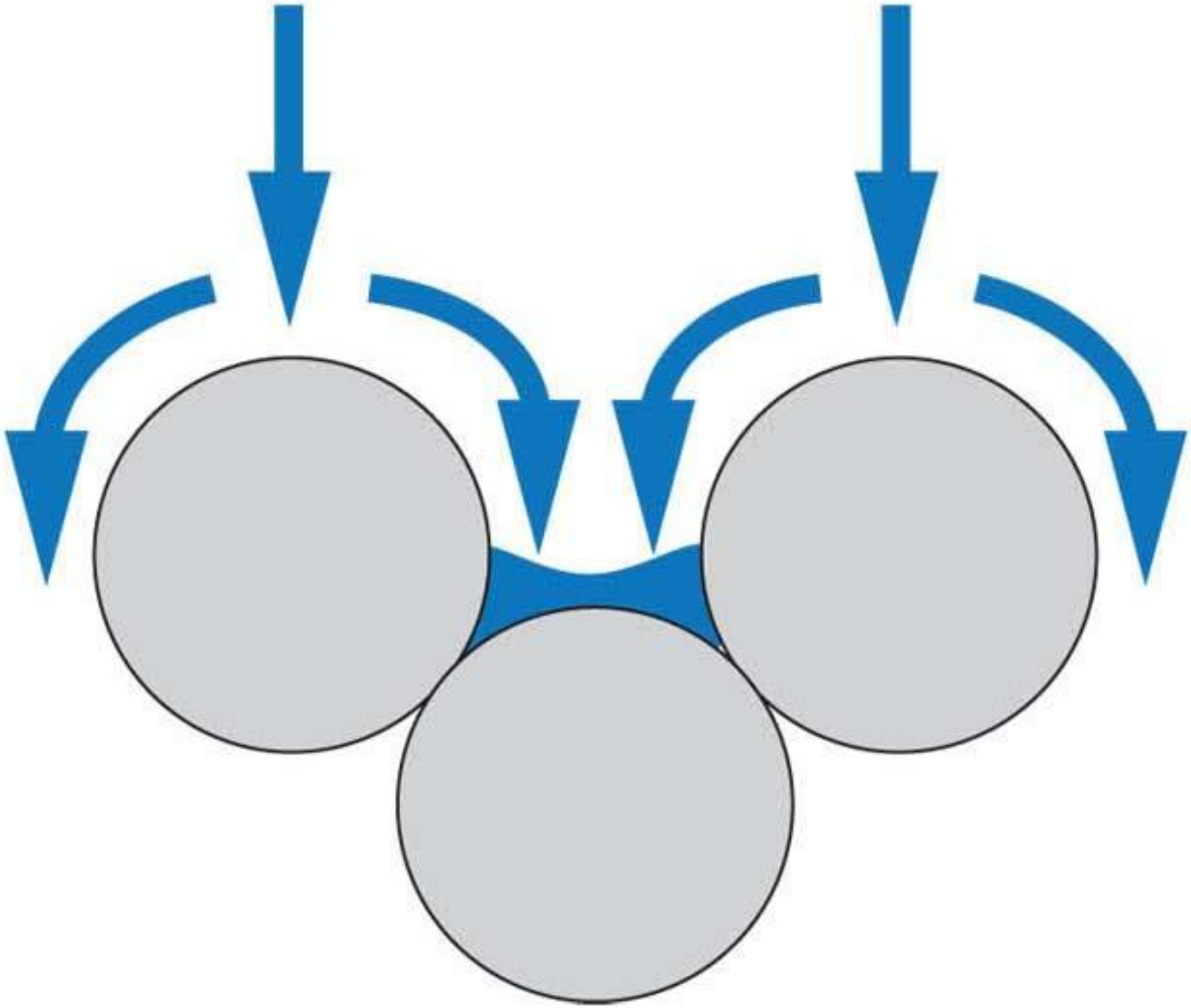

Furring
Sheathing
Wood Siding
(cladding)
Building Paper
(drainage plane)
Flashing

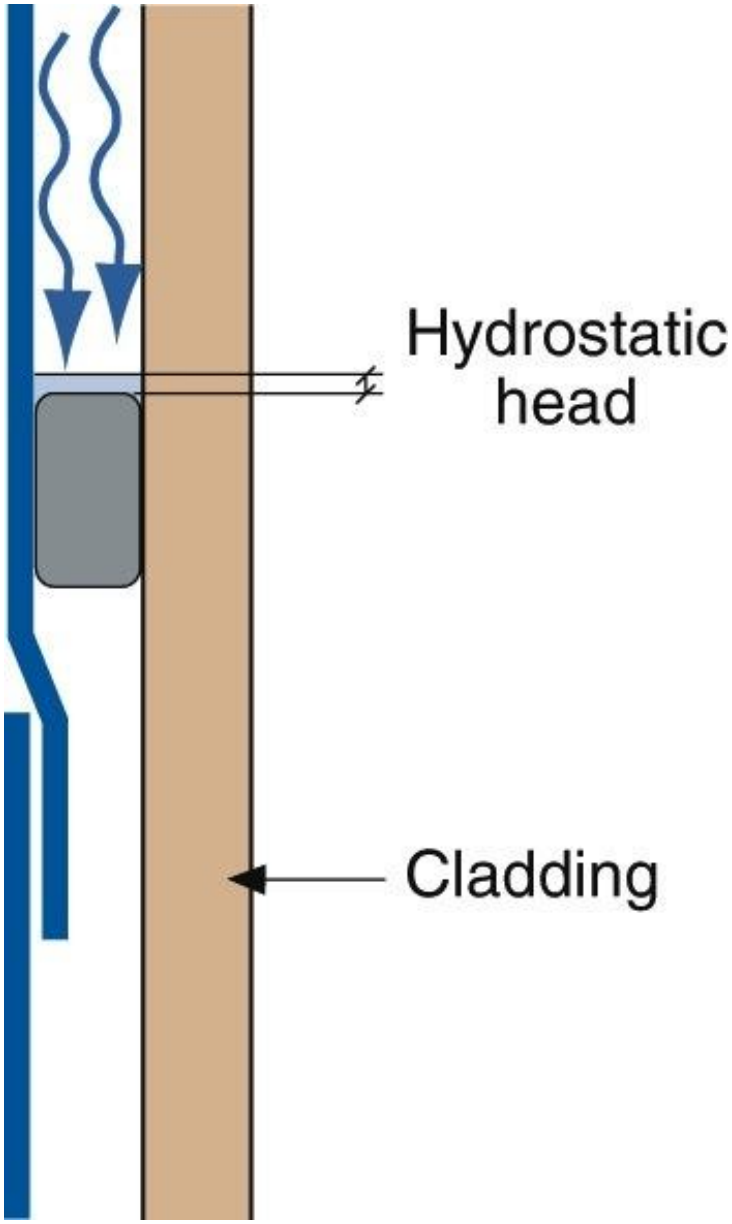

Hydrostatic
pressure

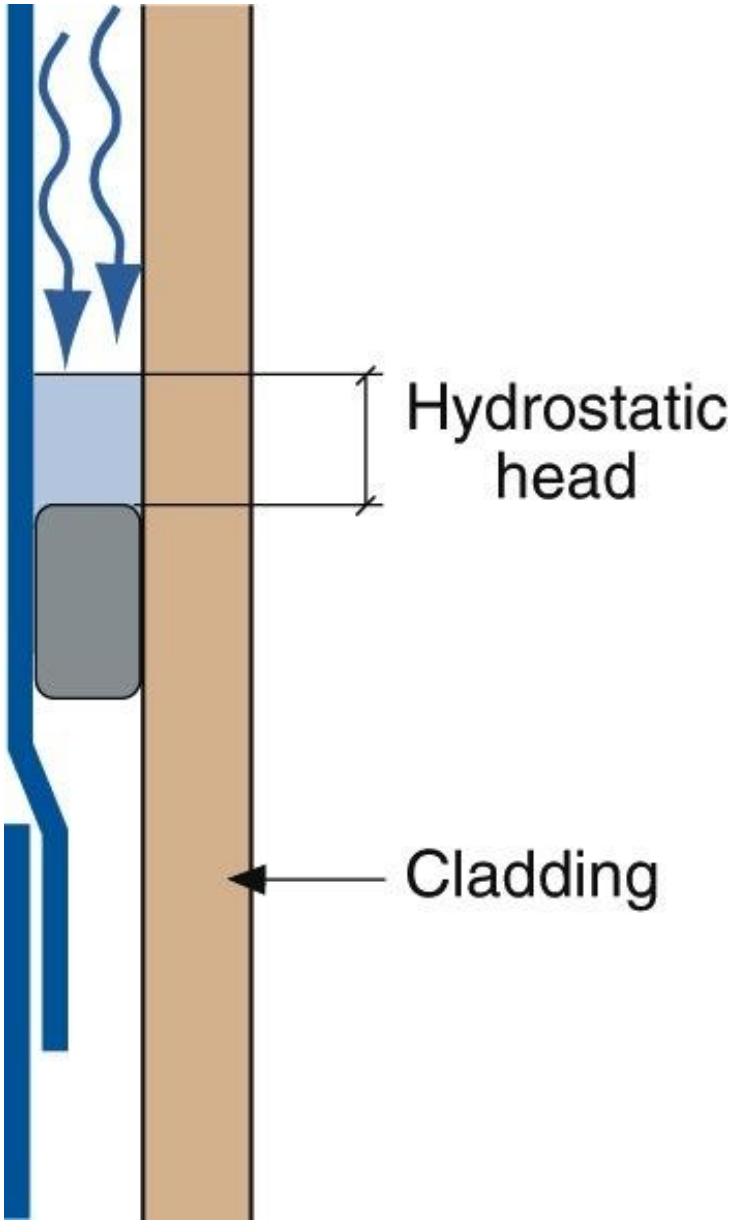

Hydrostatic
pressure

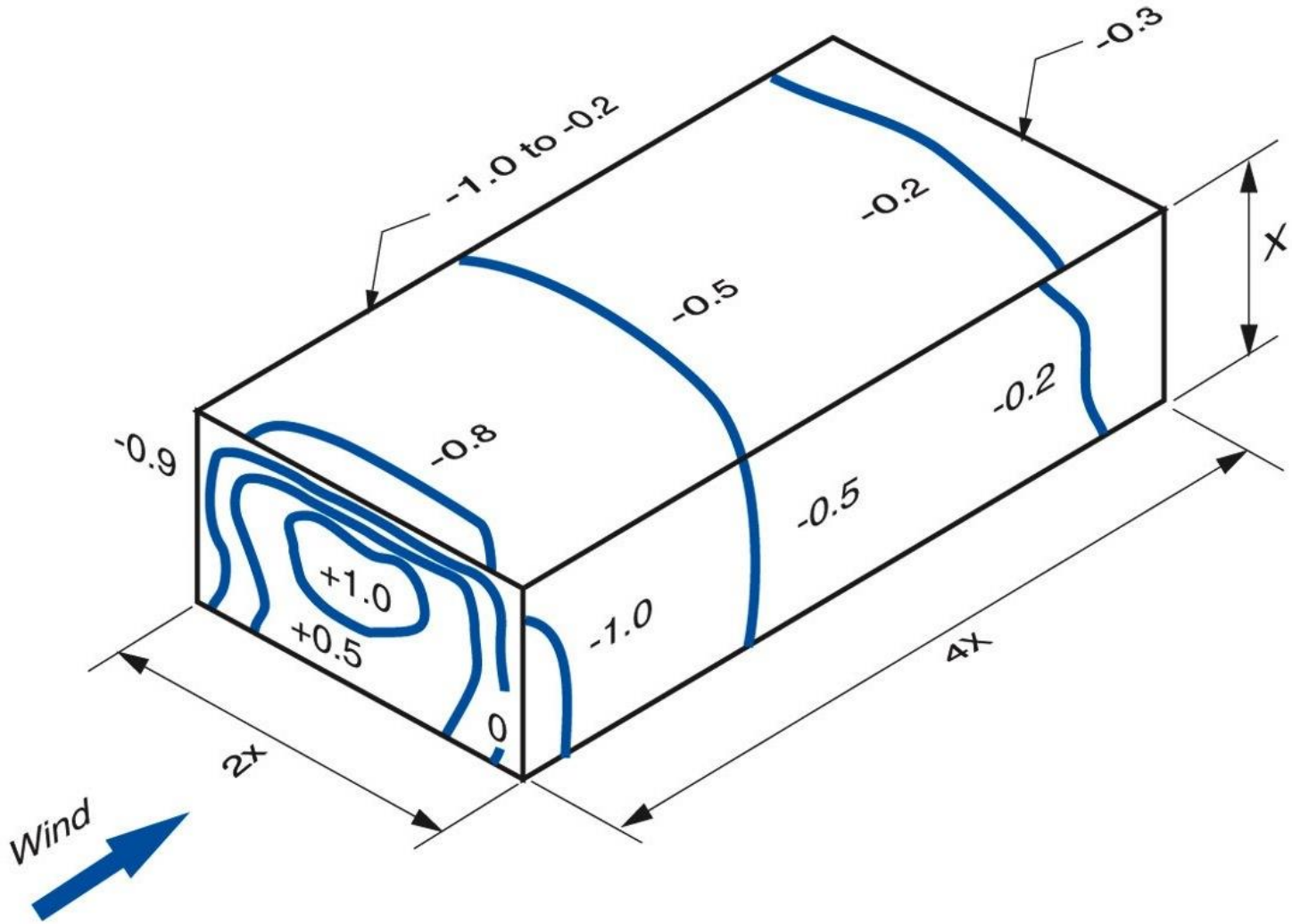




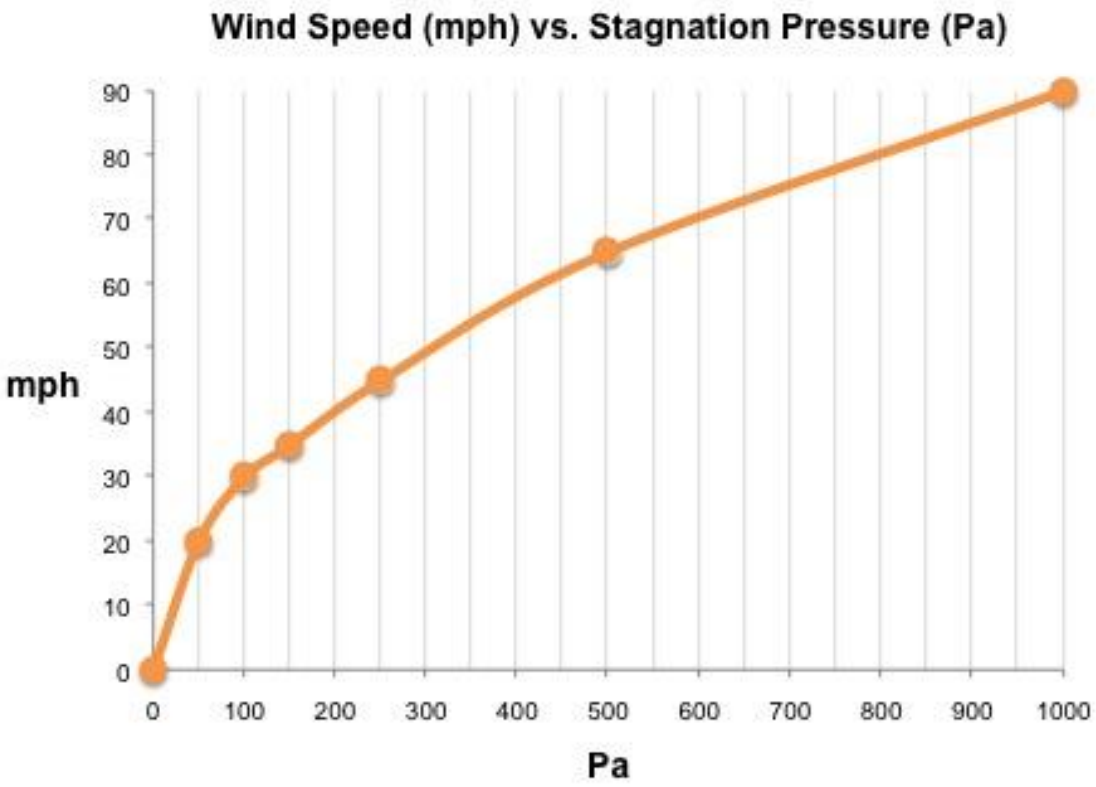



Hydrostatic
head
Cladding


Hydrostatic
head
Cladding


-0.3
-1.0 to -0.2
-0.2
-0.5
-0.2
-0.9
-0.8
-0.5
+1.0
+0.5
-1.0
0
X
2X
4X
Wind

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




DUPONT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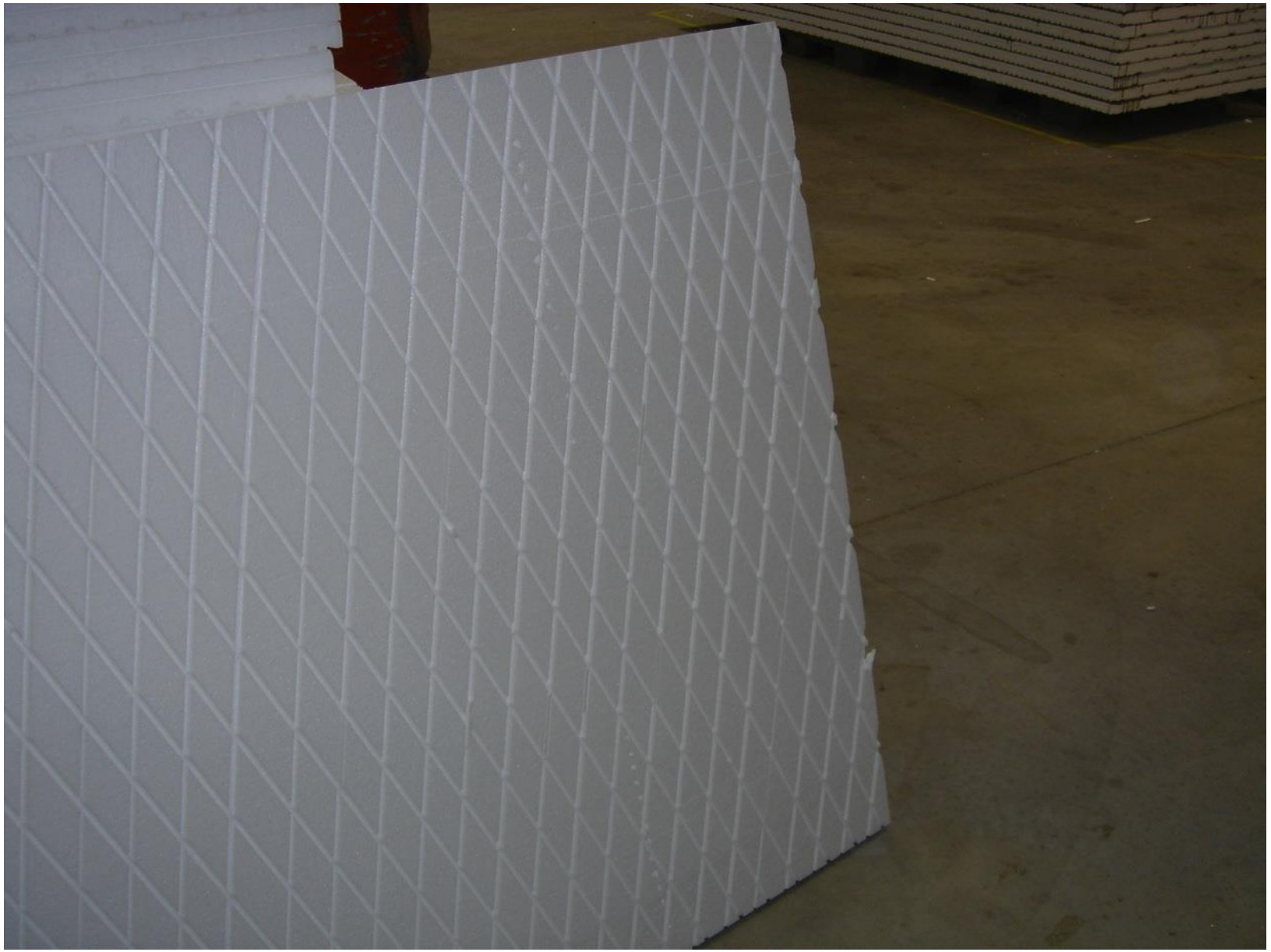
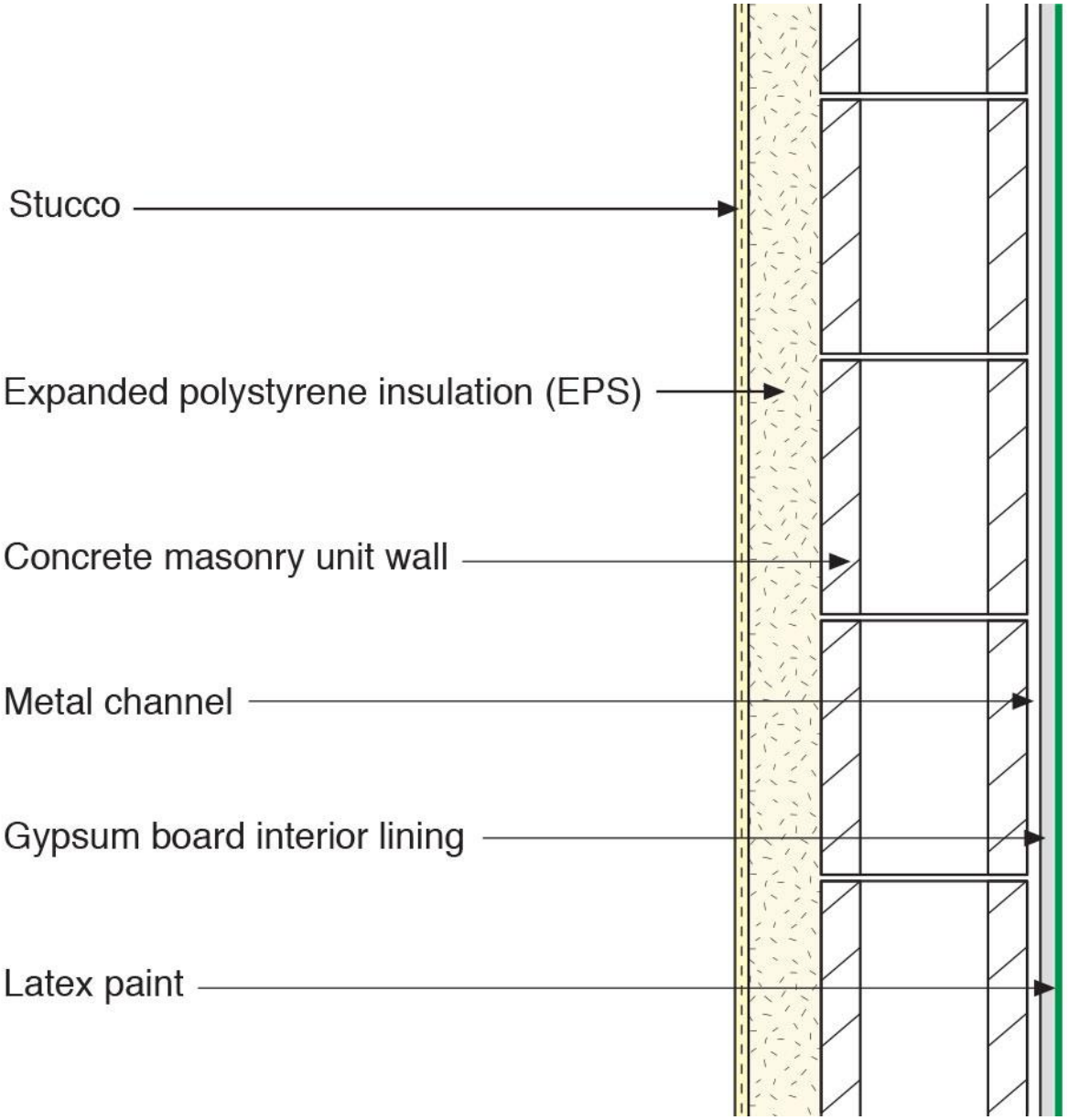
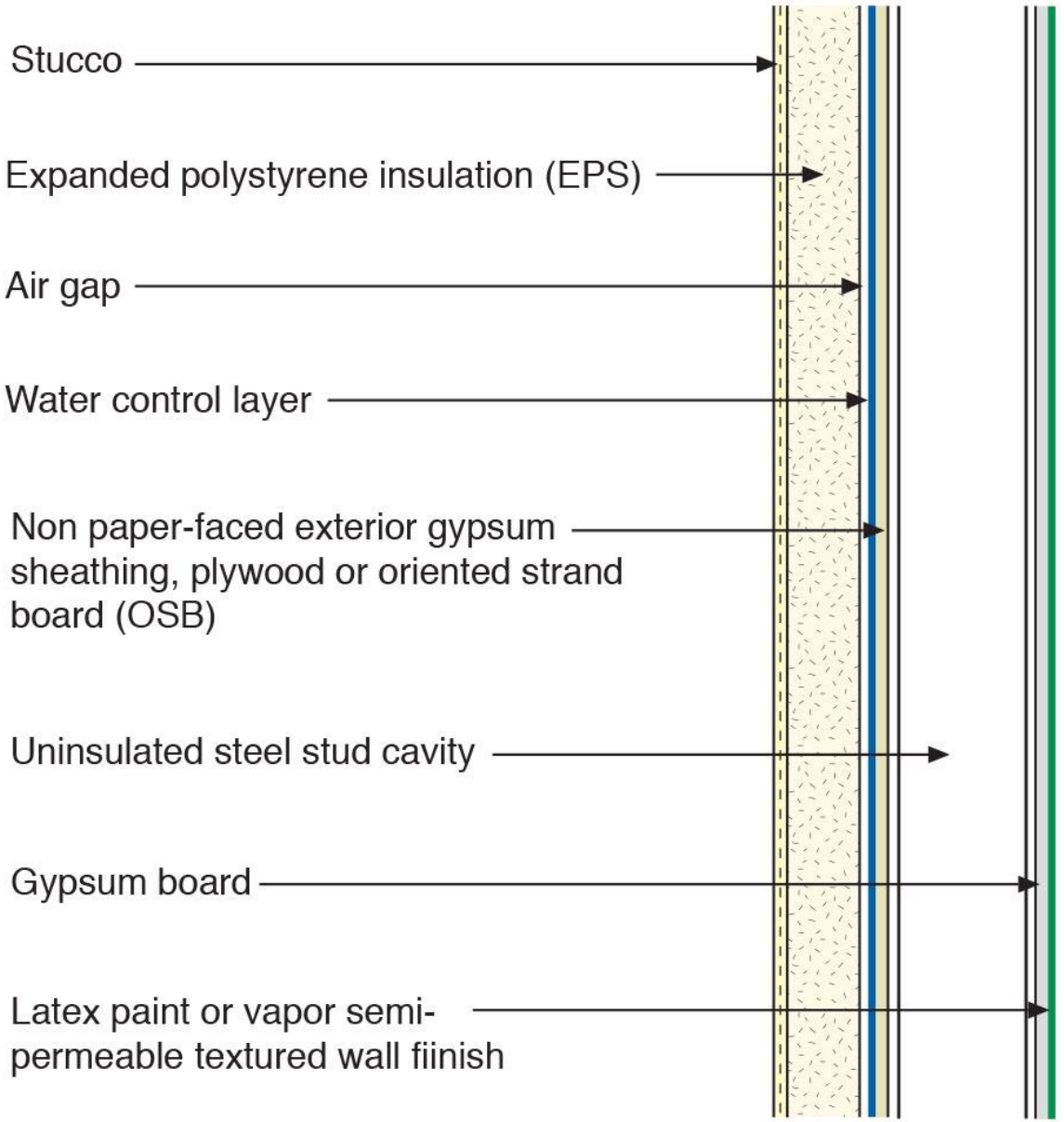
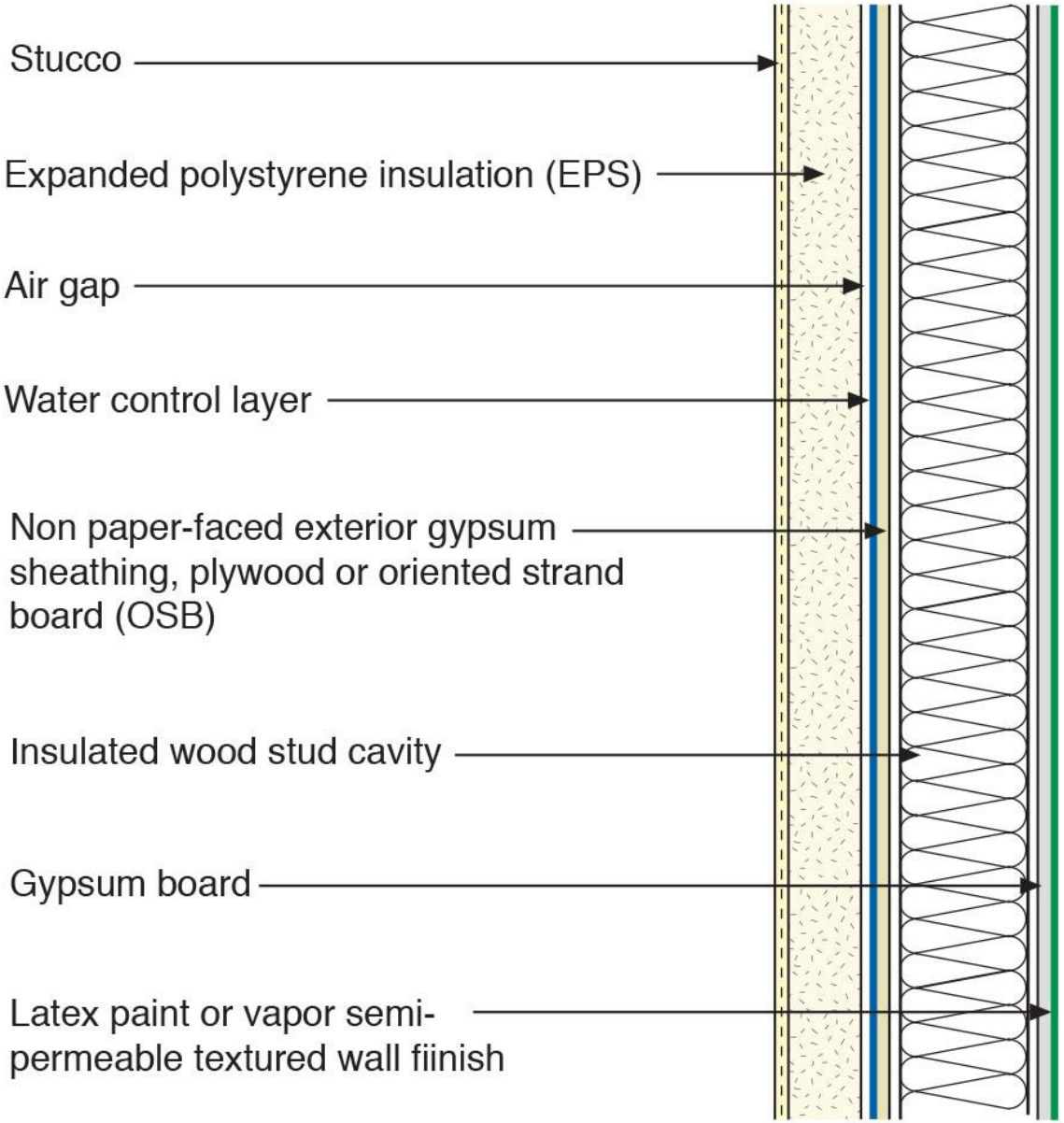


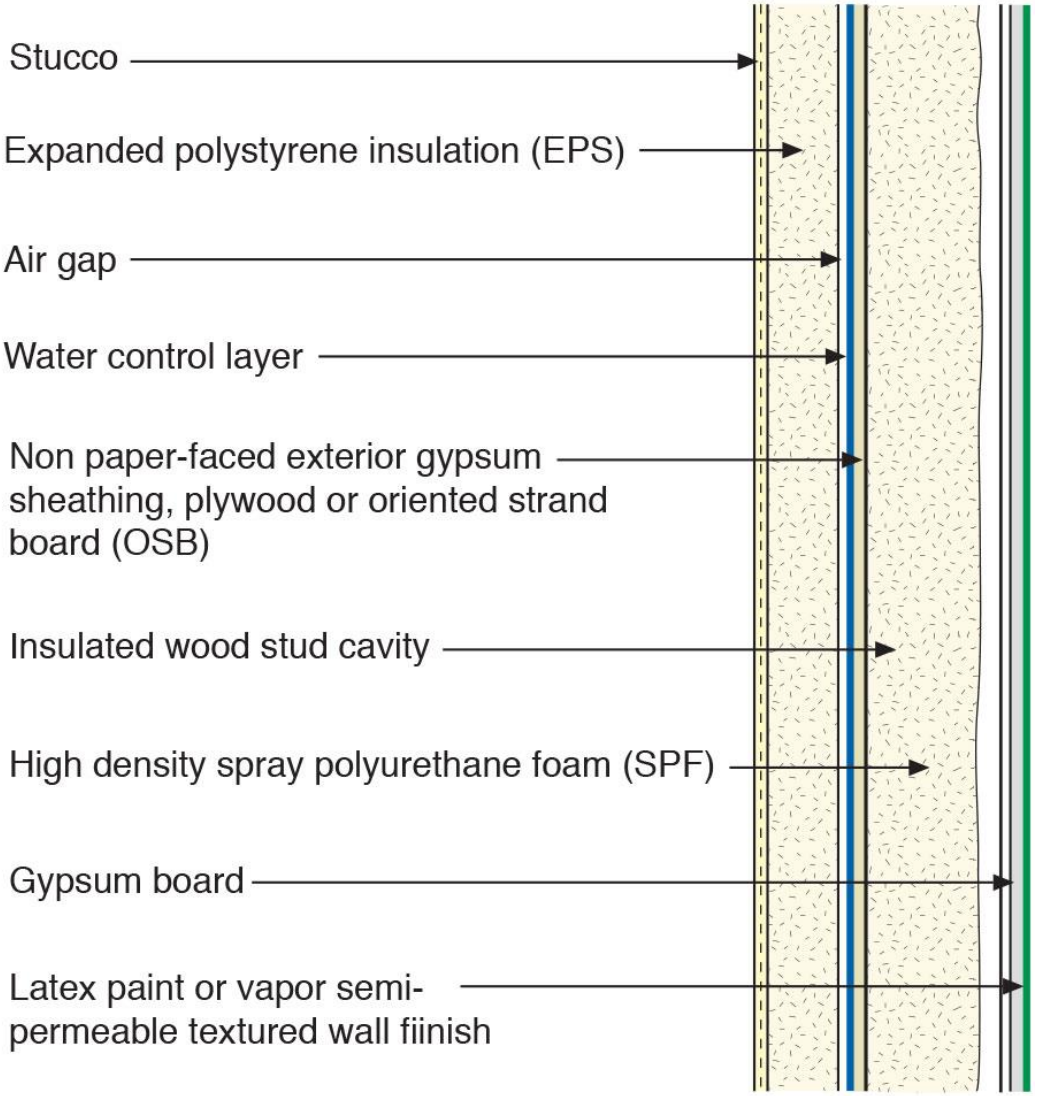
Side Trip To Woodbury, MN….

EIFS No Longer Has Issues


Stucco
Expanded polystyrene insulation (EPS)
Concrete masonry unit wall
Metal channel
Gypsum board interior lining
Latex paint


Stucco
Expanded polystyrene insulation (EPS)
Air gap
Water control layer
Non paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)
Uninsulated steel stud cavity
Gypsum board
Latex paint or vapor semi-permeable textured wall fiinish


Stucco
Expanded polystyrene insulation (EPS)
Air gap
Water control layer
Non paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)
Insulated wood stud cavity
Gypsum board
Latex paint or vapor semi-permeable textured wall fiinish

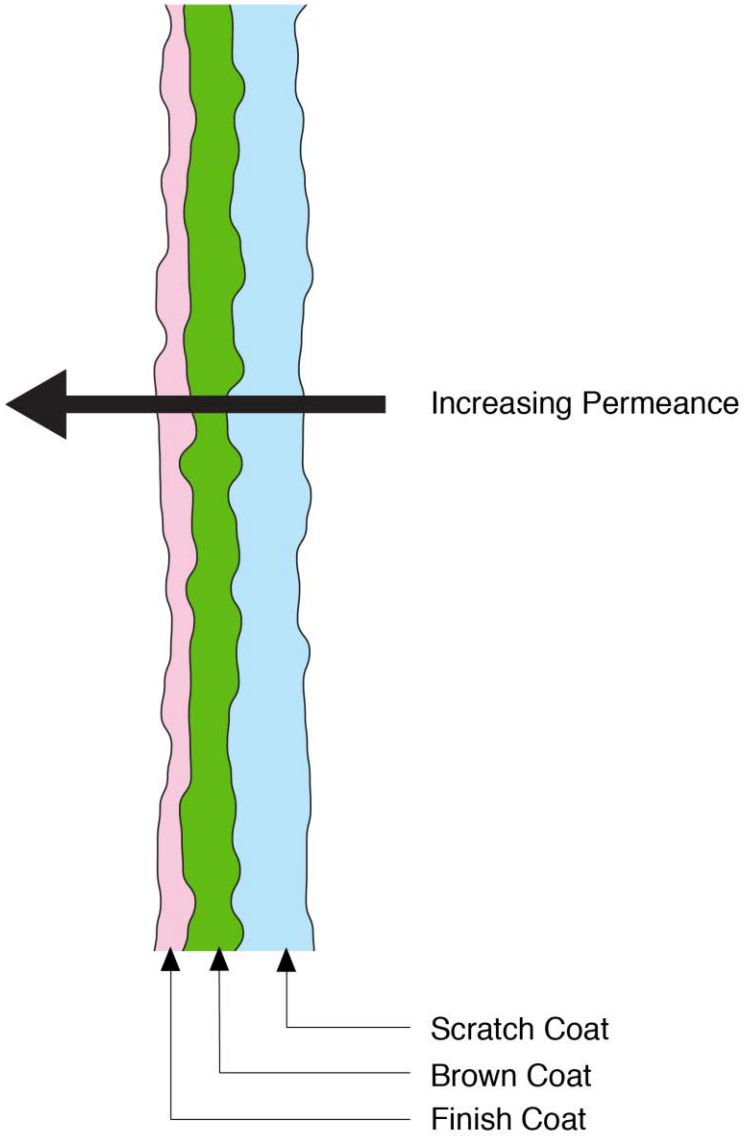

Stucco
Expanded polystyrene insulation (EPS)
Air gap
Water control layer
Non paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)
Insulated wood stud cavity
High density spray polyurethane foam (SPF)
Gypsum board
Latex paint or vapor semi-permeable textured wall fiinish

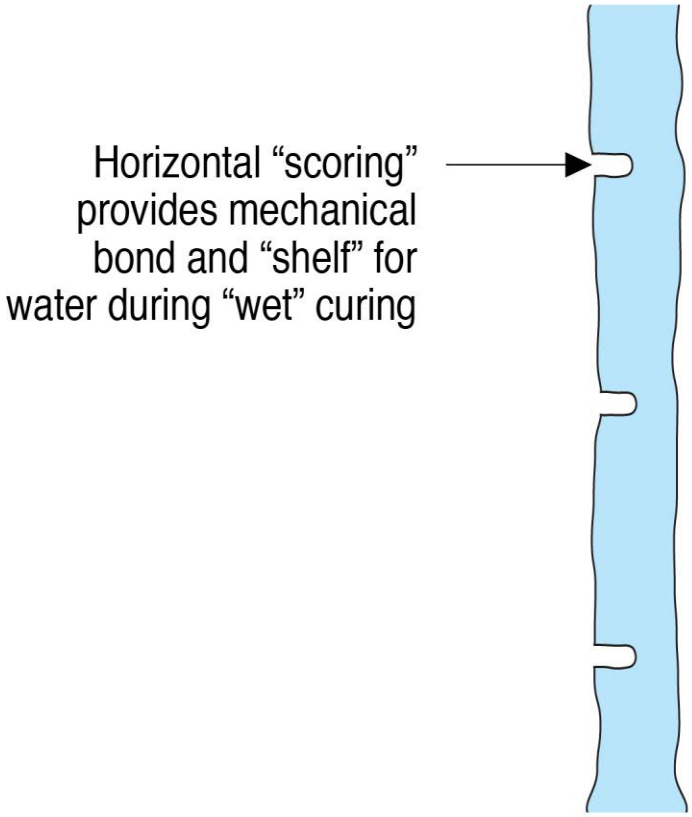
Back To Stucco….

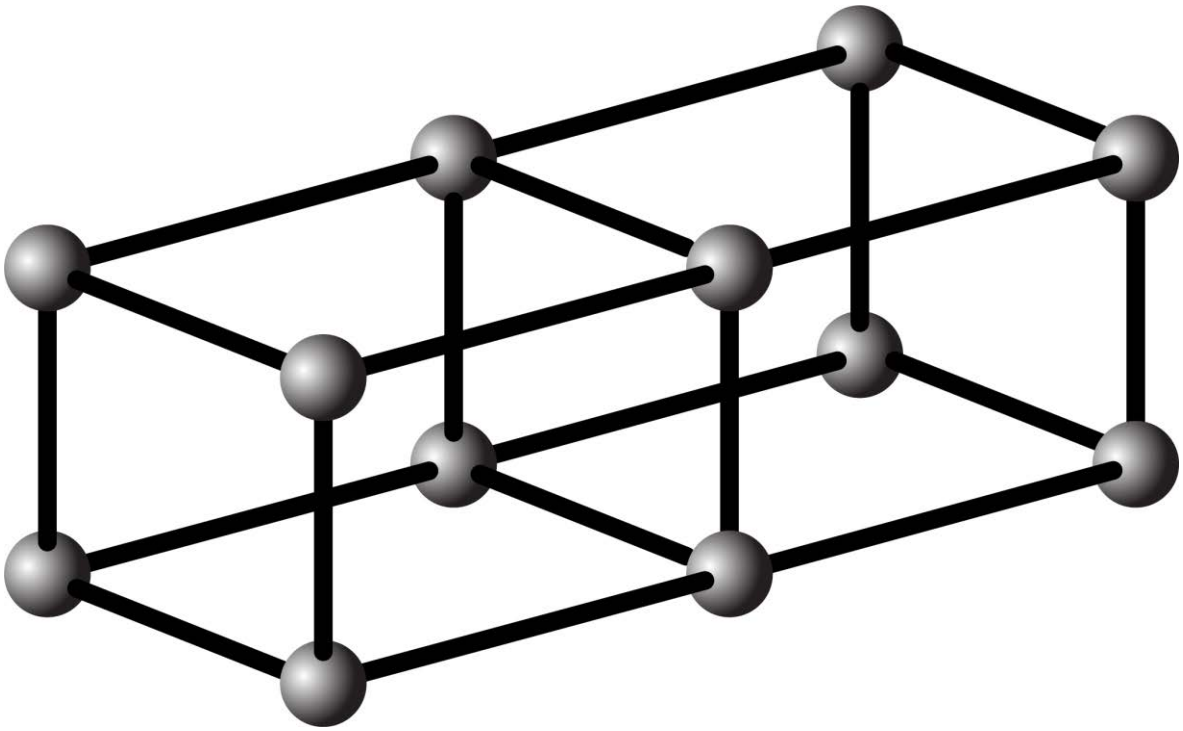
Lime vs Portland Cement

Polymer Modification

Traditional Lime Stucco	Greater than 20 perms
Lime/Portland Cement Stucco	5 to 10 perms
Portland Cement Stucco	1 to 5 perms
Polymer Modification	Less than 1


Increasing Permeance
Scratch Coat
Brown Coat
Finish Coat


Horizontal “scoring” provides mechanical bond and “shelf” for water during “wet” curing



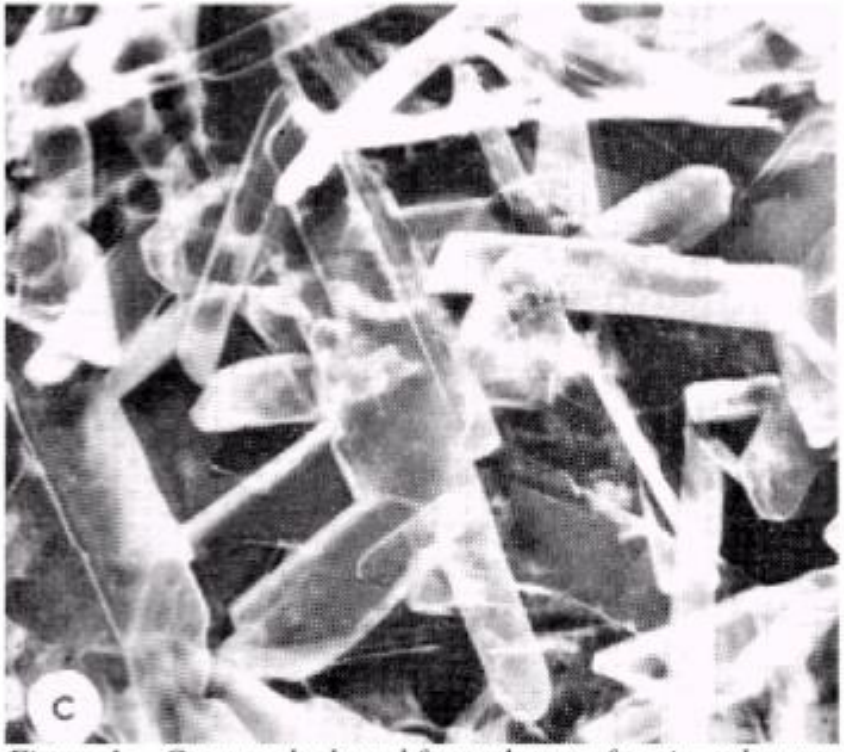


Figure 1c. Gypsum, hydrated from plaster of paris and water, porosity 30 per cent.

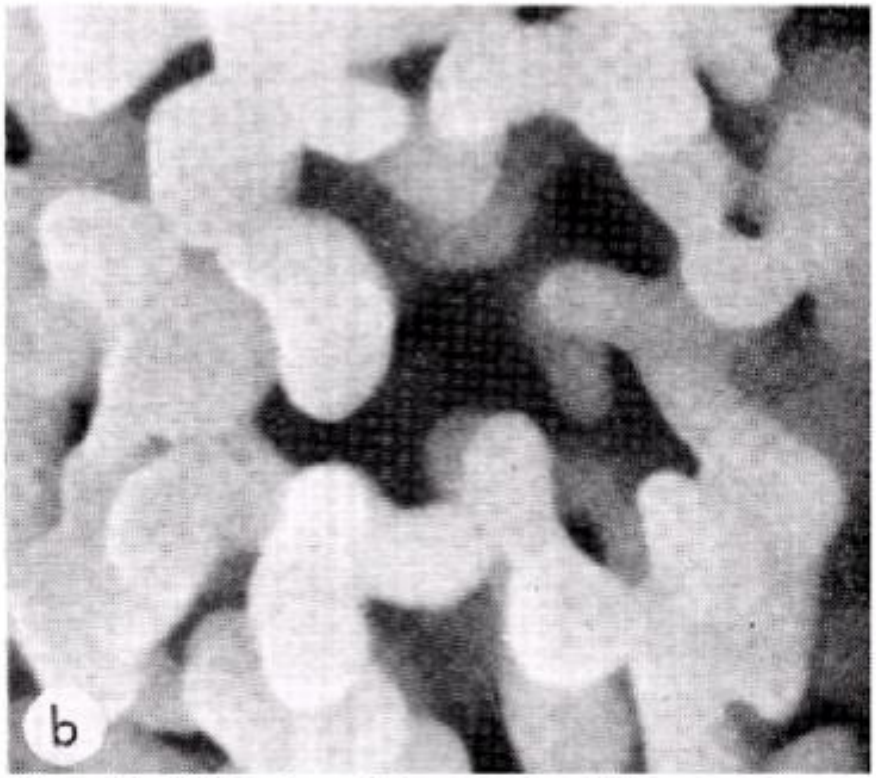
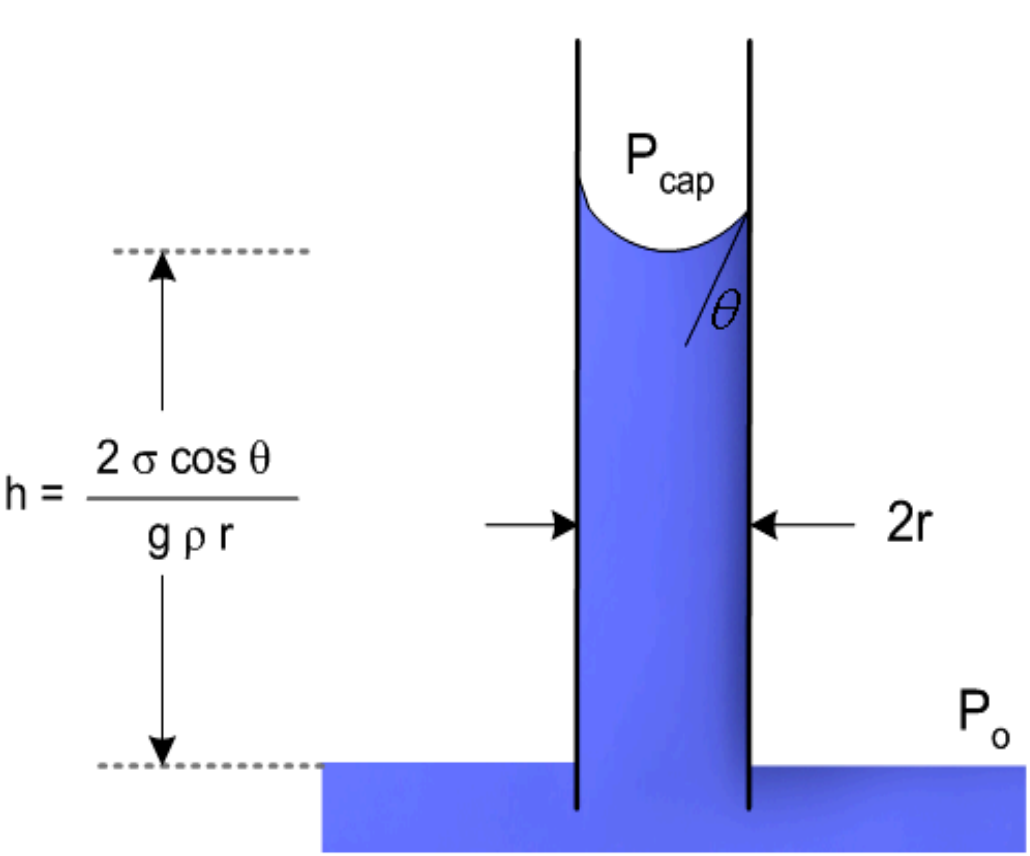
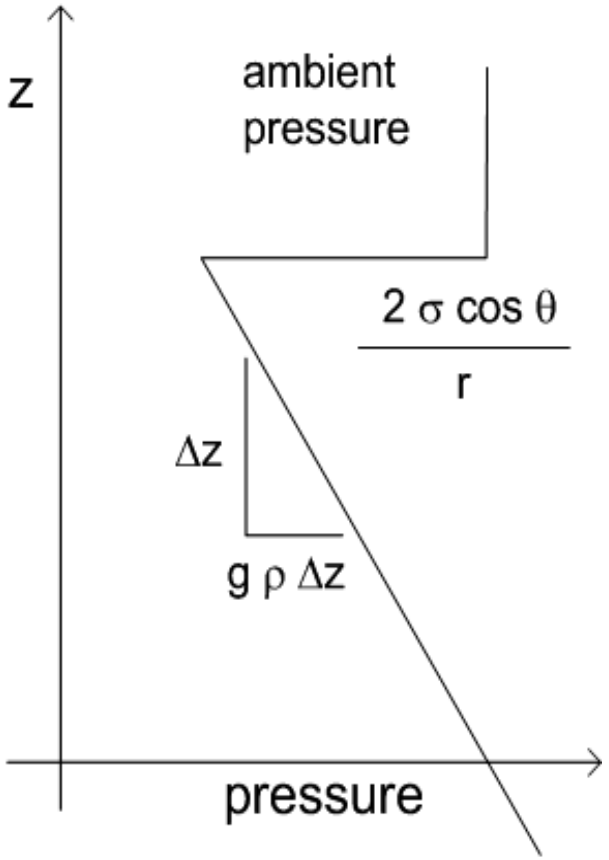


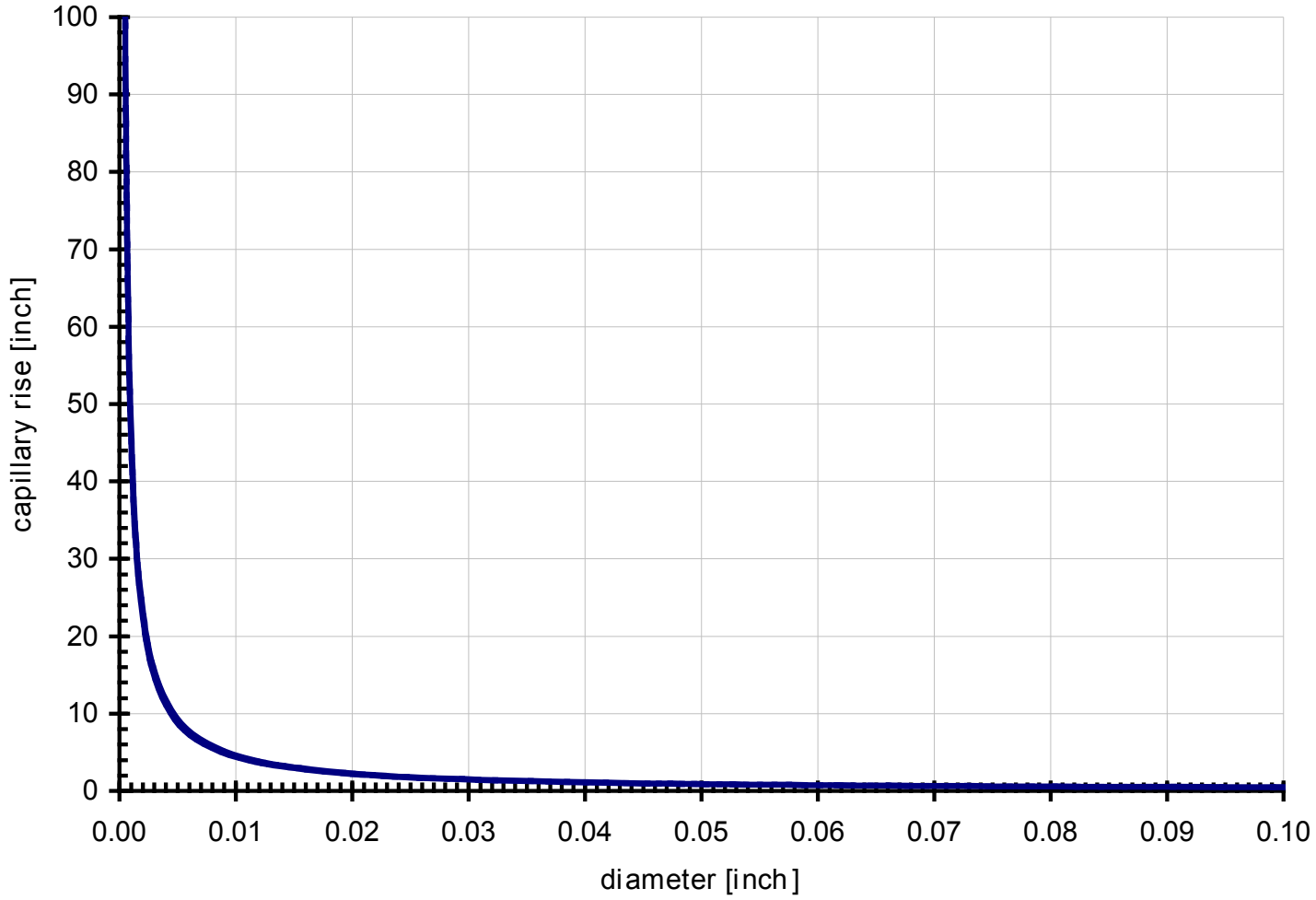
Figure 1b. Brick, sintered clay, porosity 40 per cent.

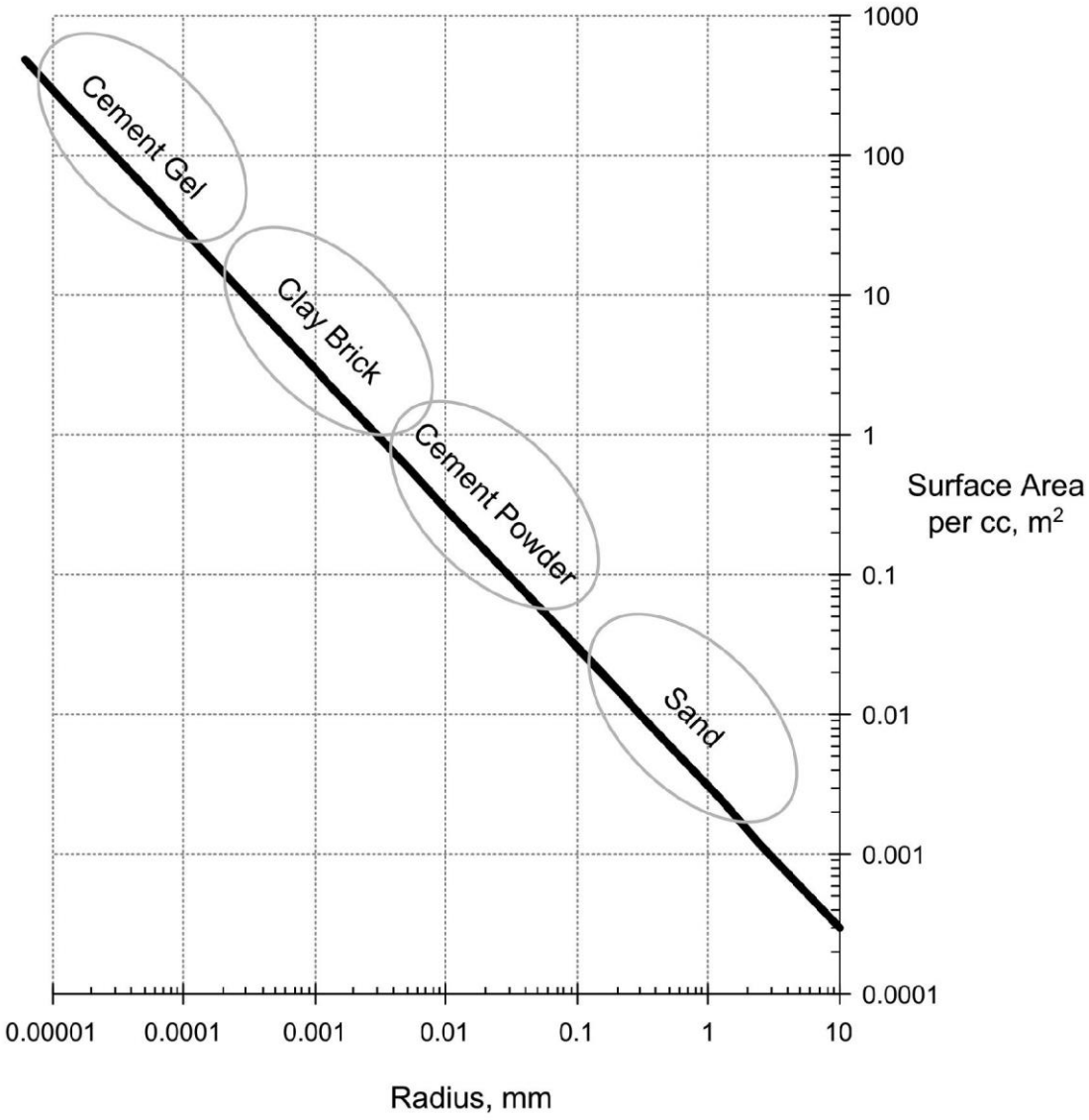
Calculating capillary rise



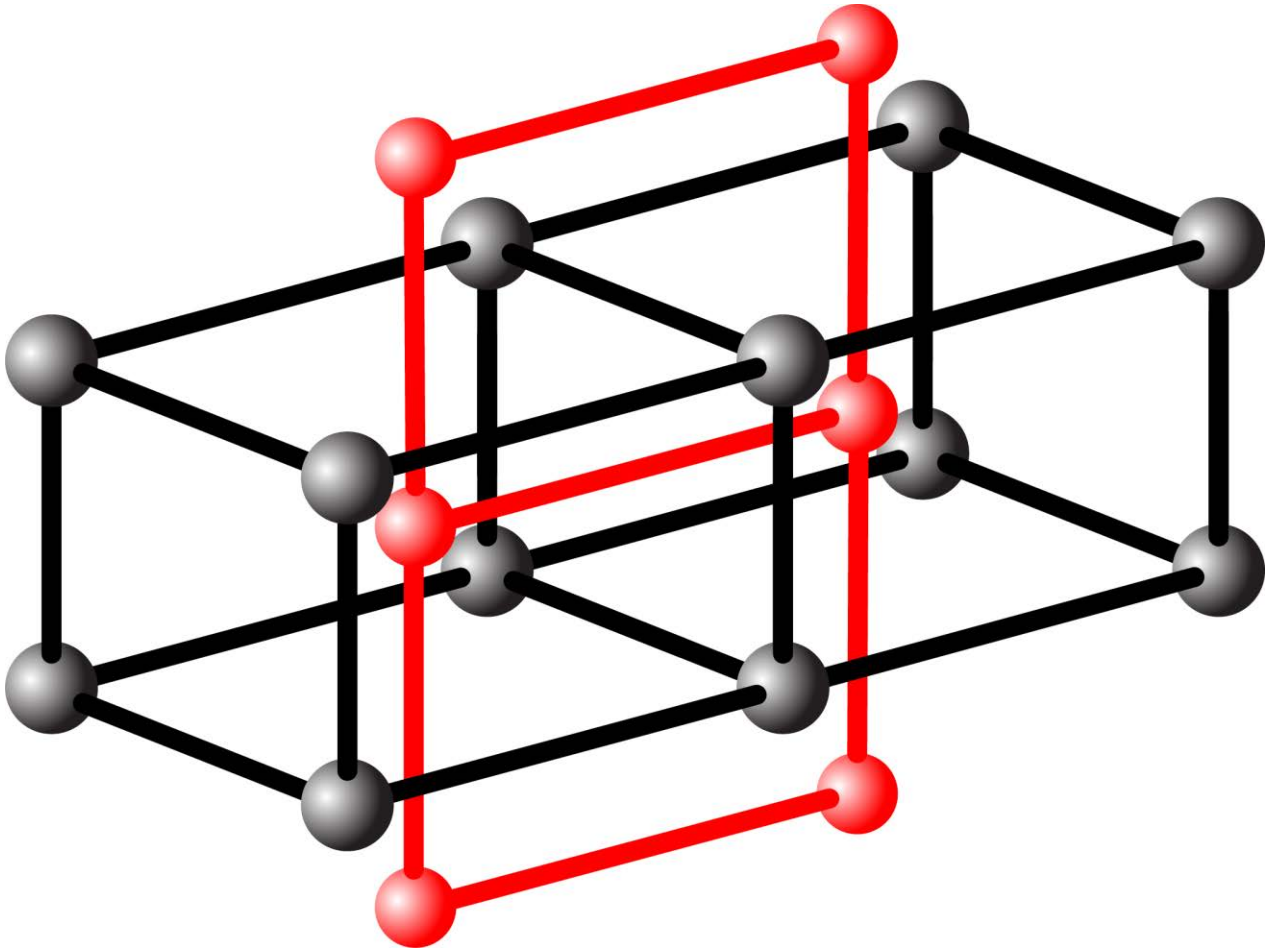


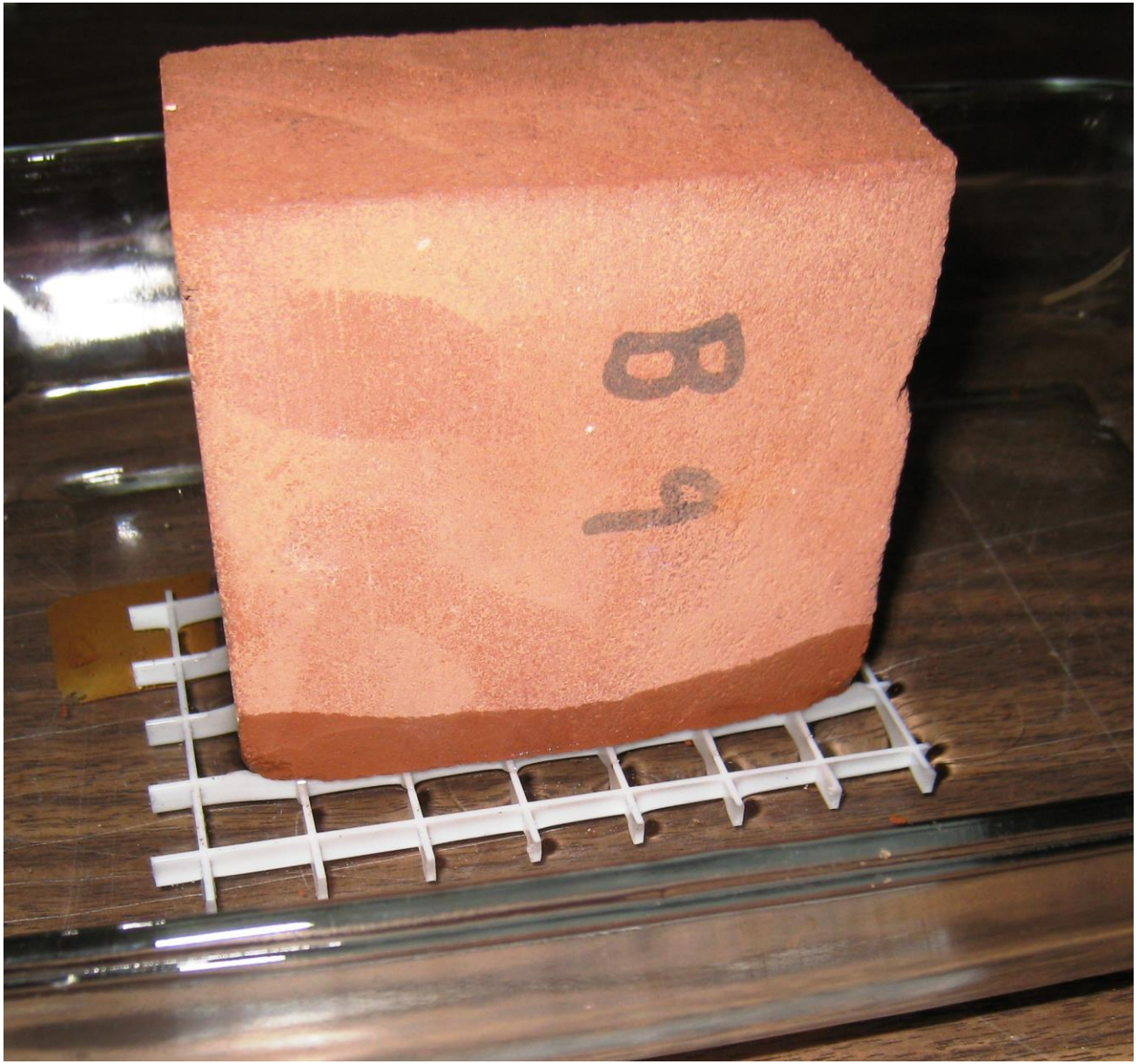
Capillary rise versus diameter





Surface area vs. particle size
From Straube & Burnett, 2005





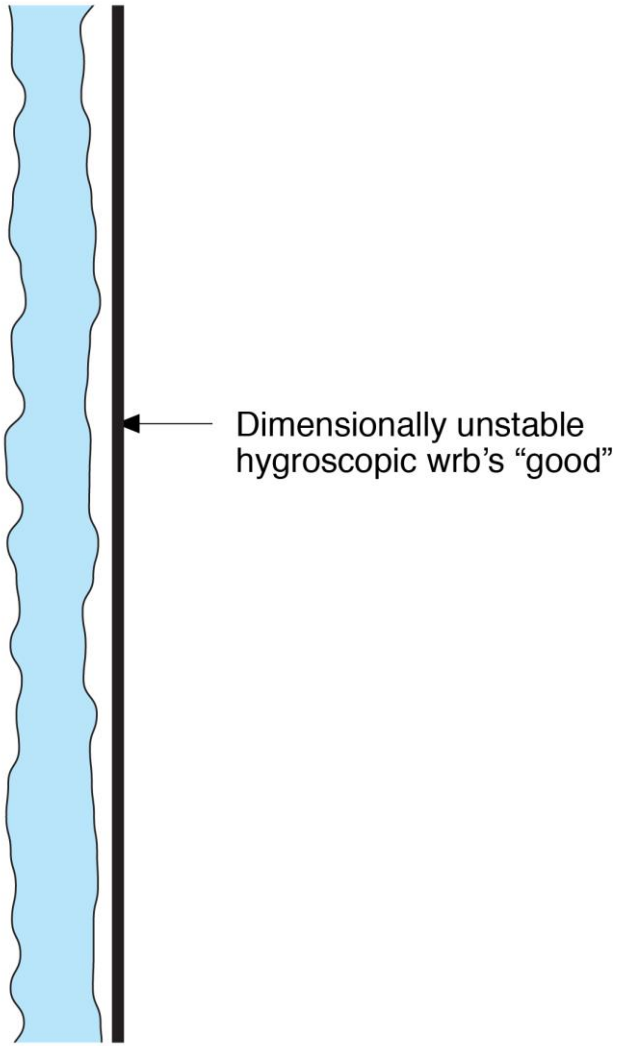
Ancient Modification Additives

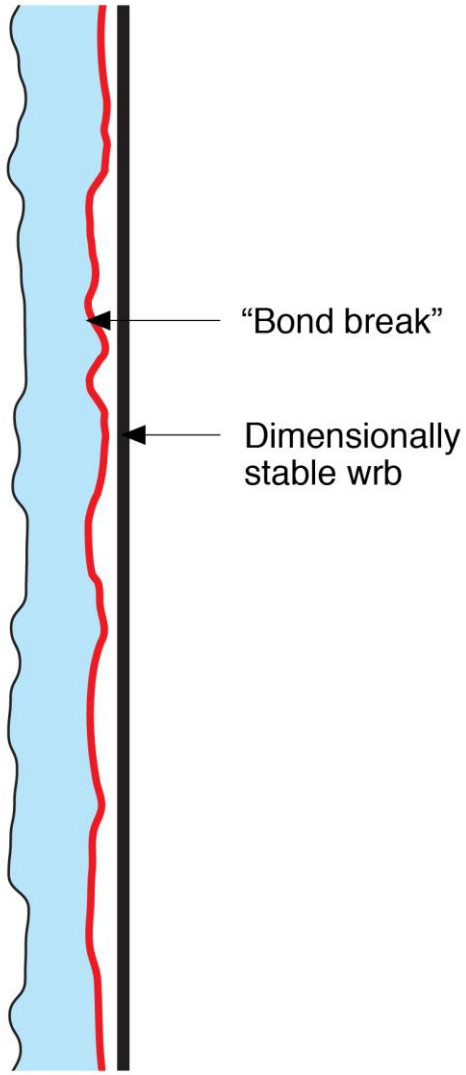
Cow Dung

Egg Whites

Pig Blood

Non Traditional Building Wraps


Dimensionally unstable
hygroscopic wrb's "good"


“Bond break”
Dimensionally
stable wrb


STO


DEC 3 2002

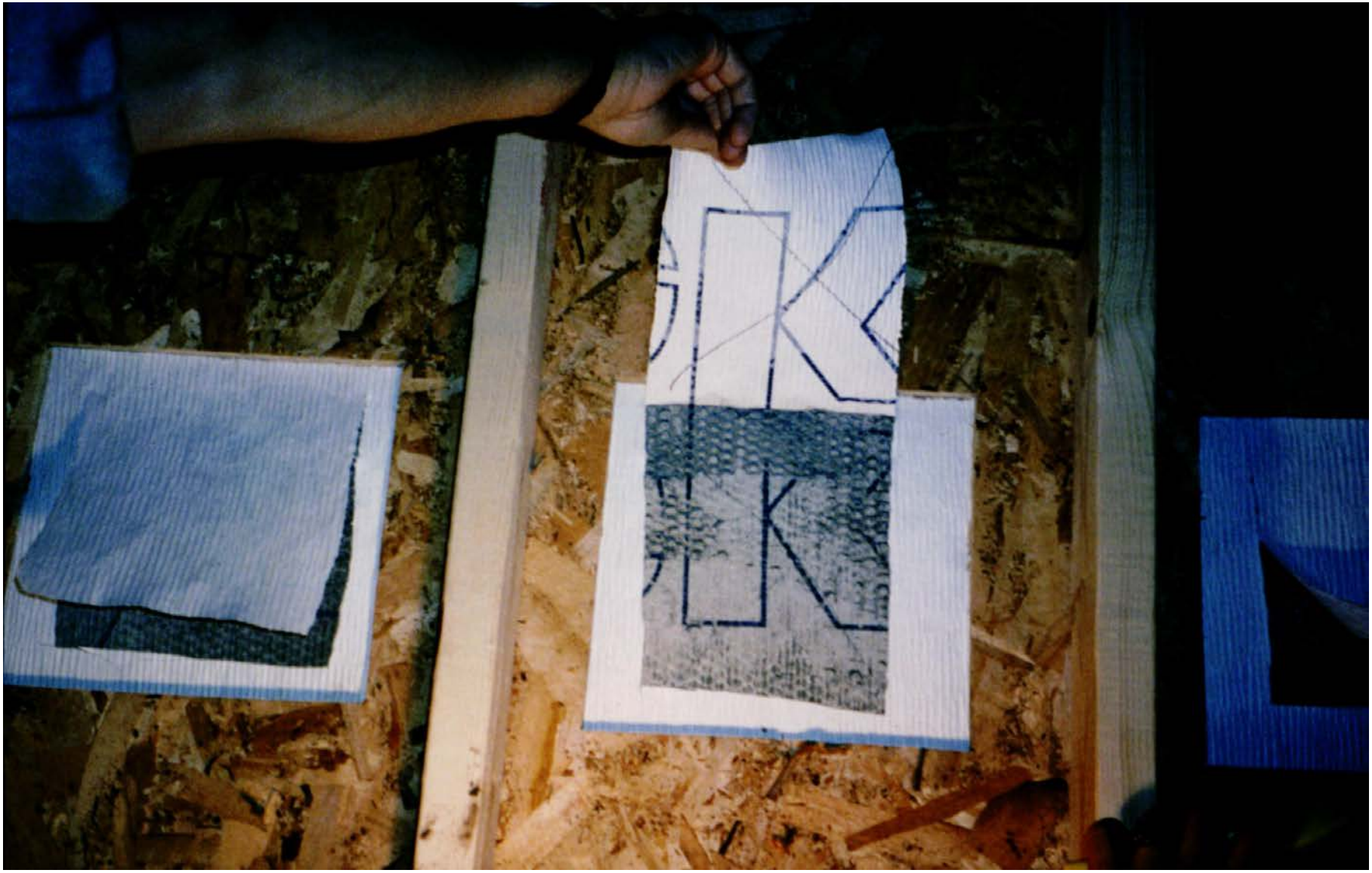

NO PARKING
Parking For Garage
Residents Only
10/24/2002

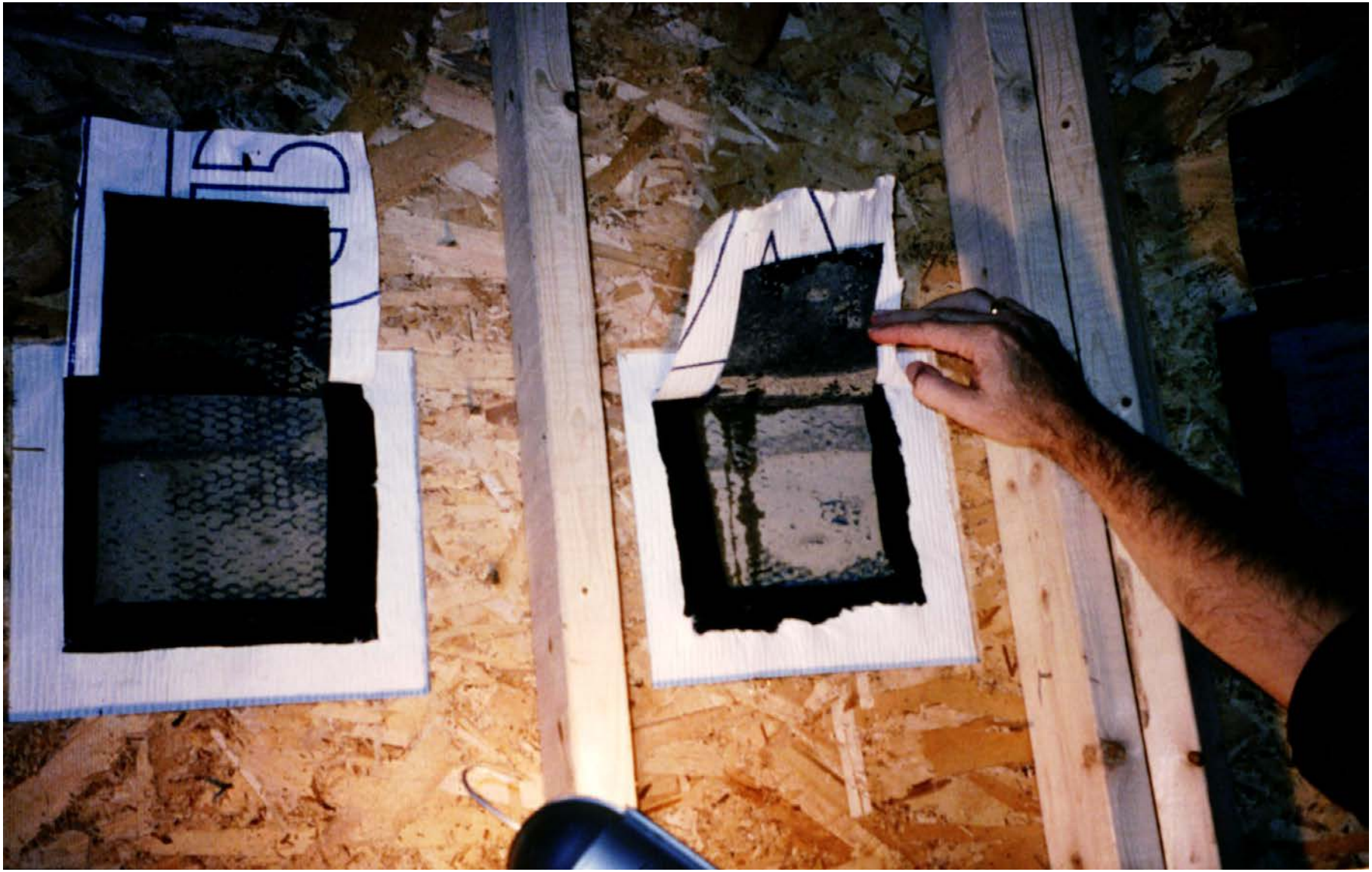

Parking For Garage
Residents Only
12/19/2002

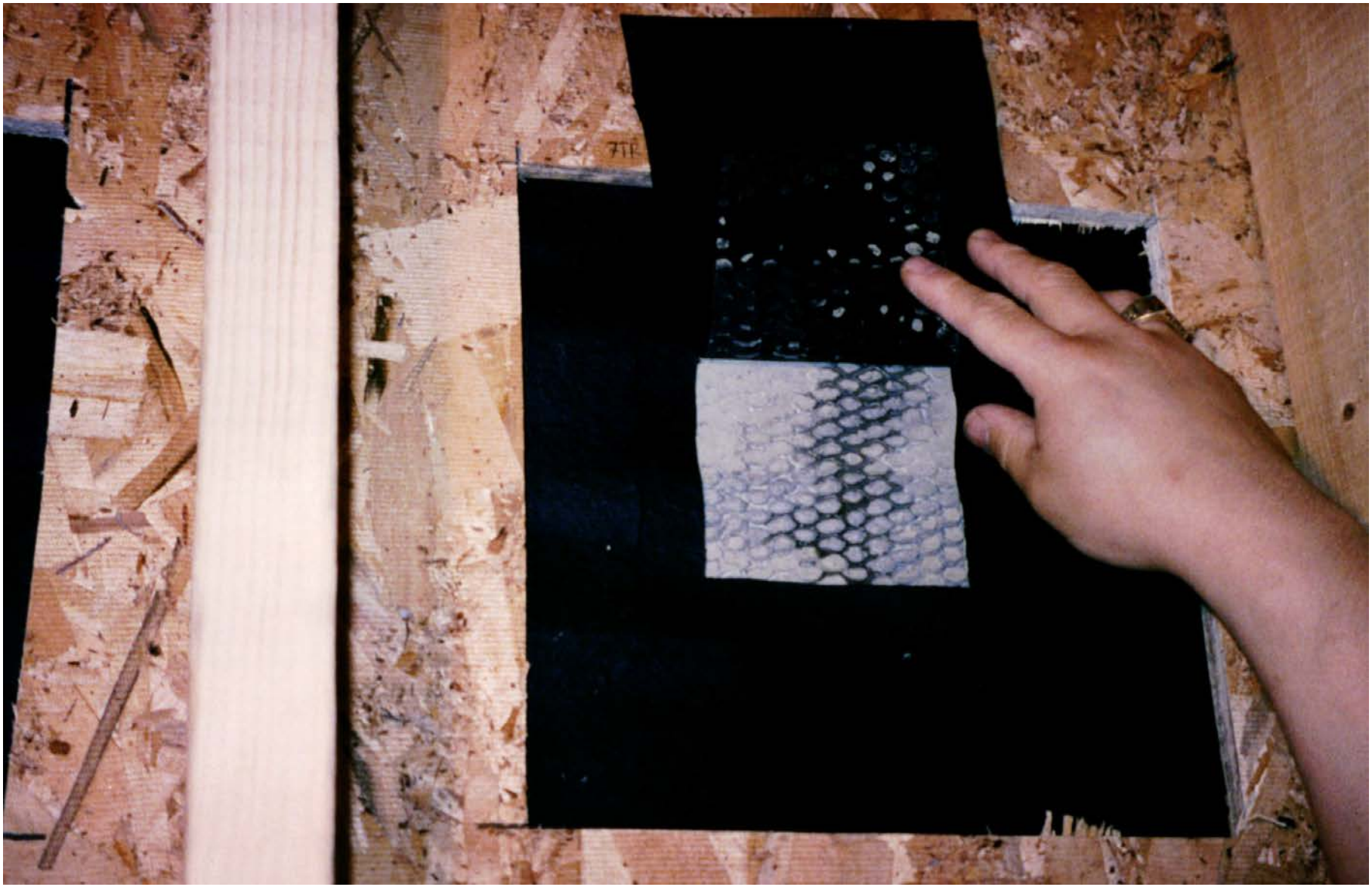

10/24/2002


3514
DUPONT
Finish

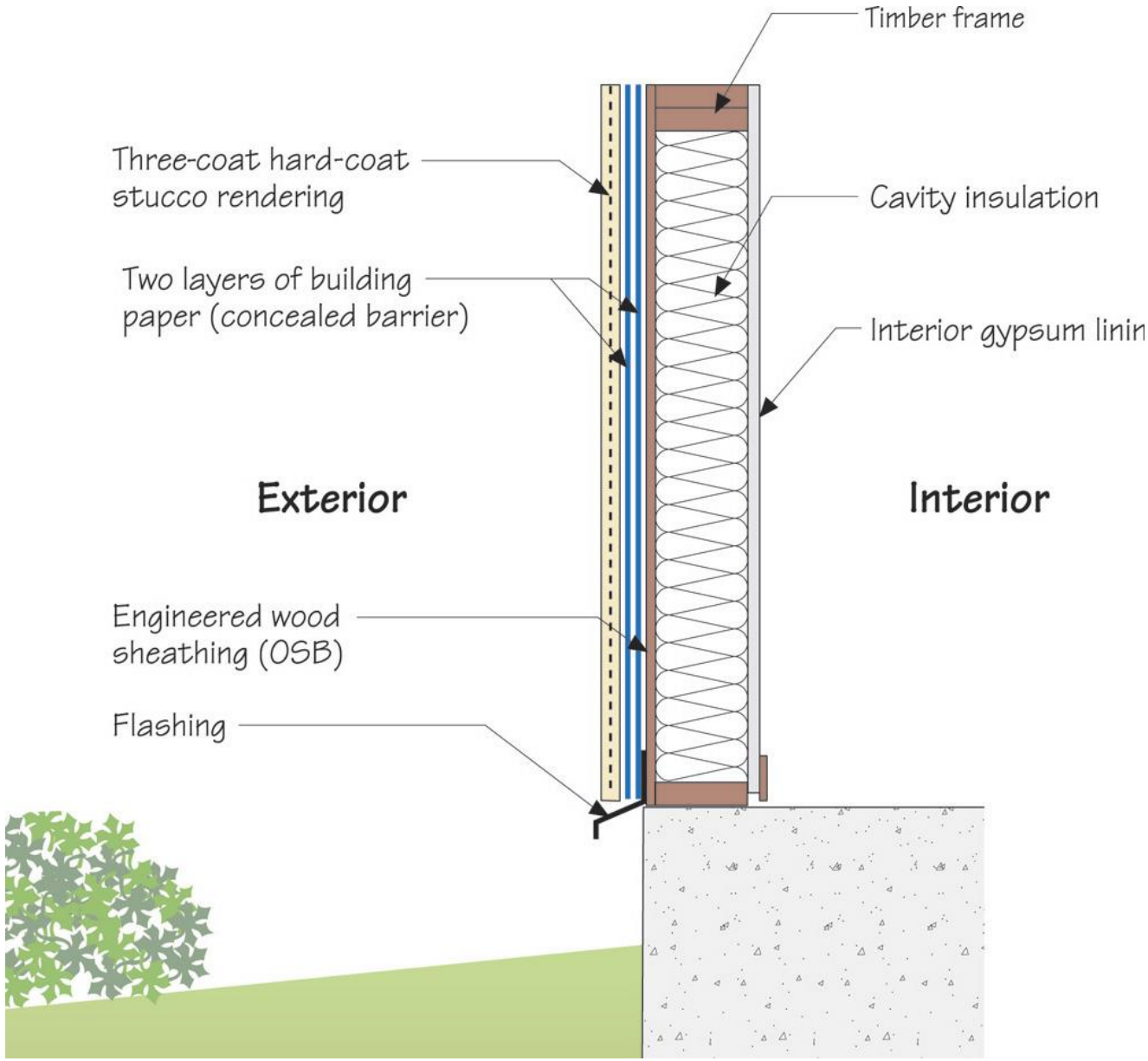
Side Trip To My Backyard….








Gypsum


Timber frame
Three-coat hard-coat stucco rendering
Cavity insulation
Two layers of building paper (concealed barrier)
Interior gypsum linin
Exterior
Interior
Engineered wood sheathing (OSB)
Flashing

“Lumpy Stucco”….

Should Have Been The Big US Warning….


Andersen
AW

Back To America….Pennslyvania….

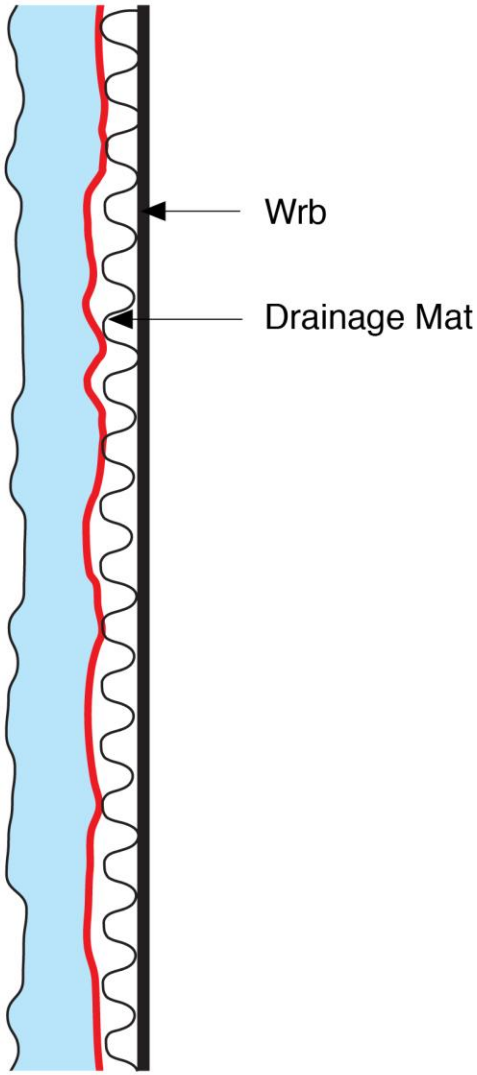
And Then Pretty Much Anywhere It Rains…


JLG ULTRA
1250AJP


LOWE'S

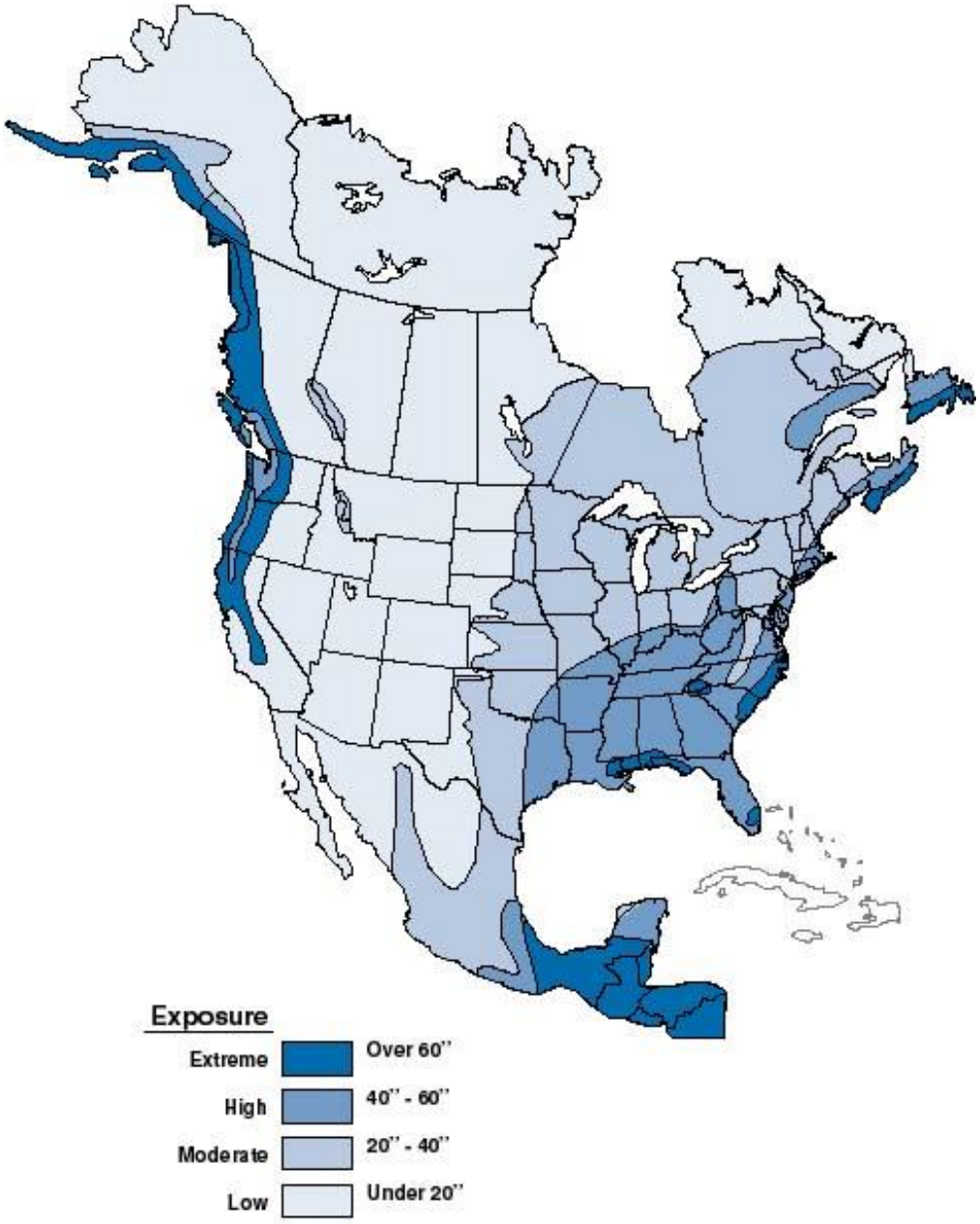
Back To Lumpy Stucco….

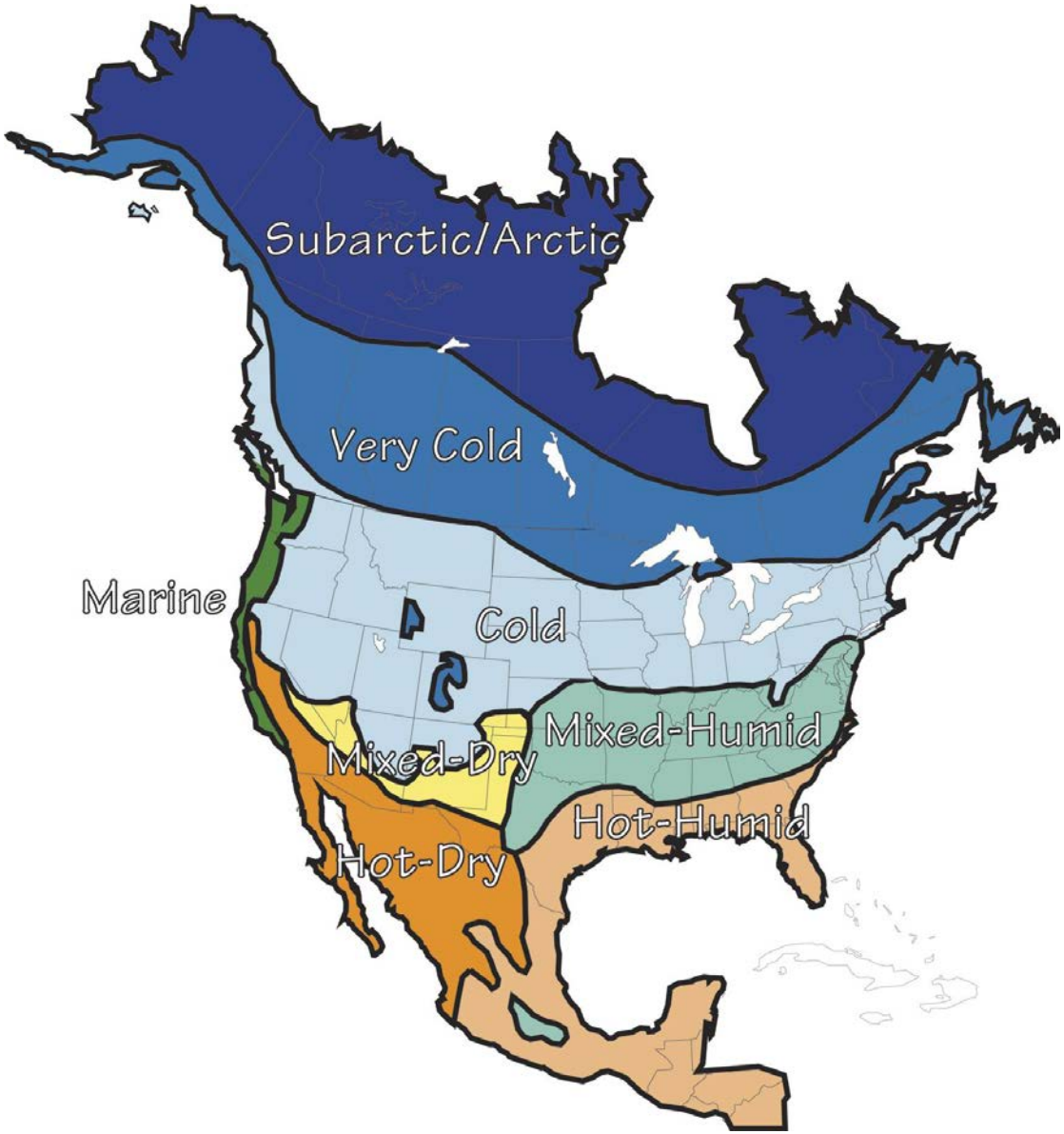
Easy Solution….


Wrb
Drainage Mat


Genie Z-60/34

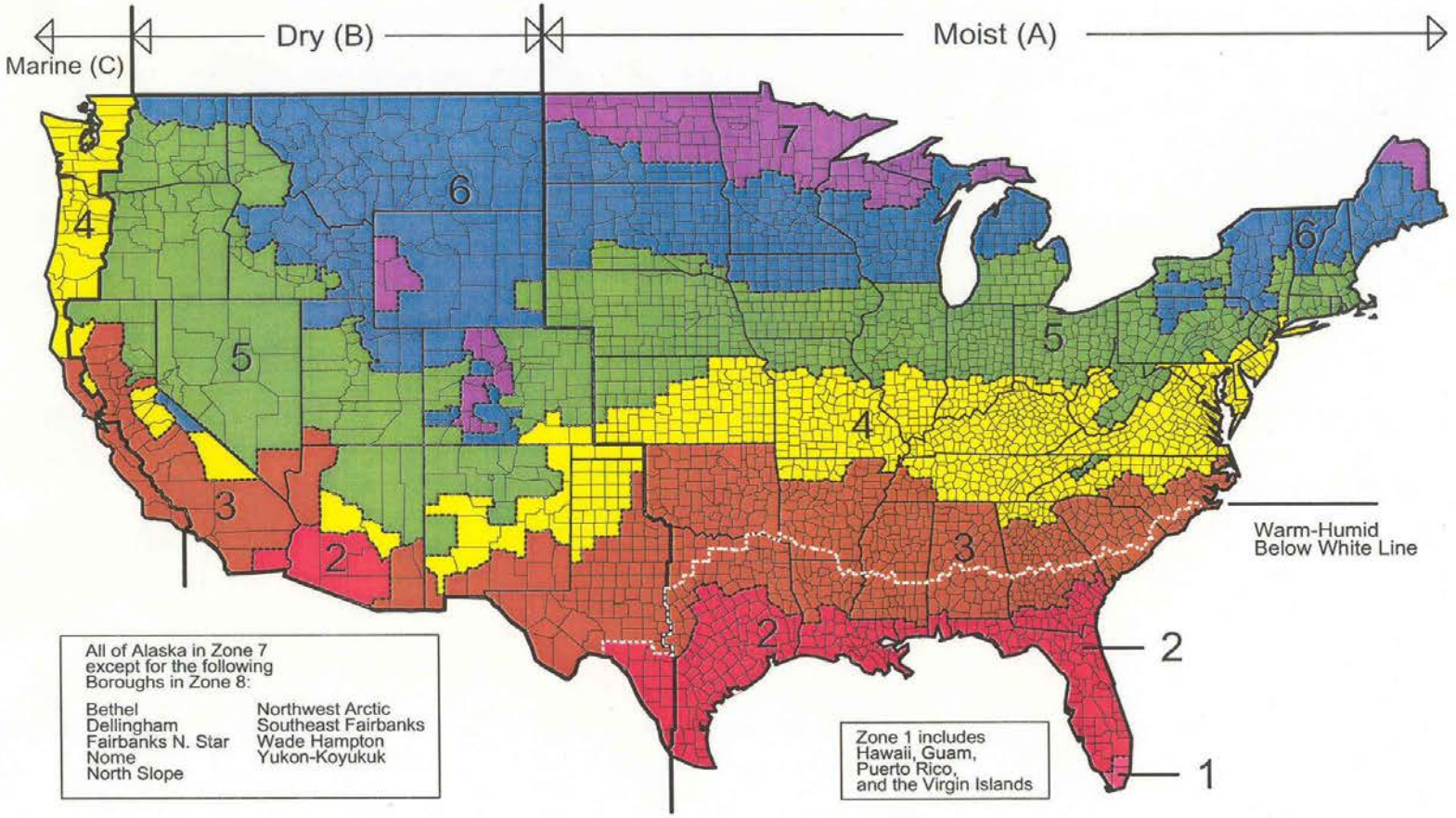

VRAP


Exposure
Extreme
Over 60''
High
40'' - 60''
Moderate
20'' - 40''
Low
Under 20''


Subarctic/Arctic
Very Cold
Marine
Cold
Mixed-Humid
Mixed-Dry
Hot-Humid
Hot-Dry


Arctic Bay
Anchorage
Seattle
Minneapolis
Los Angeles
El Paso
Houston
Monterrey
Havana
Belize City
Tropical Wet
Tropical Wet-Dry
Steppe
Desert
Mediterranean
Subtropical humid
Marine West Coast
Continental humid
Subarctic
Tundra
Ice sheet
Highlands

Map of DOE's Proposed Climate Zones



March 24, 2003

Recommendations….

Provide a 3/8 inch air space behind all stucco in regions where it rains more than 20 inches per year

Provide a 3/8 inch air space behind all stucco over three stories

Don’t install interior vapor barriers

Air space can be reduced to 1/16 inch where inward vapor drive is limited

Recommendations….

Barrier works in Florida over block

Barrier does not work in Florida over OSB

Don’t install interior vapor barriers in Florida

Don’t drain a drained system into a barrier system

Exterior Conditions

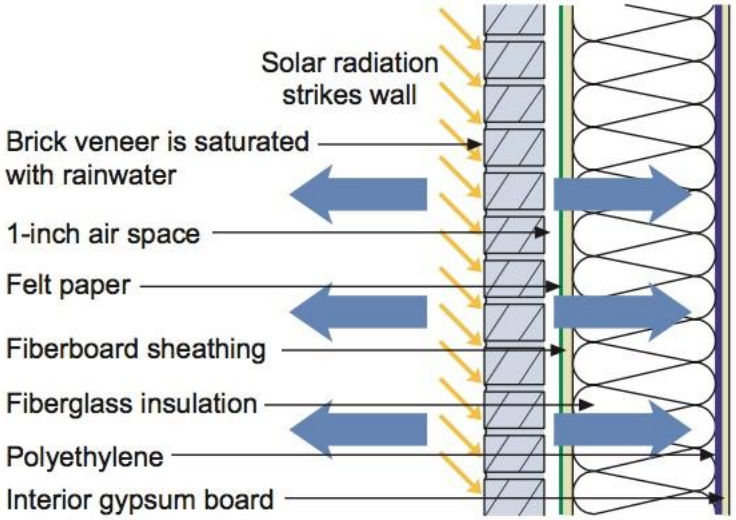
Temperature: 80°F
Relative humidity: 75%
Vapor pressure: 2.49 kPa

Conditions within Cavity:

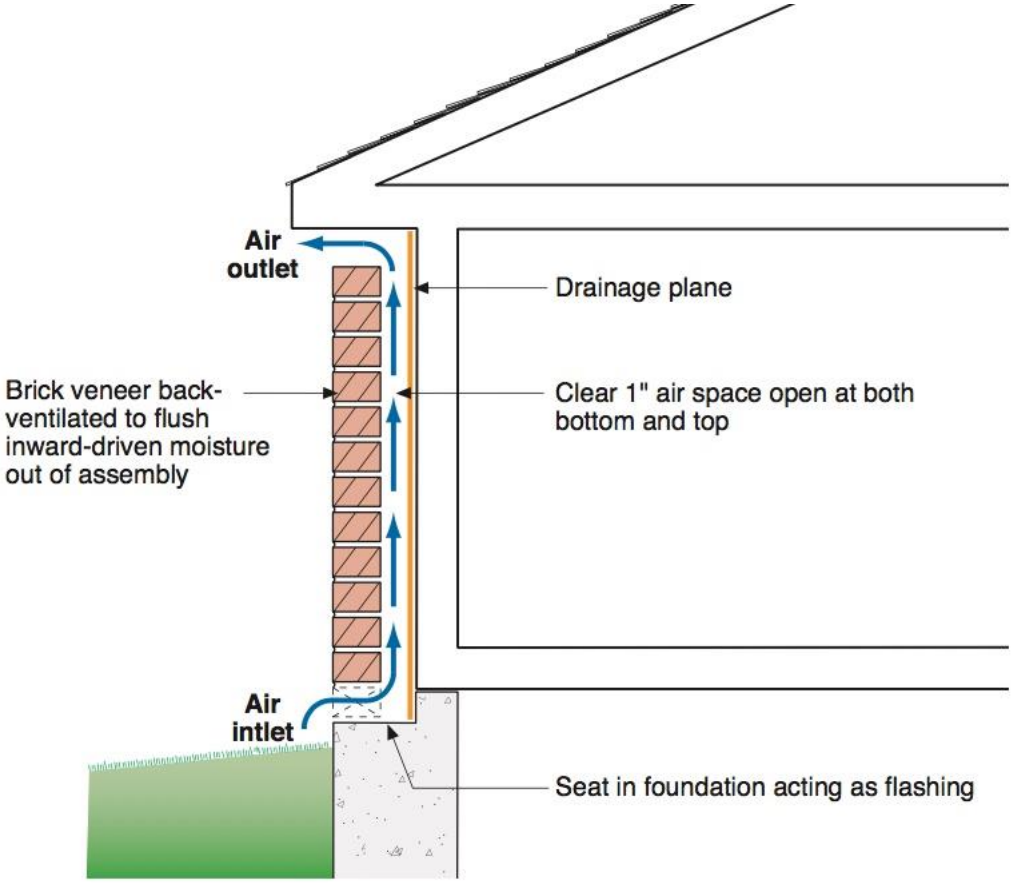
Temperature: 100°F
Relative humidity: 100%
Vapor pressure: 6.45 kPa

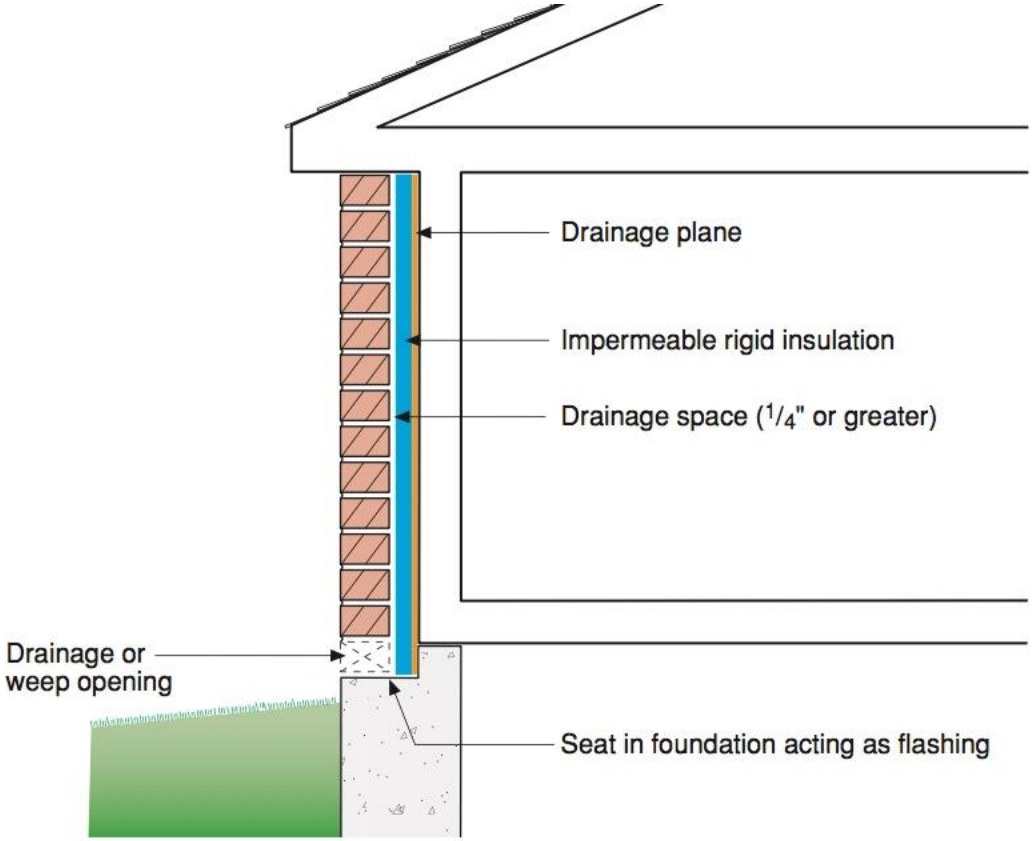
Interior Conditions

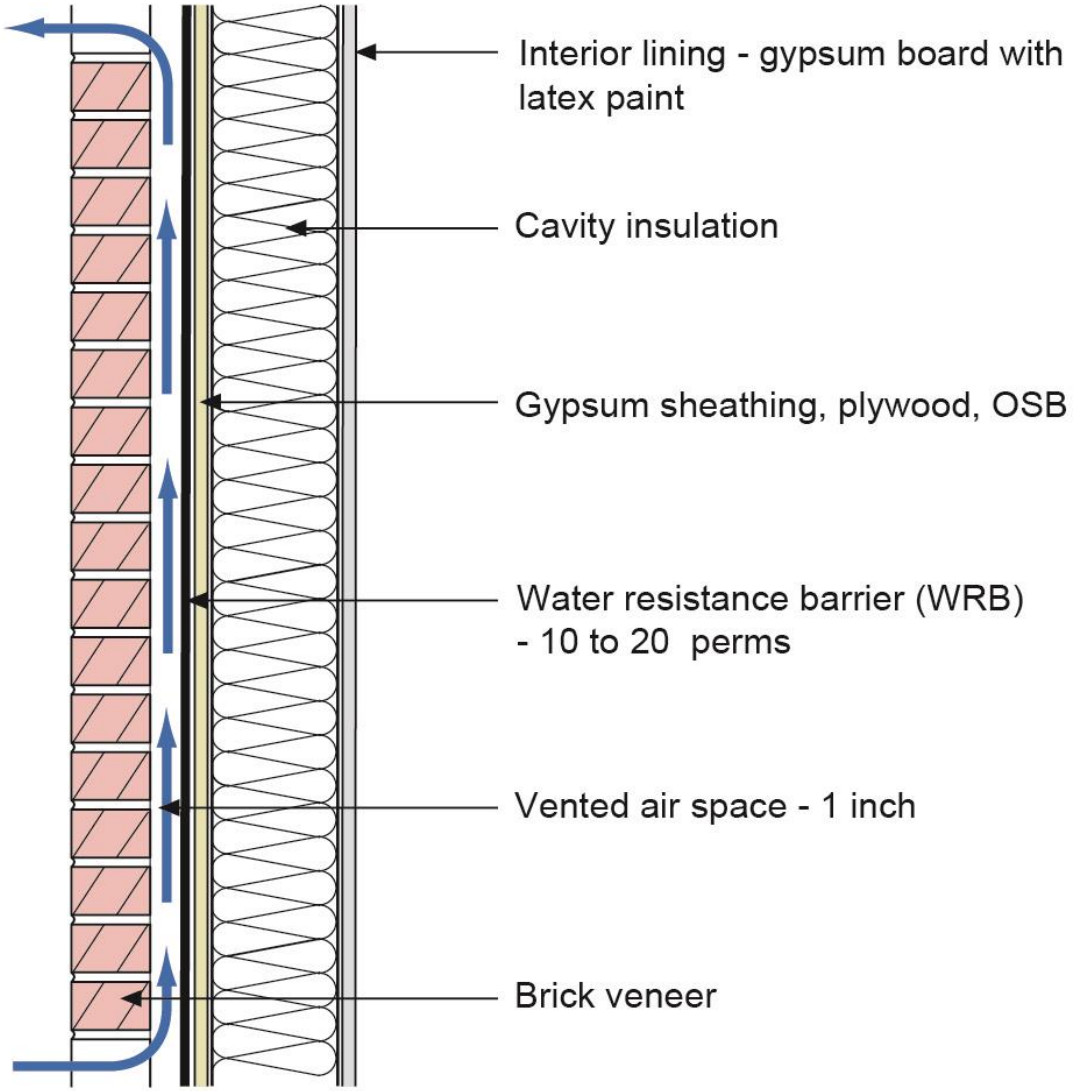
Temperature: 75°F
Relative humidity: 60%
Vapor pressure: 1.82 kPa

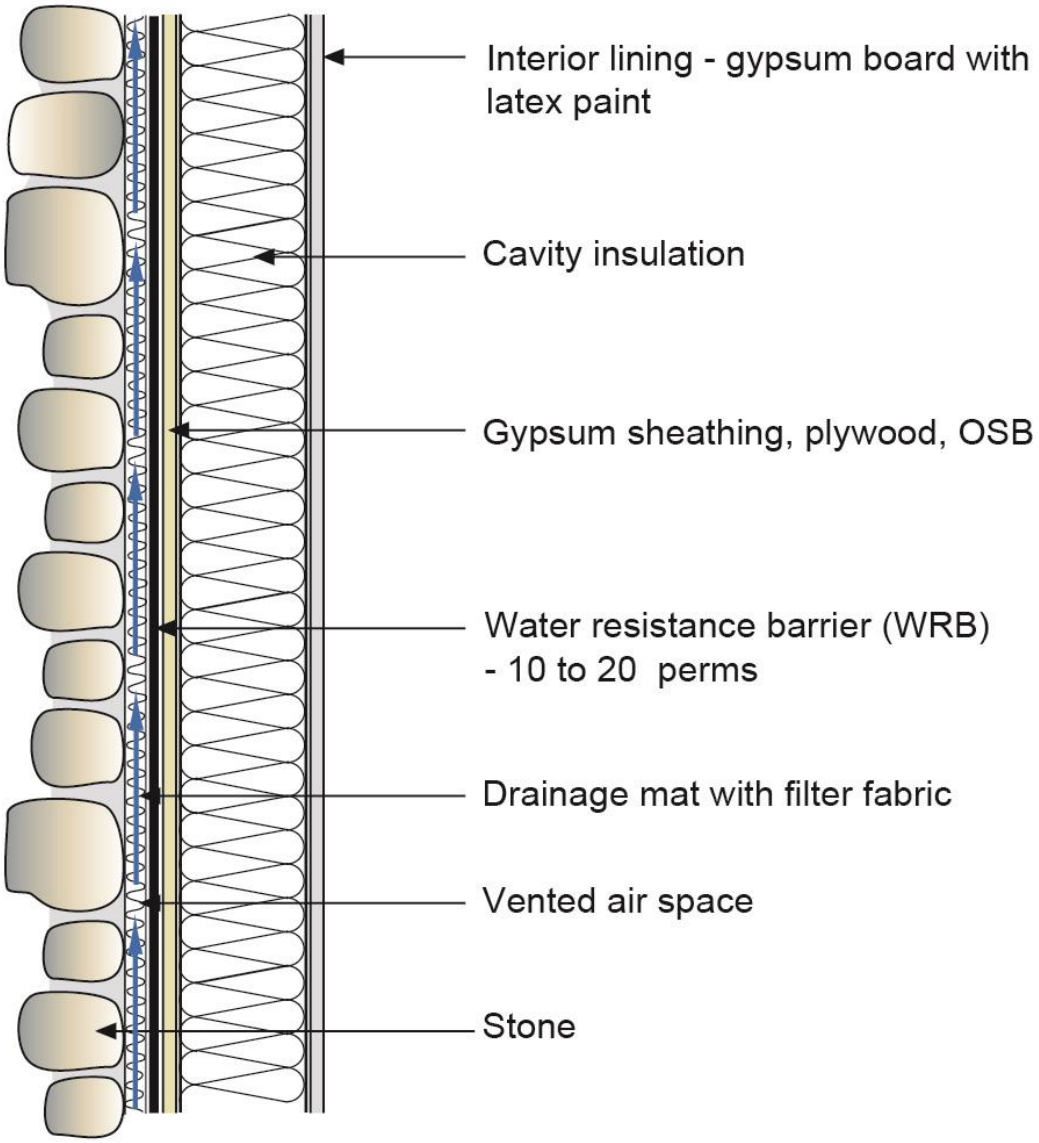


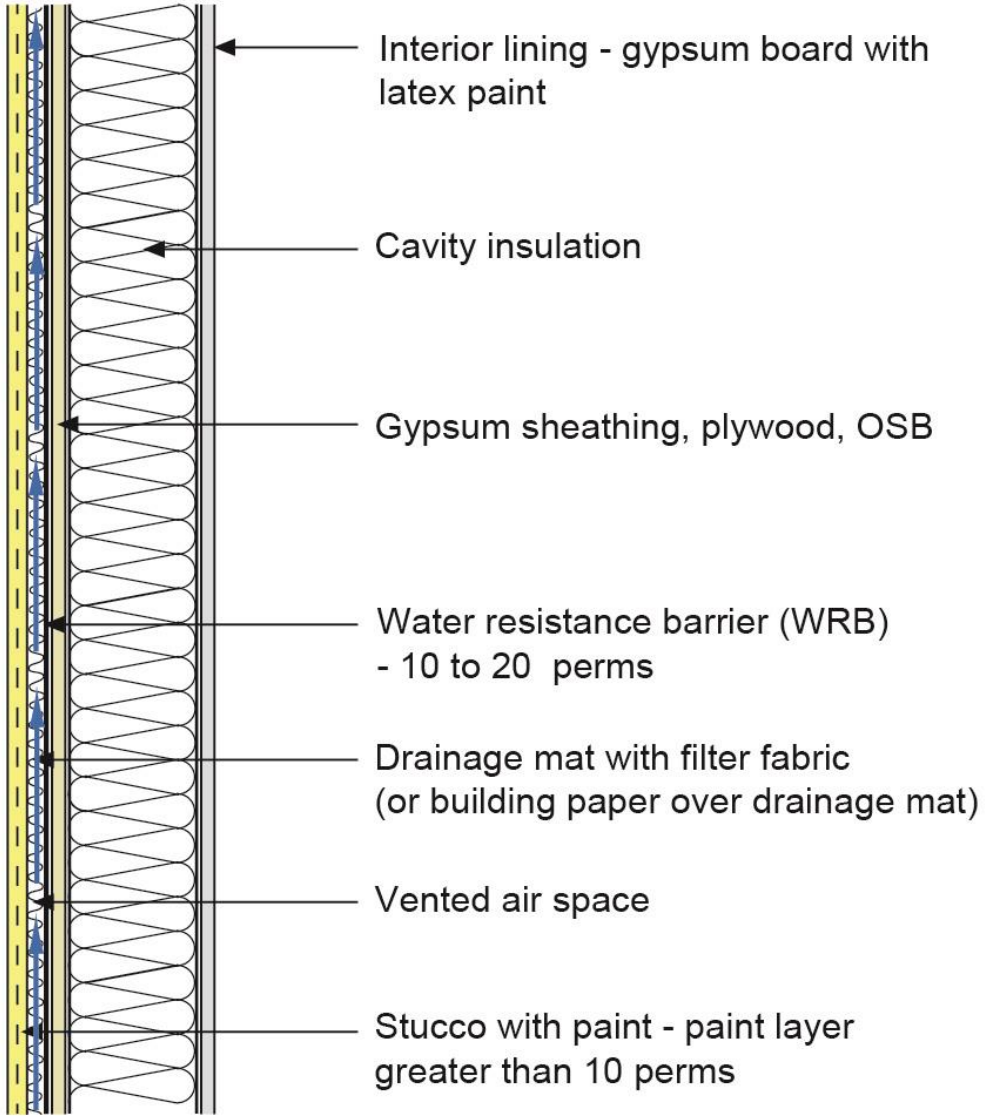
Vapor is driven both inward and outward by a high vapor pressure differential between the brick and the interior and the brick and the exterior.

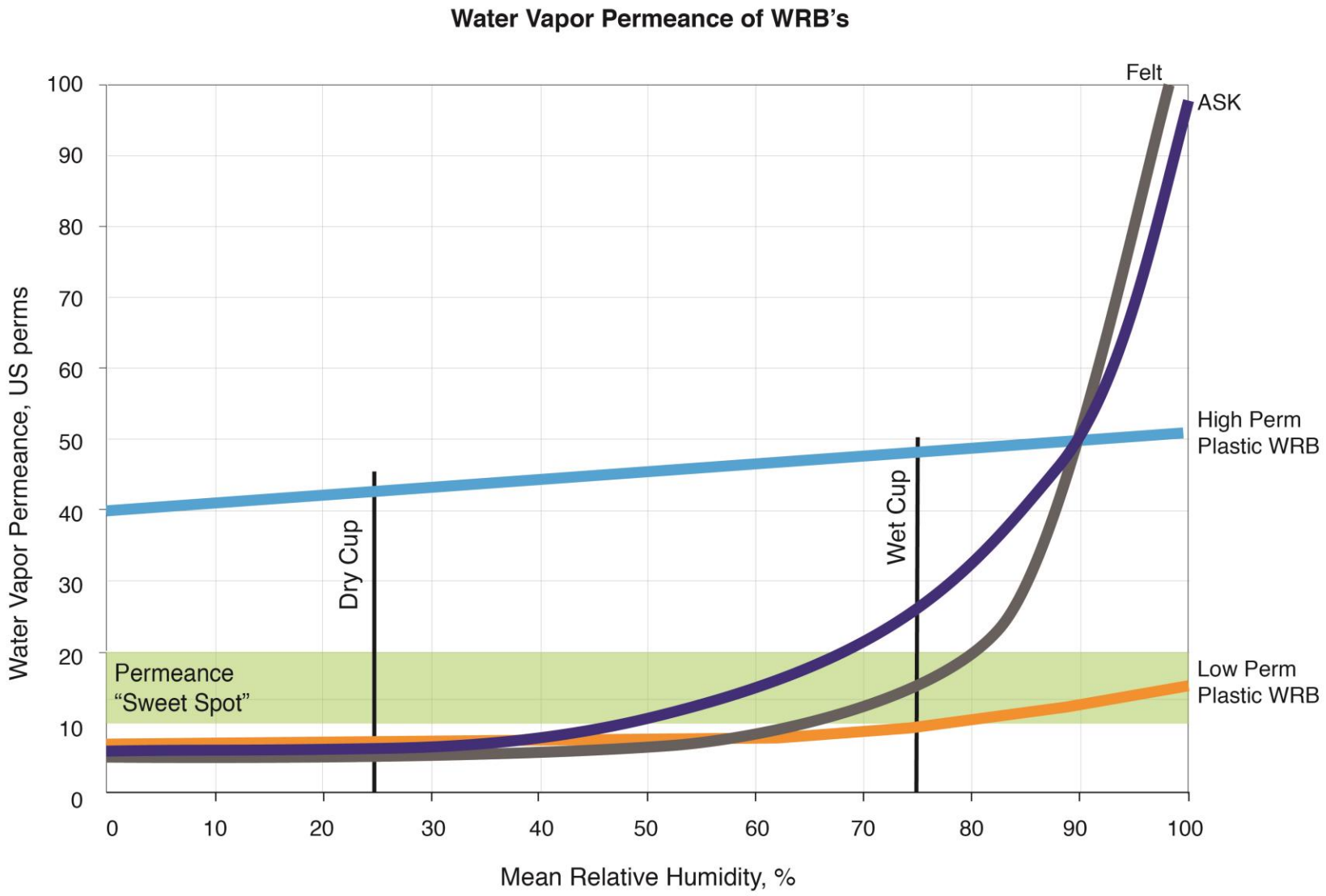

Air
outlet
Drainage plane
Brick veneer back-
ventilated to flush
inward-driven moisture
out of assembly
Clear 1" air space open at both
bottom and top
Air
intlet
Seat in foundation acting as flashing


Drainage plane
Impermeable rigid insulation
Drainage space (1/4" or greater)
Drainage or
weep opening
Seat in foundation acting as flashing


Interior lining - gypsum board with latex paint
Cavity insulation
Gypsum sheathing, plywood, OSB
Water resistance barrier (WRB) - 10 to 20 perms
Vented air space - 1 inch
Brick veneer


Interior lining - gypsum board with latex paint
Cavity insulation
Gypsum sheathing, plywood, OSB
Water resistance barrier (WRB) - 10 to 20 perms
Drainage mat with filter fabric
Vented air space
Stone


Interior lining - gypsum board with latex paint
Cavity insulation
Gypsum sheathing, plywood, OSB
Water resistance barrier (WRB) - 10 to 20 perms
Drainage mat with filter fabric (or building paper over drainage mat)
Vented air space
Stucco with paint - paint layer greater than 10 perms


Water Vapor Permeance of WRB's
Water Vapor Permeance, US perms
Mean Relative Humidity, %
Felt
ASK
High Perm
Plastic WRB
Low Perm
Plastic WRB
Dry Cup
Wet Cup
Permeance
"Sweet Spot"
0
10
20
30
40
50
60
70
80
90
100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DrainWra
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