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

Building Science

Adventures In Building Science

www.buildingscience.com

What is a Building?

A Building is an Environmental Separator

- 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

Arrhenius Equation

For Every 10 Degree K Rise

Reaction Rate Doubles

$$k = Ae^{-E_a/(RT)}$$

Damage Functions

Water

Heat

Ultra-violet Radiation

The Three Biggest Problems In Buildings Are Water, Water and Water…

80 Percent of all Construction Problems are Related to Water

Thermodynamics

Zeroth Law – Equal Systems

First Law - Conservation of Energy

Second Law - Entropy

Third Law – Absolute Zero

2nd Law of Thermodynamics

In an isolated system, a process can occur only if it increases the total entropy of the system

Rudolf Clausius

Heat Flow Is From Warm To Cold

Moisture Flow Is From Warm To Cold

Moisture Flow Is From More To Less

Air Flow Is From A Higher Pressure to a Lower Pressure

Gravity Acts Down

Moisture Flow Is From Warm To Cold

Moisture Flow Is From More To Less

Moisture Flow Is From Warm To Cold

Moisture Flow Is From More To Less

Thermal Gradient – Thermal Diffusion

Concentration Gradient – Molecular Diffusion

Moisture Flow Is From Warm To Cold

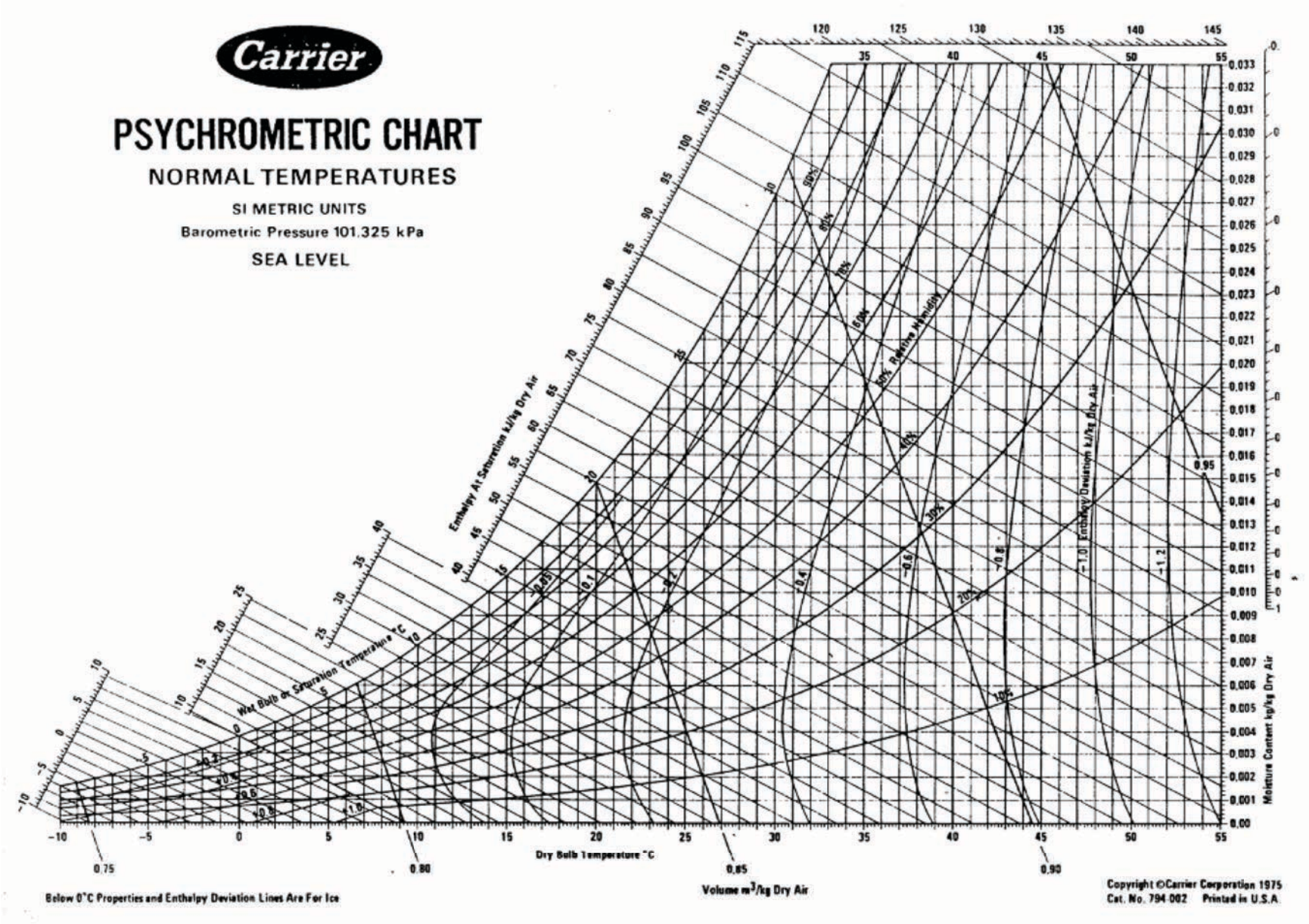
Moisture Flow Is From More To Less

Thermal Gradient – Thermal Diffusion

Concentration Gradient – Molecular Diffusion

Vapor Diffusion

Thermodynamic Potential


Carrier
PSYCHROMETRIC CHART
NORMAL TEMPERATURES
SI METRIC UNITS
Barometric Pressure 101.325 kPa
SEA LEVEL
Enthalpy At Saturation kJ/kg Dry Air
Wet Bulb or Saturation Temperature °C
Dry Bulb Temperature °C
Moisture Content kg/kg Dry Air
50% Relative Humidity
Below 0°C Properties and Enthalpy Deviation Lines Are For Ice
Volume m³/kg Dry Air
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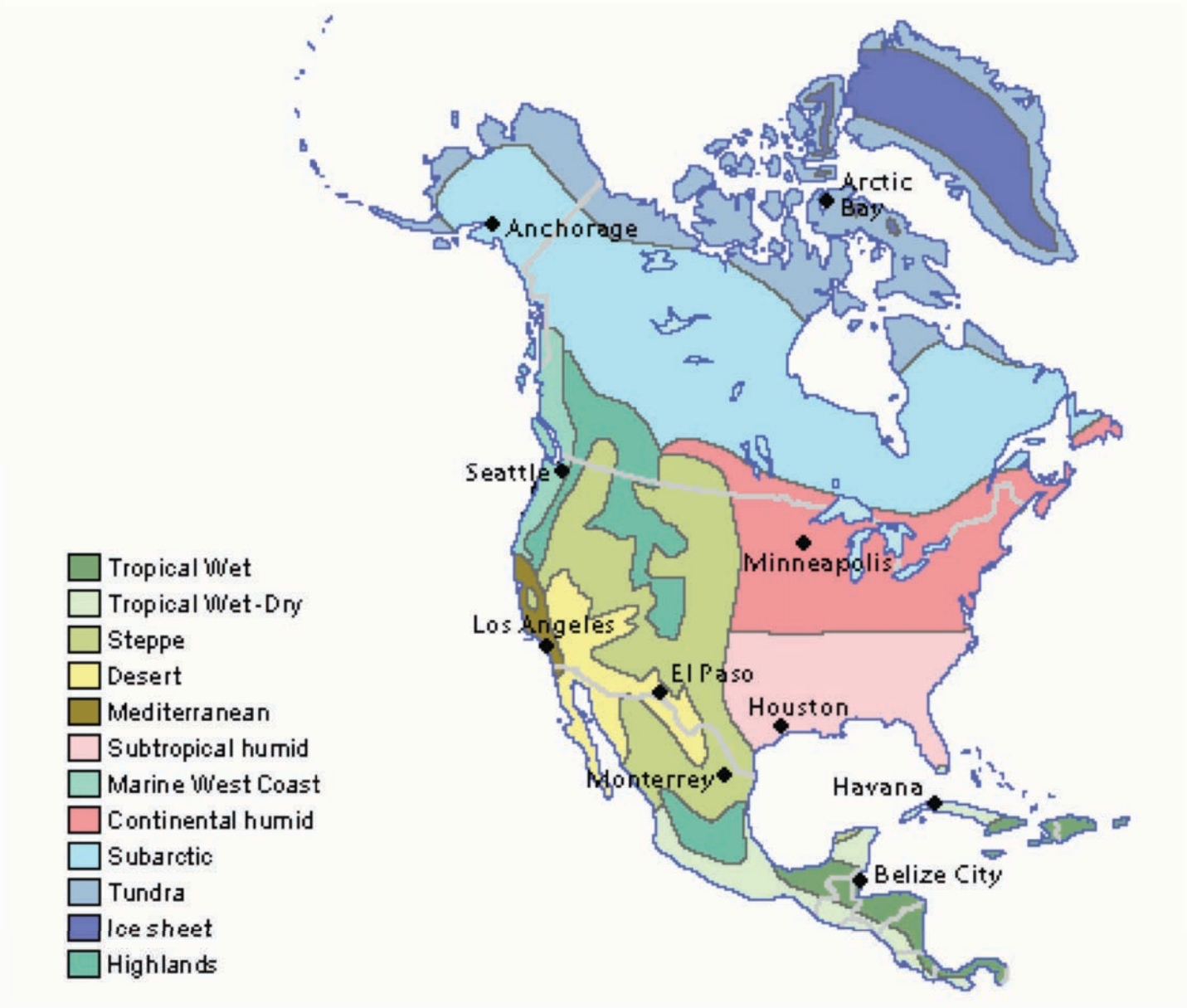
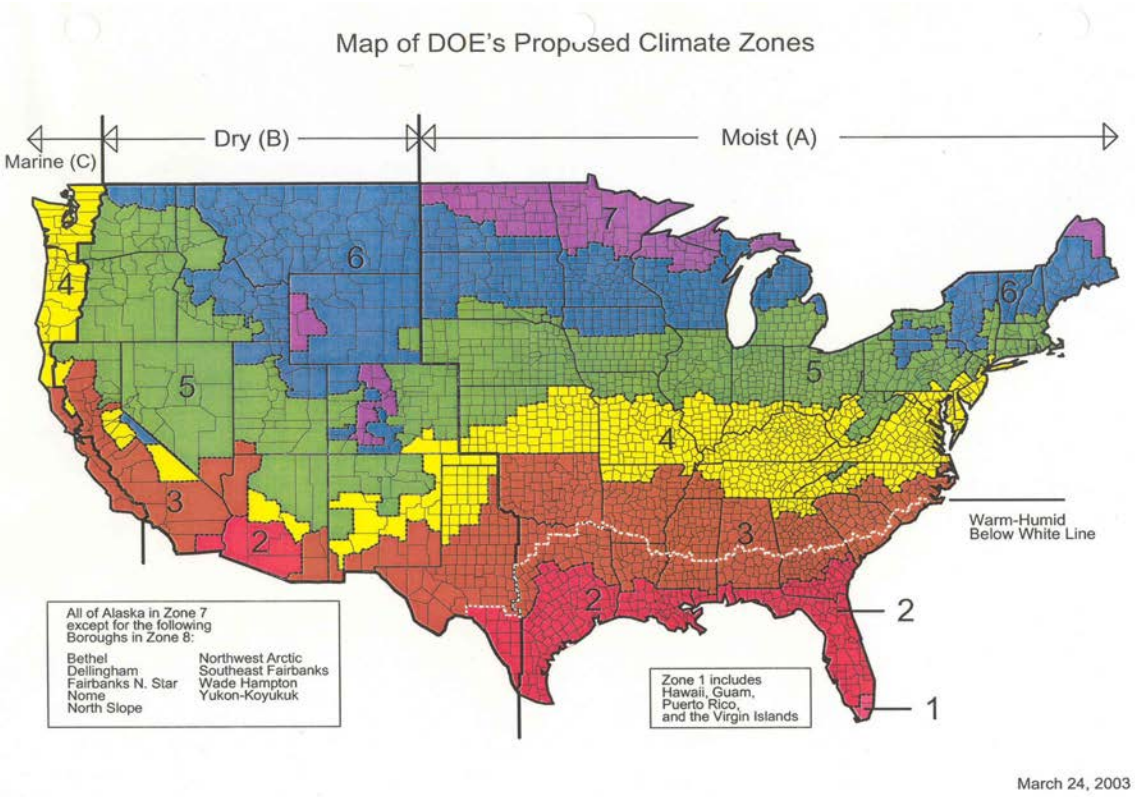
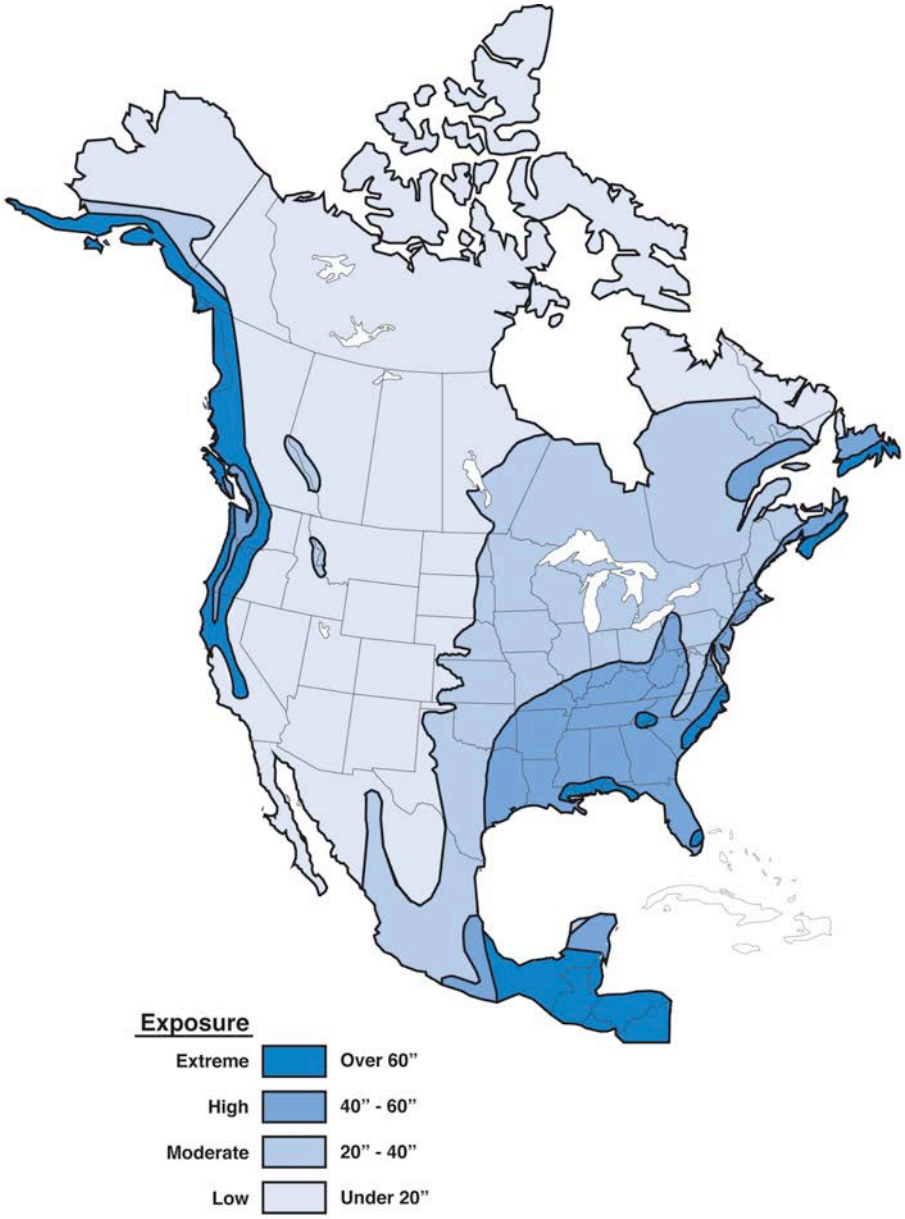
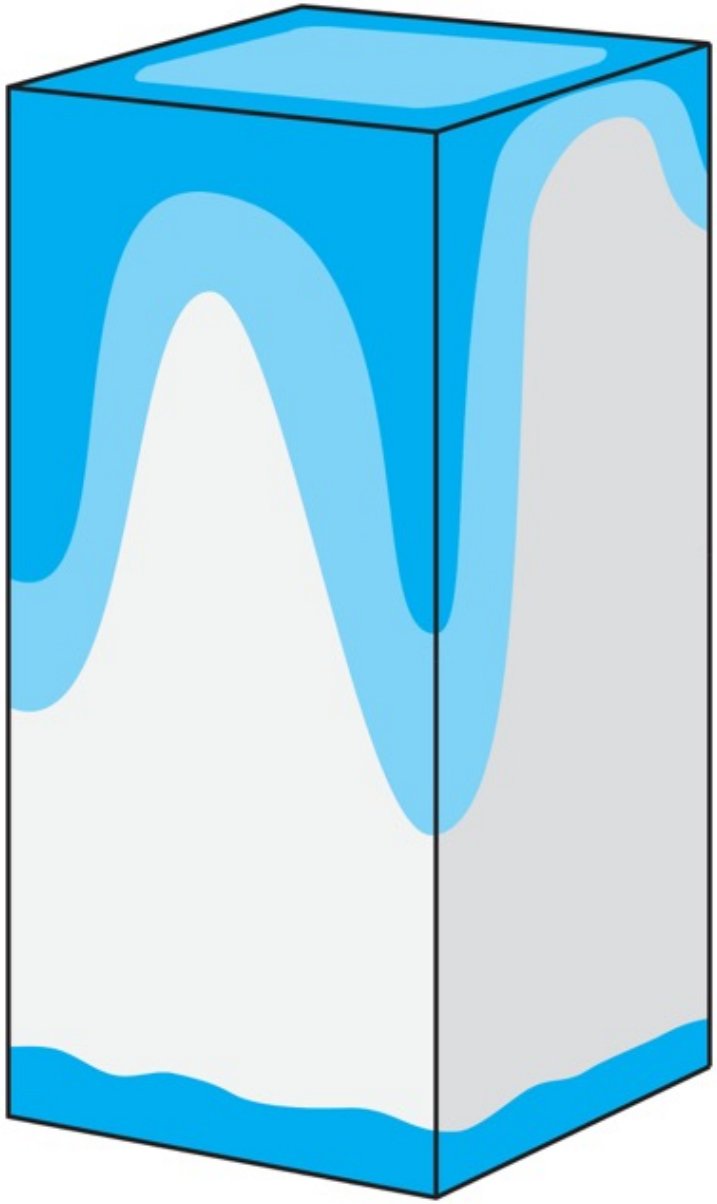
Subarctic/Arctic
Very Cold
Marine
Cold
Mixed-Humid
Mixed-Dry
Hot-Humid
Hot-Dry

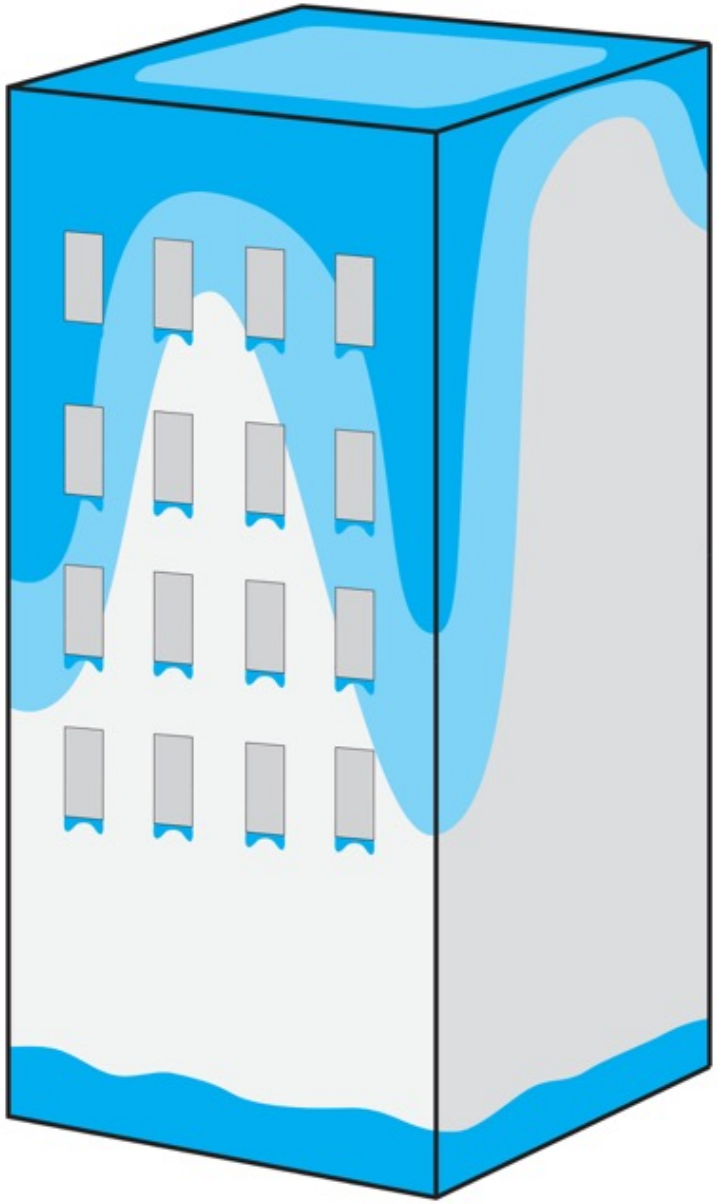

Arctic Bay
Anchorage
Seattle
Minneapolis
Los Angeles
El Paso
Houston
Monterrey
Havana
Belize City
Tropical Wet
Tropical Wet-Dry
Steppe
Desert
Mediterranean
Subtropical humid
Marine West Coast
Continental humid
Subarctic
Tundra
Ice sheet
Highlands


Map of DOE's Proposed Climate Zones
Marine (C)
Dry (B)
Moist (A)
Warm-Humid
Below White Line
All of Alaska in Zone 7
except for the following
Boroughs in Zone 8:
Bethel
Dellingham
Fairbanks N. Star
Nome
North Slope
Northwest Arctic
Southeast Fairbanks
Wade Hampton
Yukon-Koyukuk
Zone 1 includes
Hawaii, Guam,
Puerto Rico,
and the Virgin Islands
March 24, 2003


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



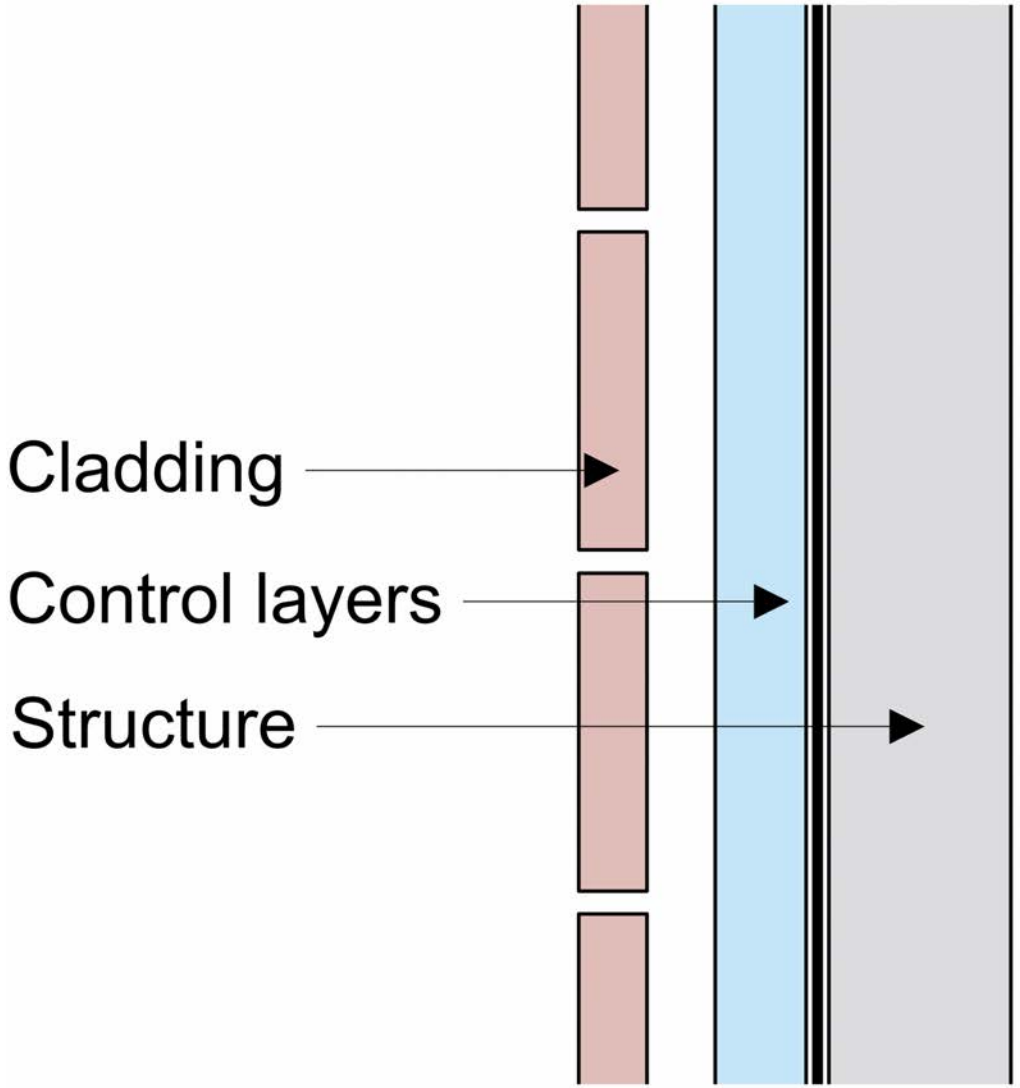


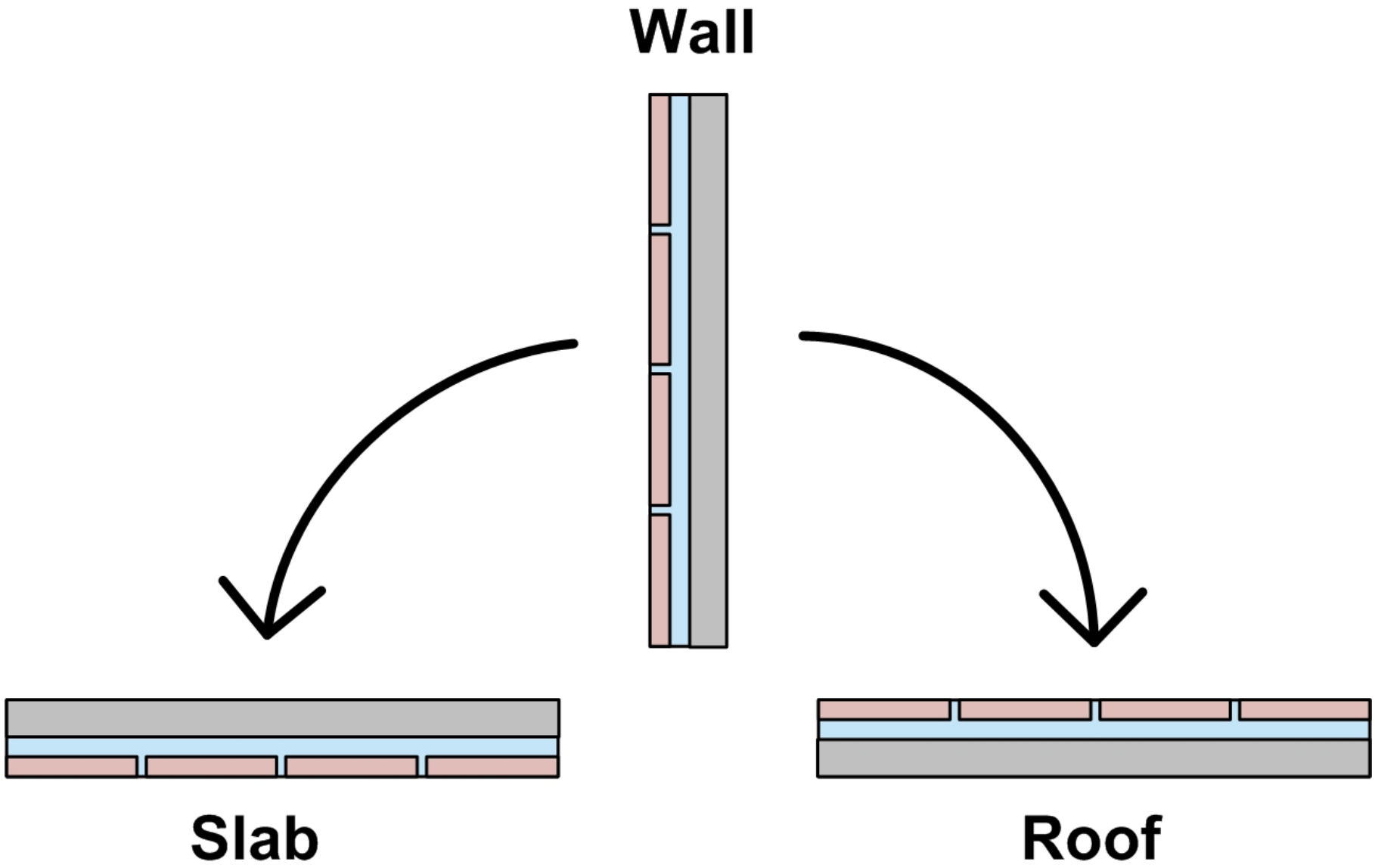
Water Control Layer

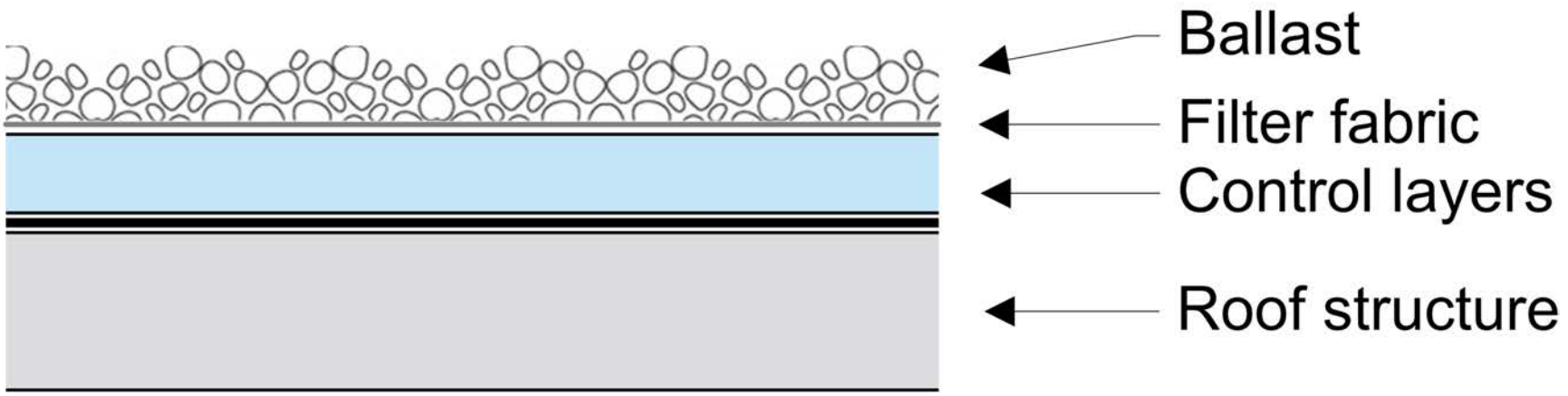
Air Control Layer

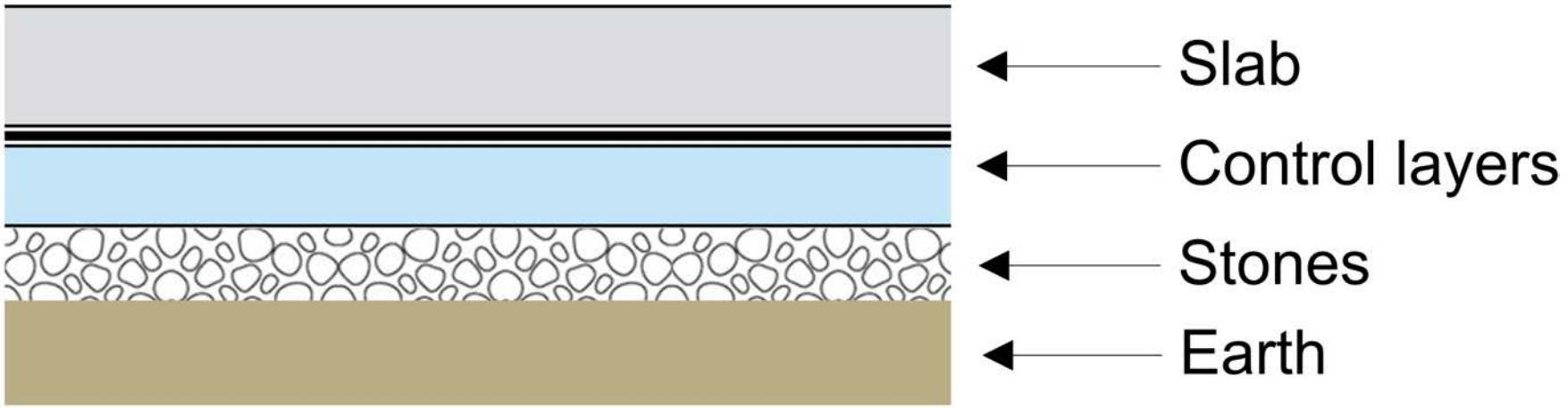
Vapor Control Layer

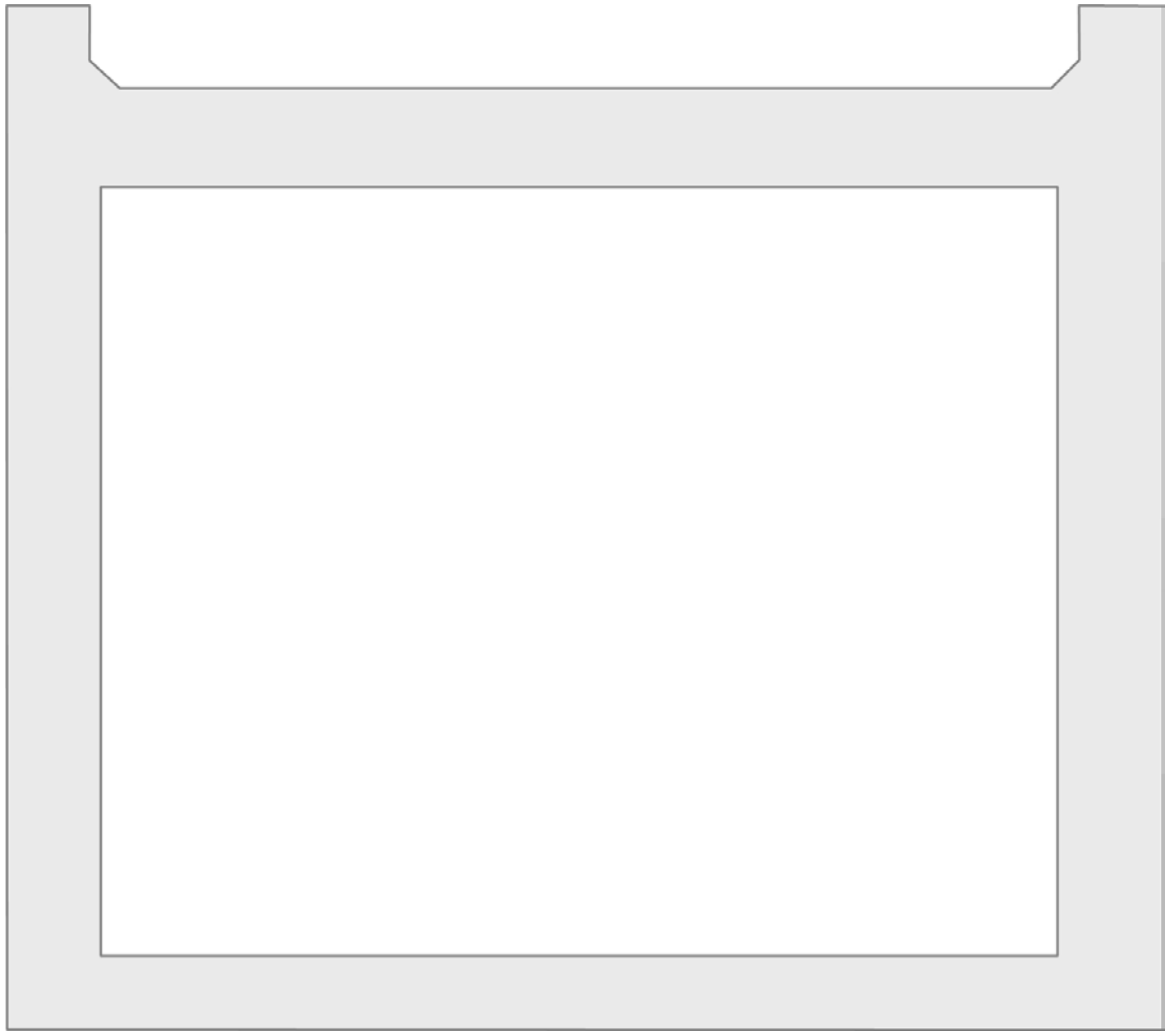
Thermal Control Layer

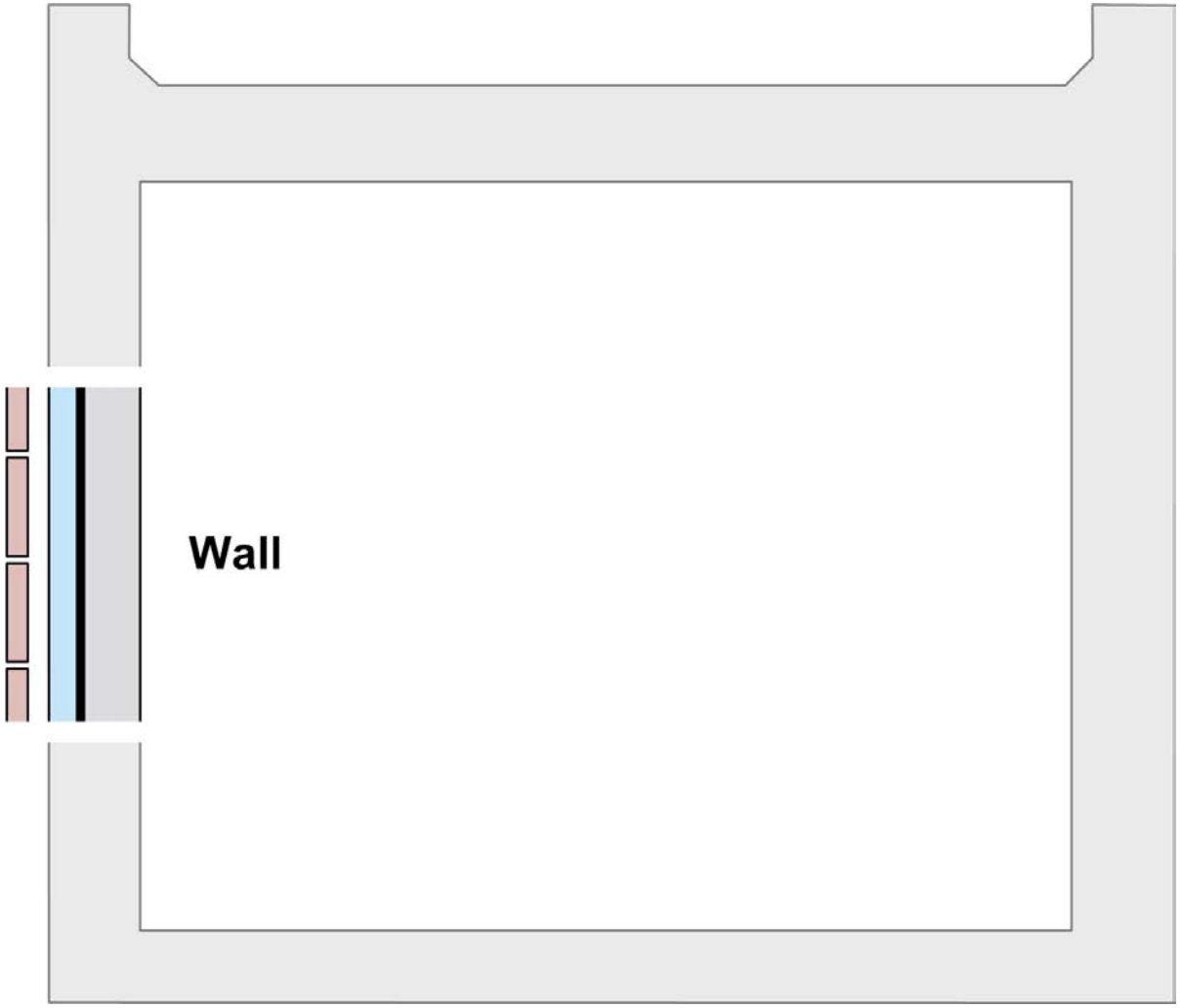

Cladding
Control layers
Structure

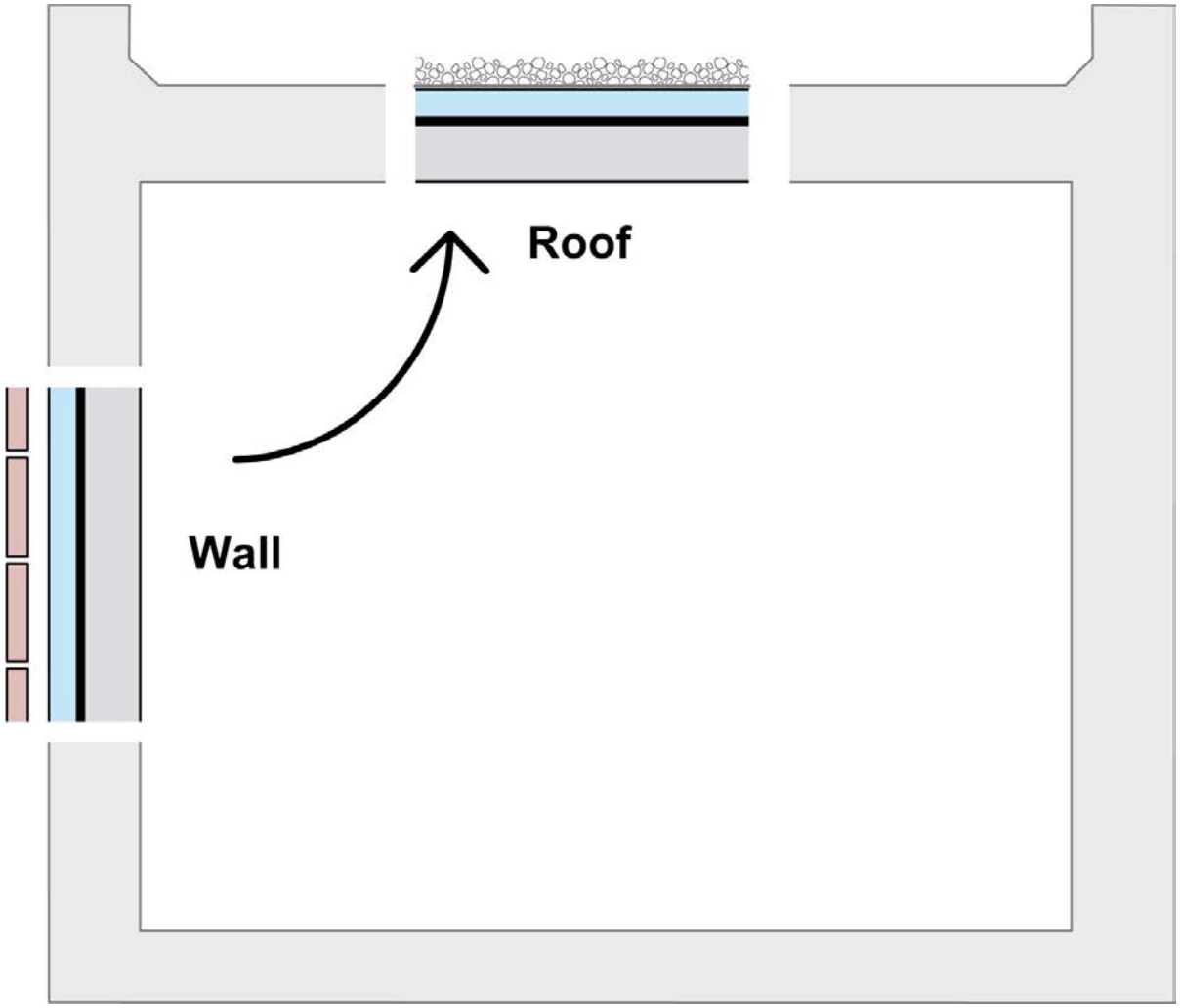

Wall
Slab
Roof

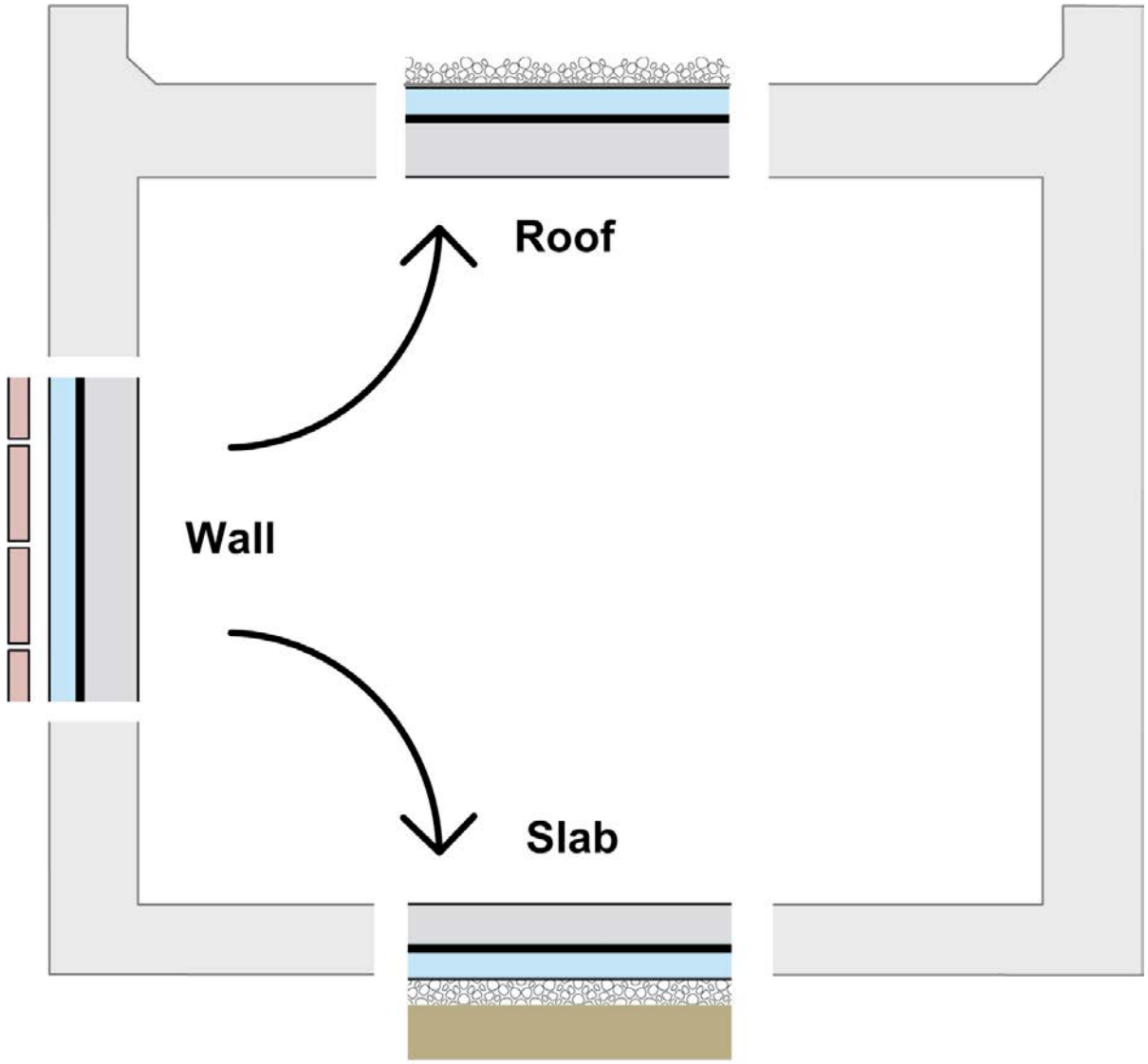

Ballast
Filter fabric
Control layers
Roof structure

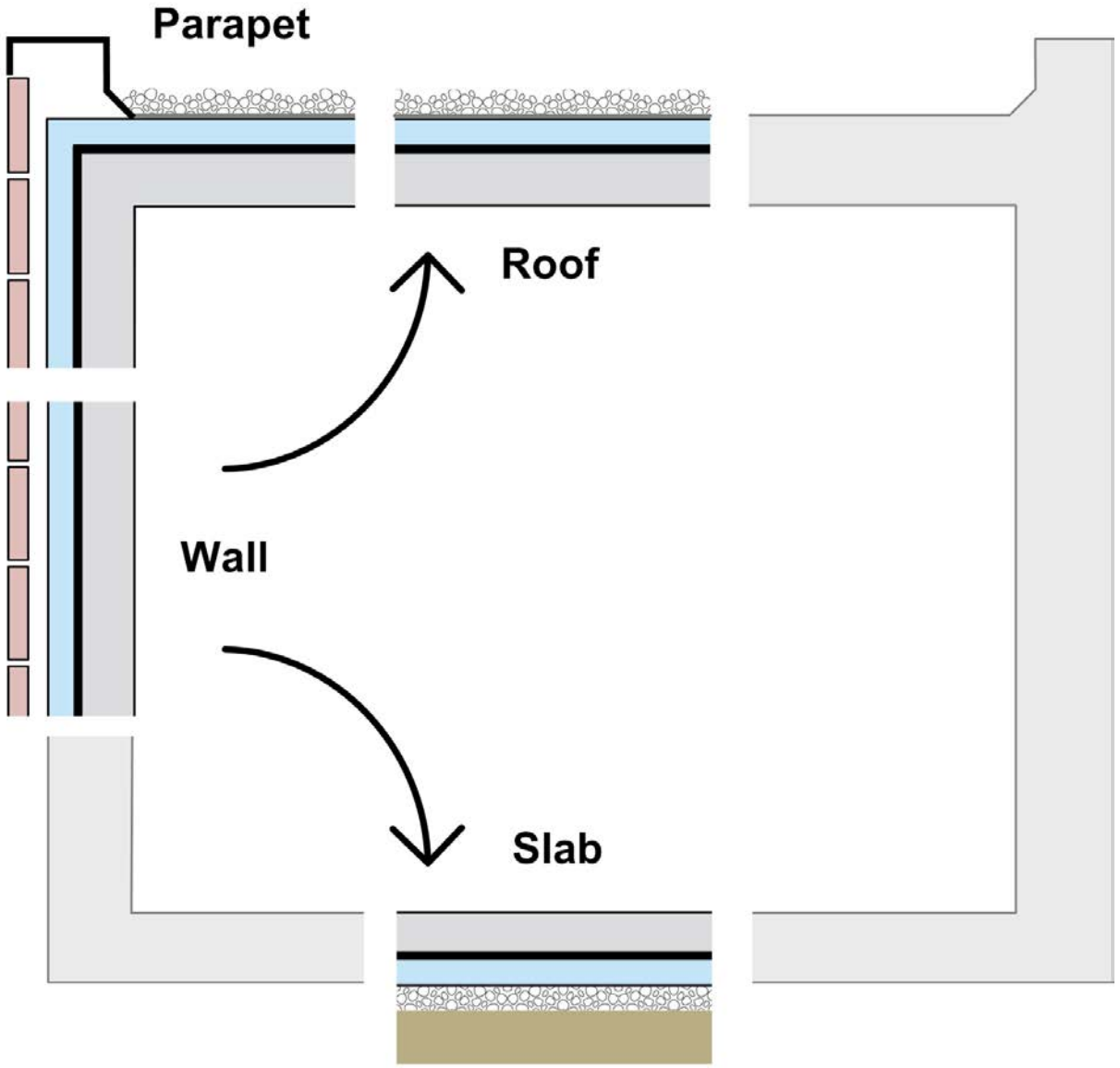

Slab
Control layers
Stones
Earth

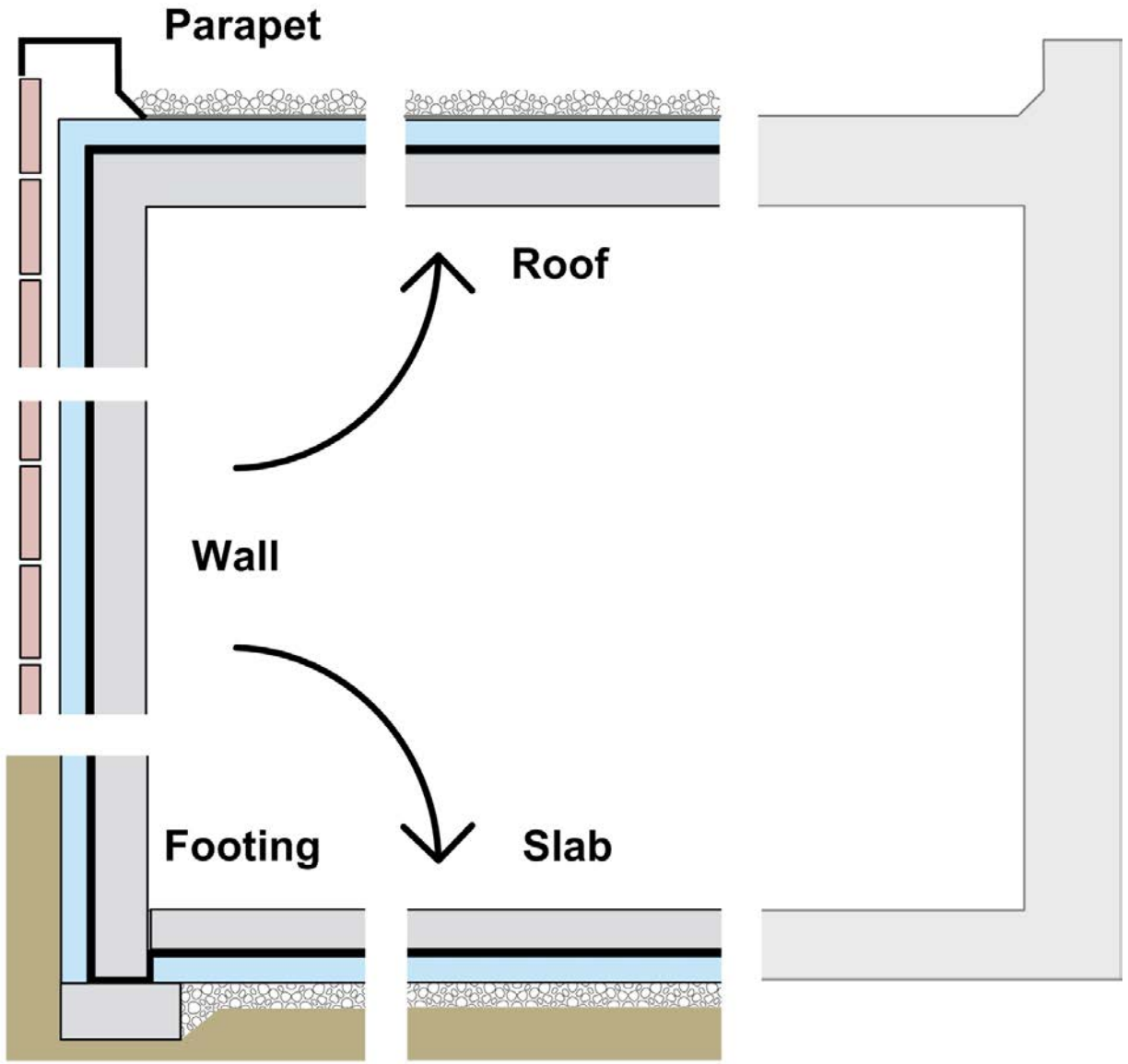


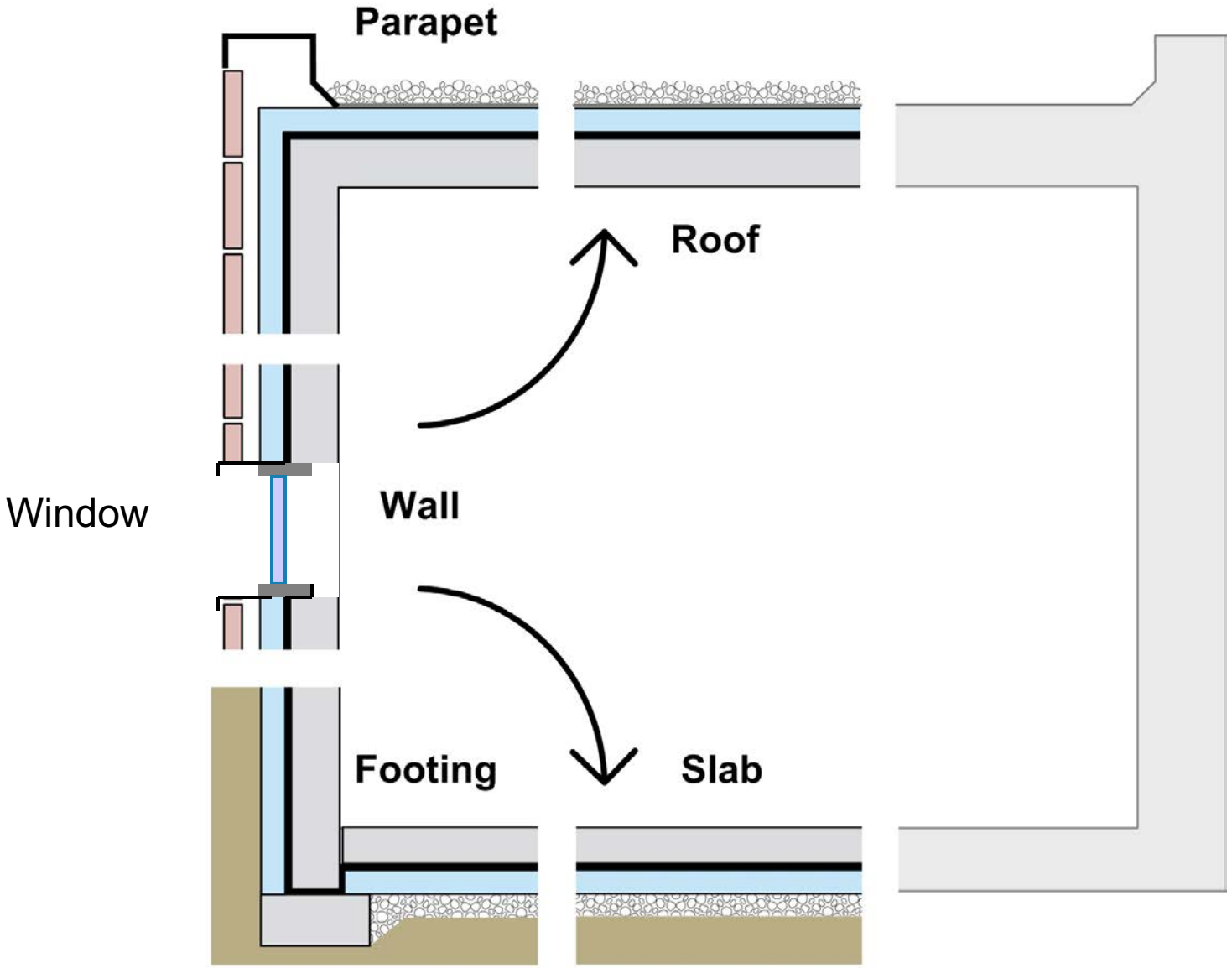

Wall

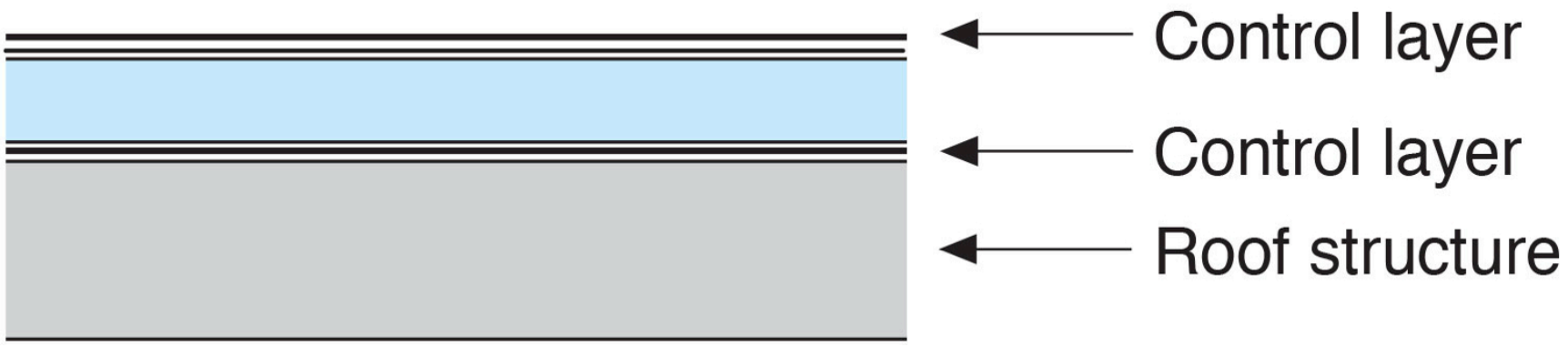

Roof
Wall

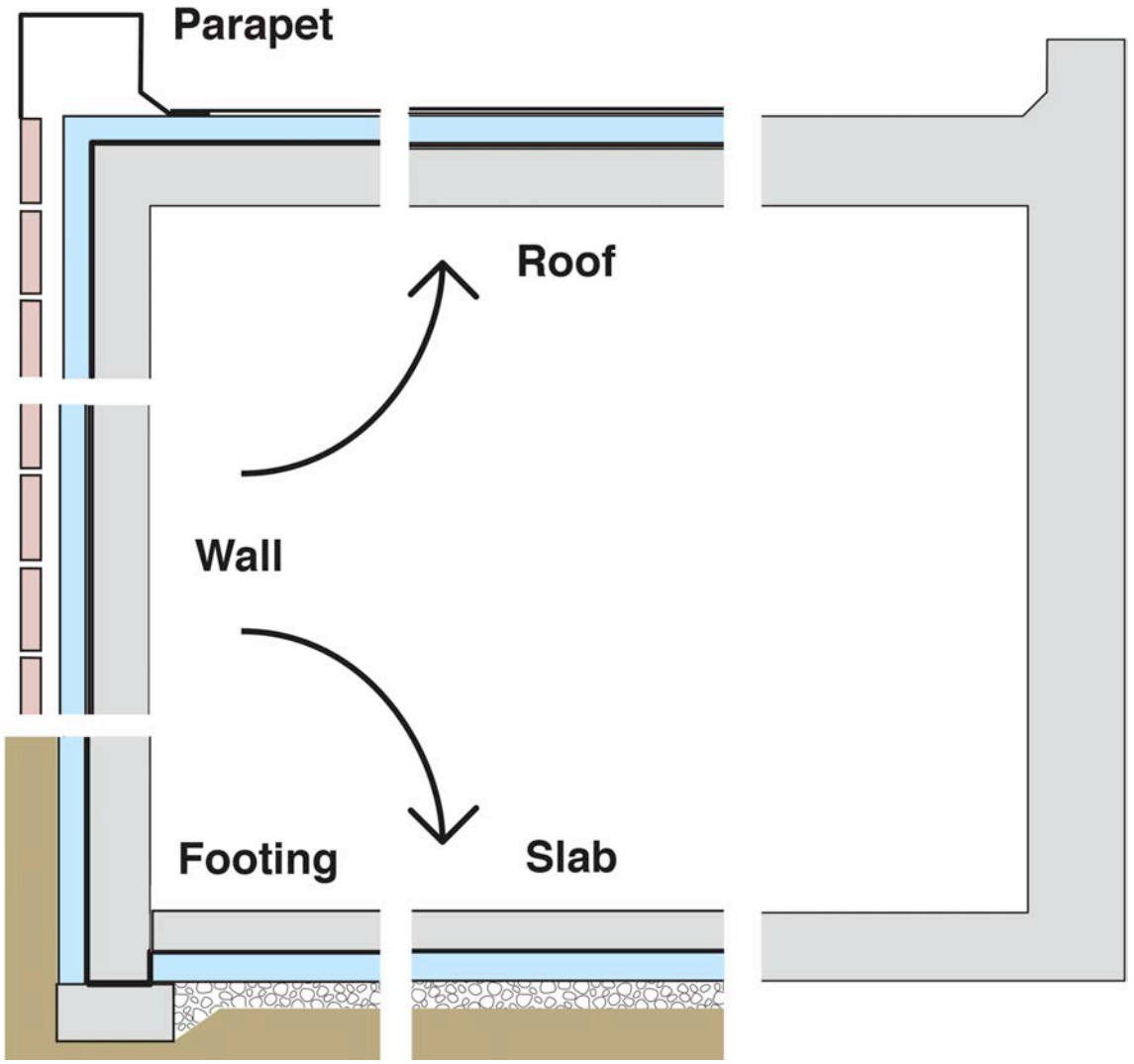

Roof
Wall
Slab

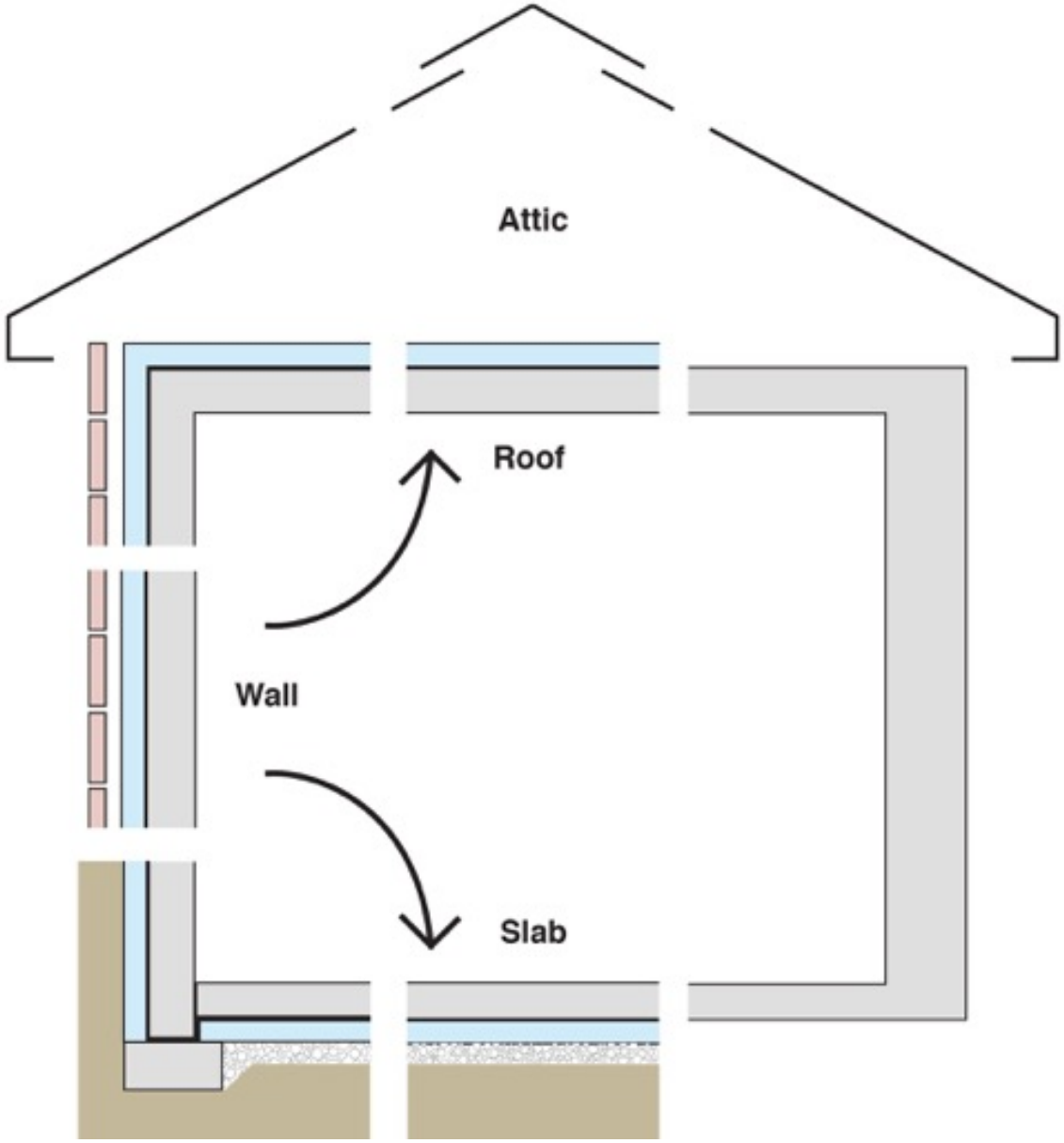

Parapet
Roof
Wall
Slab

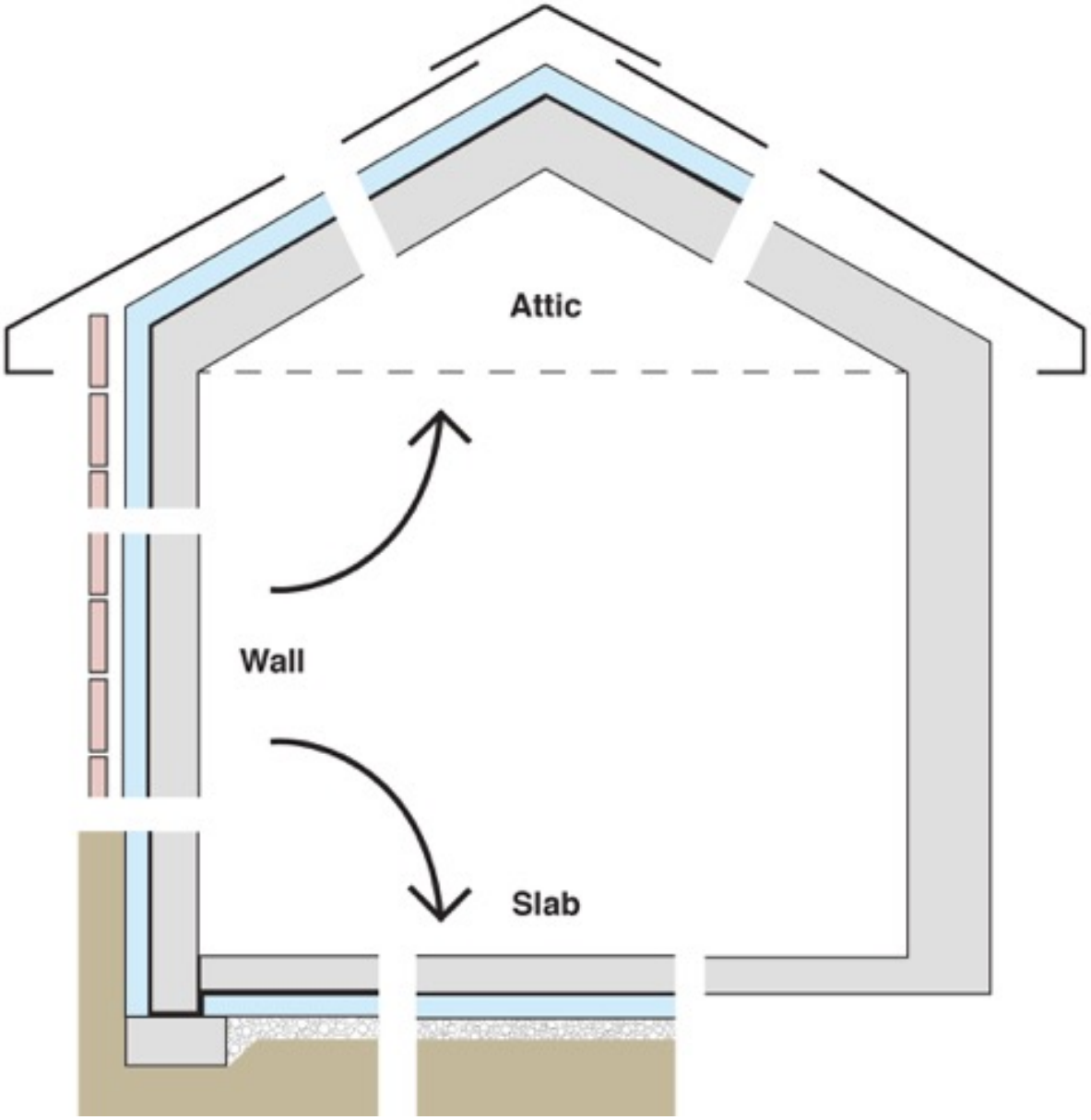

Parapet
Roof
Wall
Footing
Slab

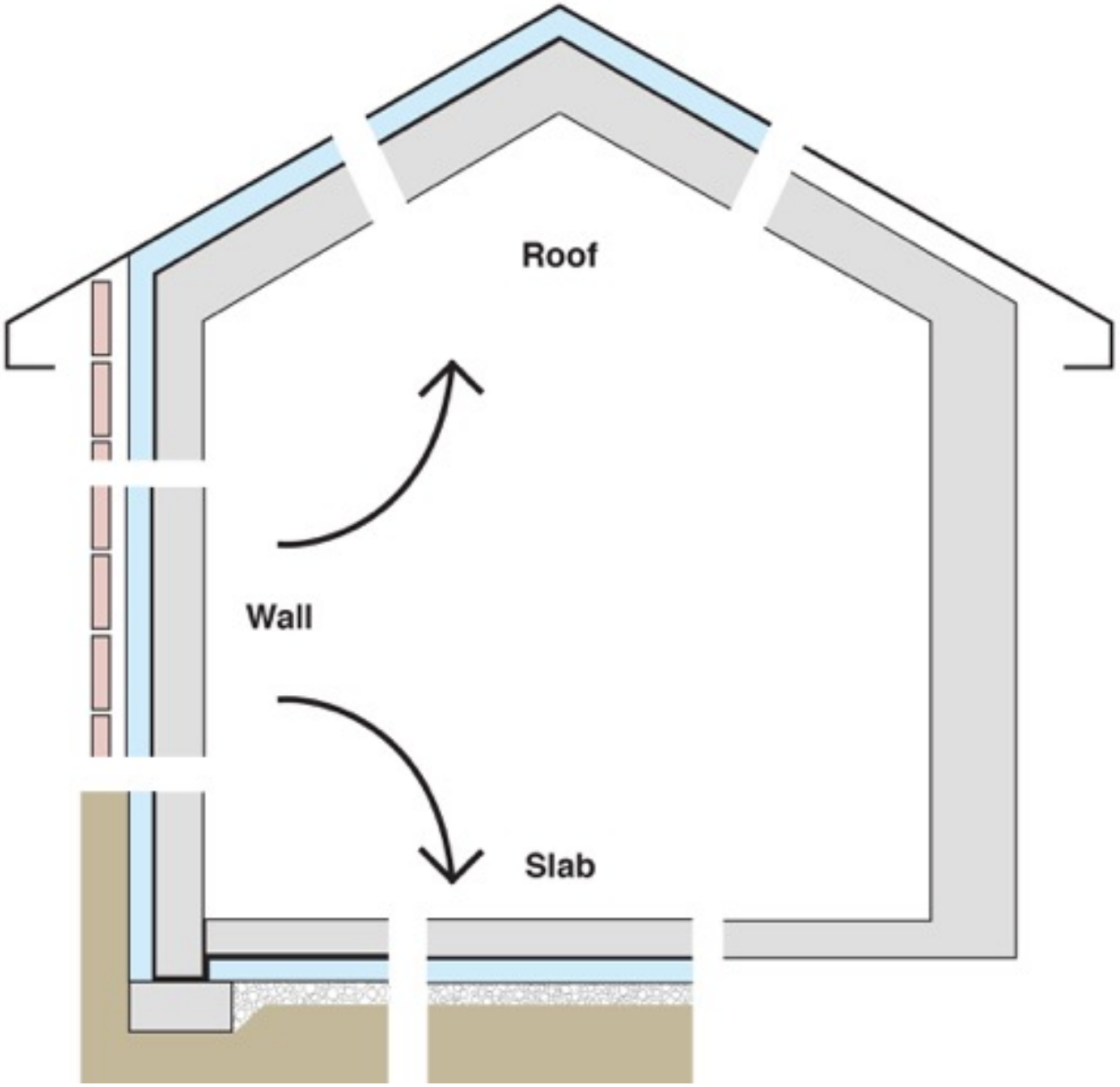

Parapet
Roof
Window
Wall
Footing
Slab

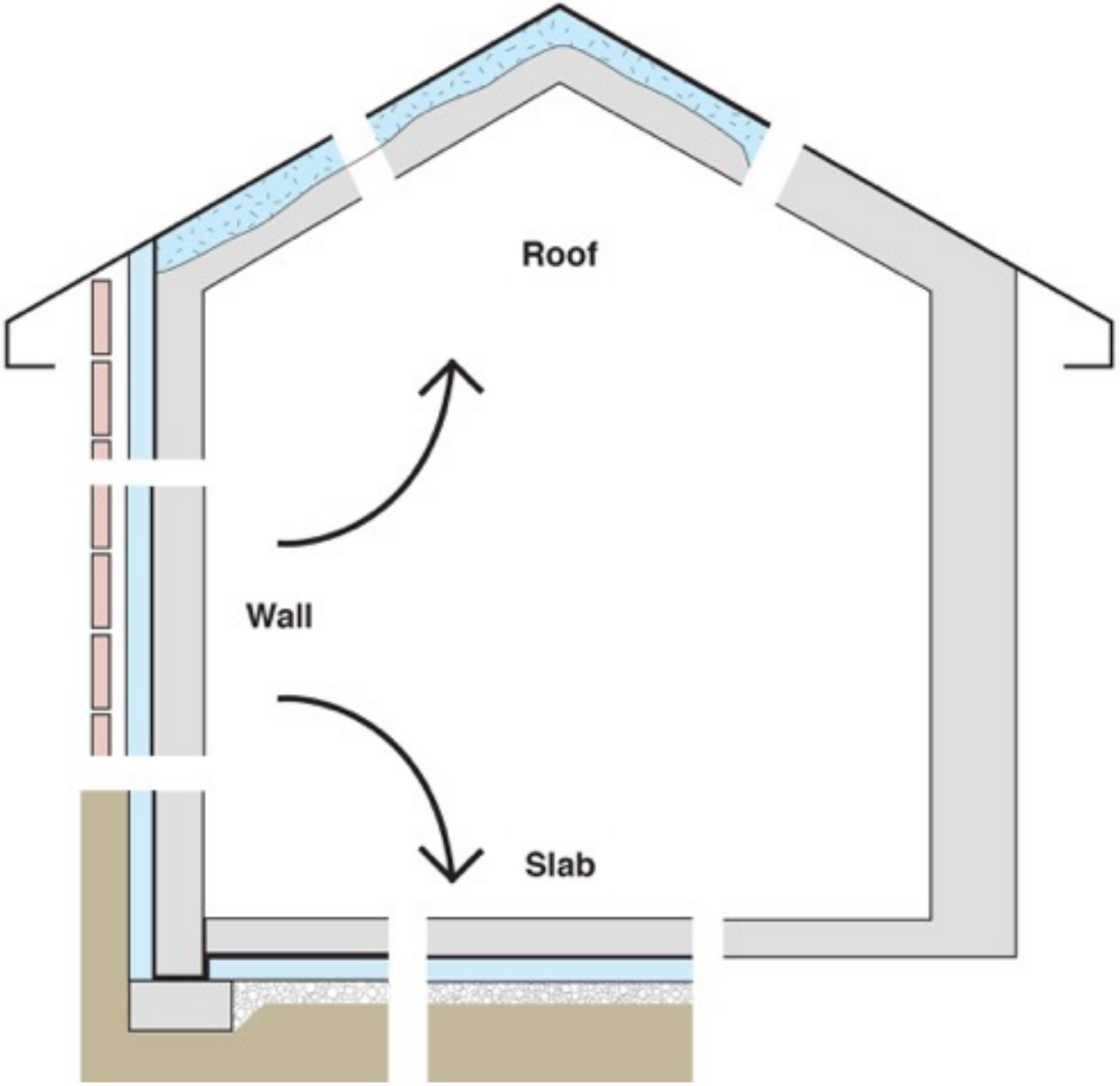

Control layer
Control layer
Roof structure


Parapet
Roof
Wall
Footing
Slab

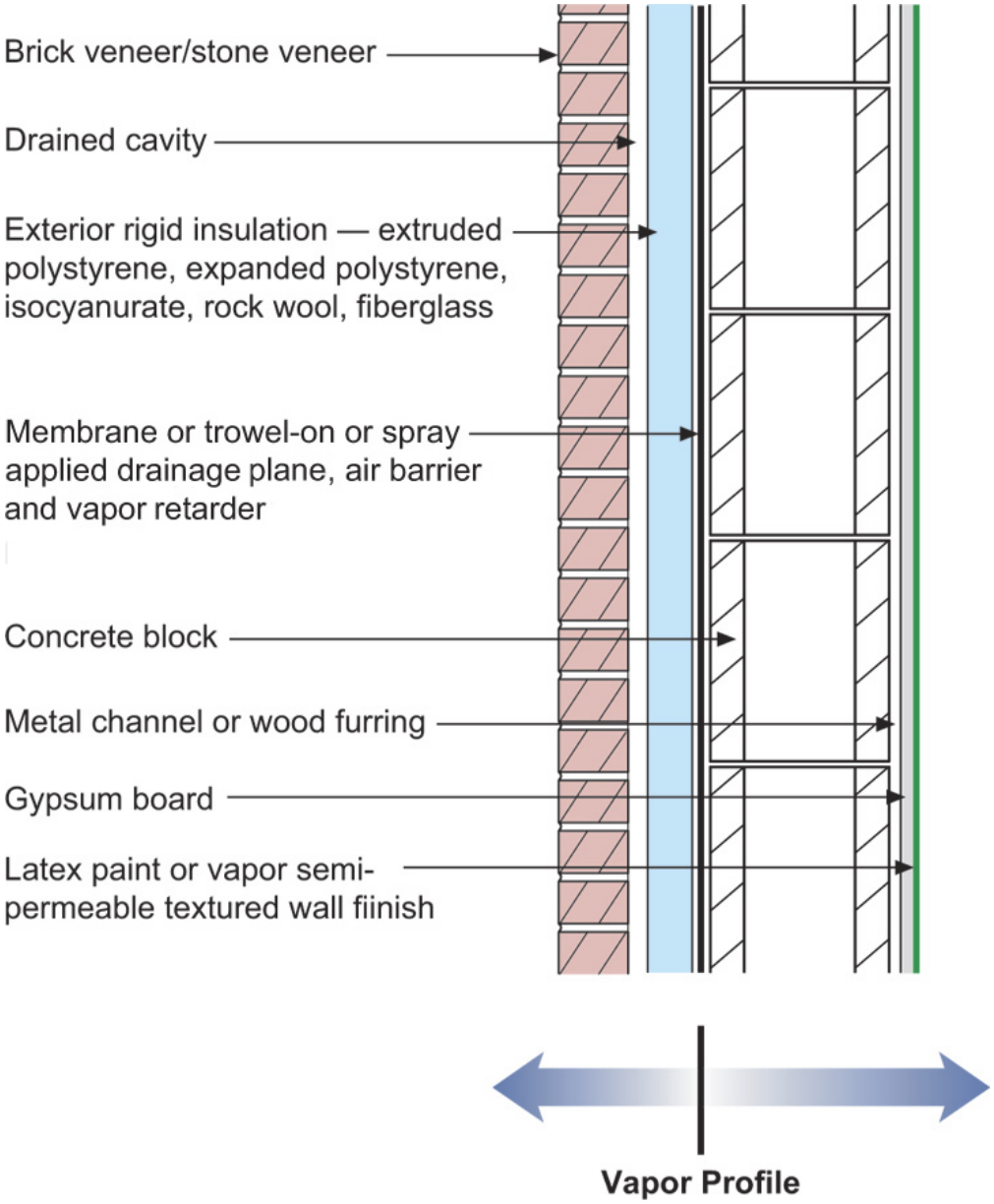

Attic
Roof
Wall
Slab

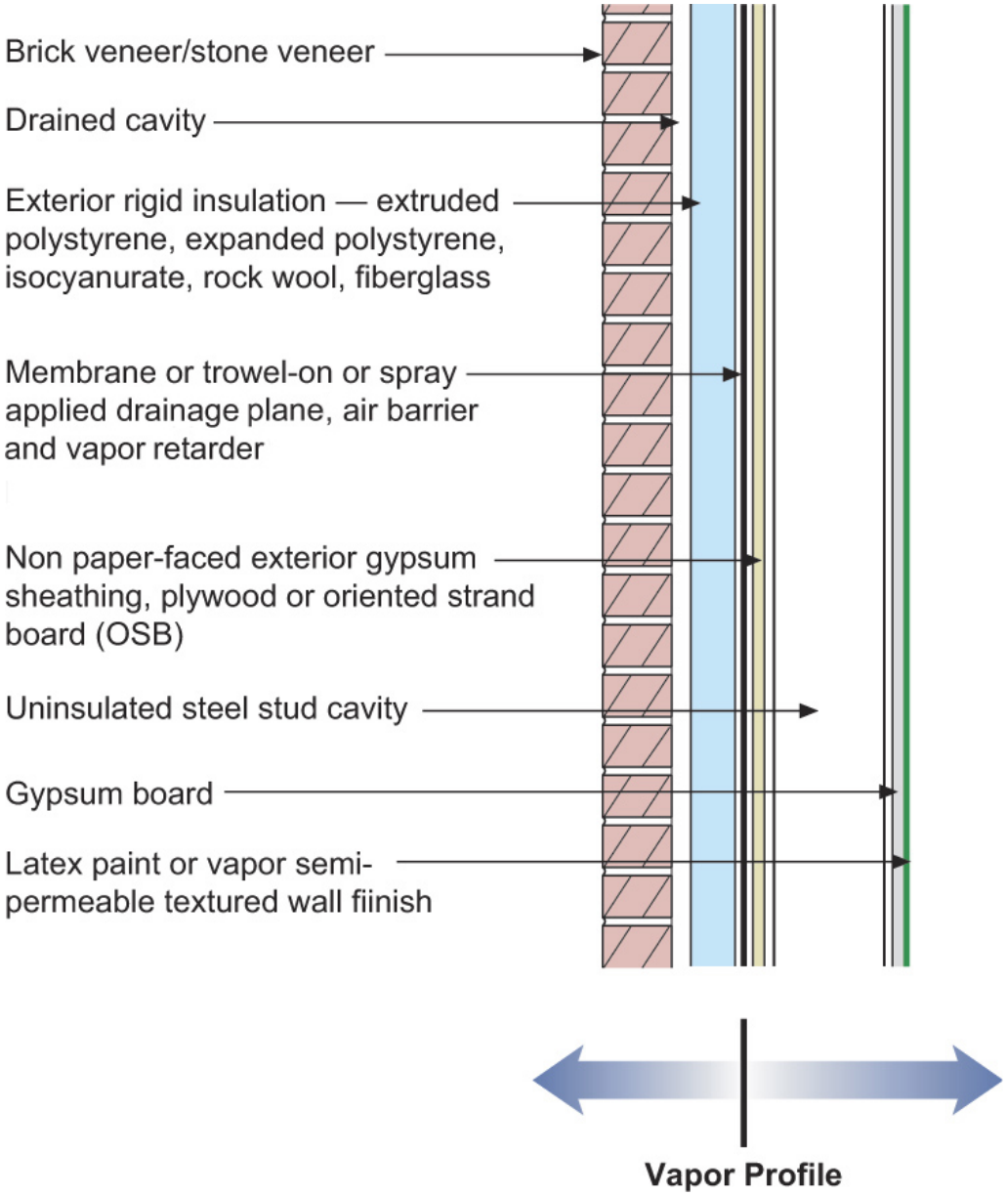

Attic
Wall
Slab

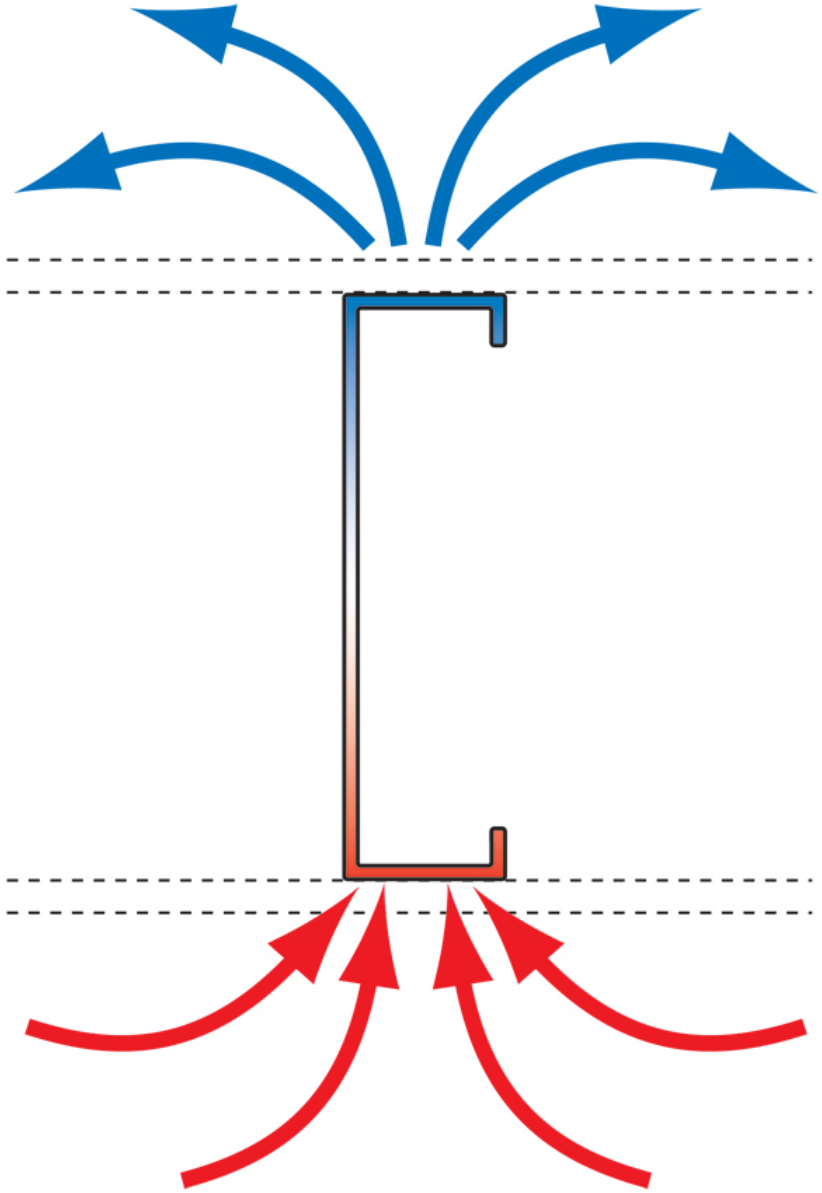

Roof
Wall
Slab

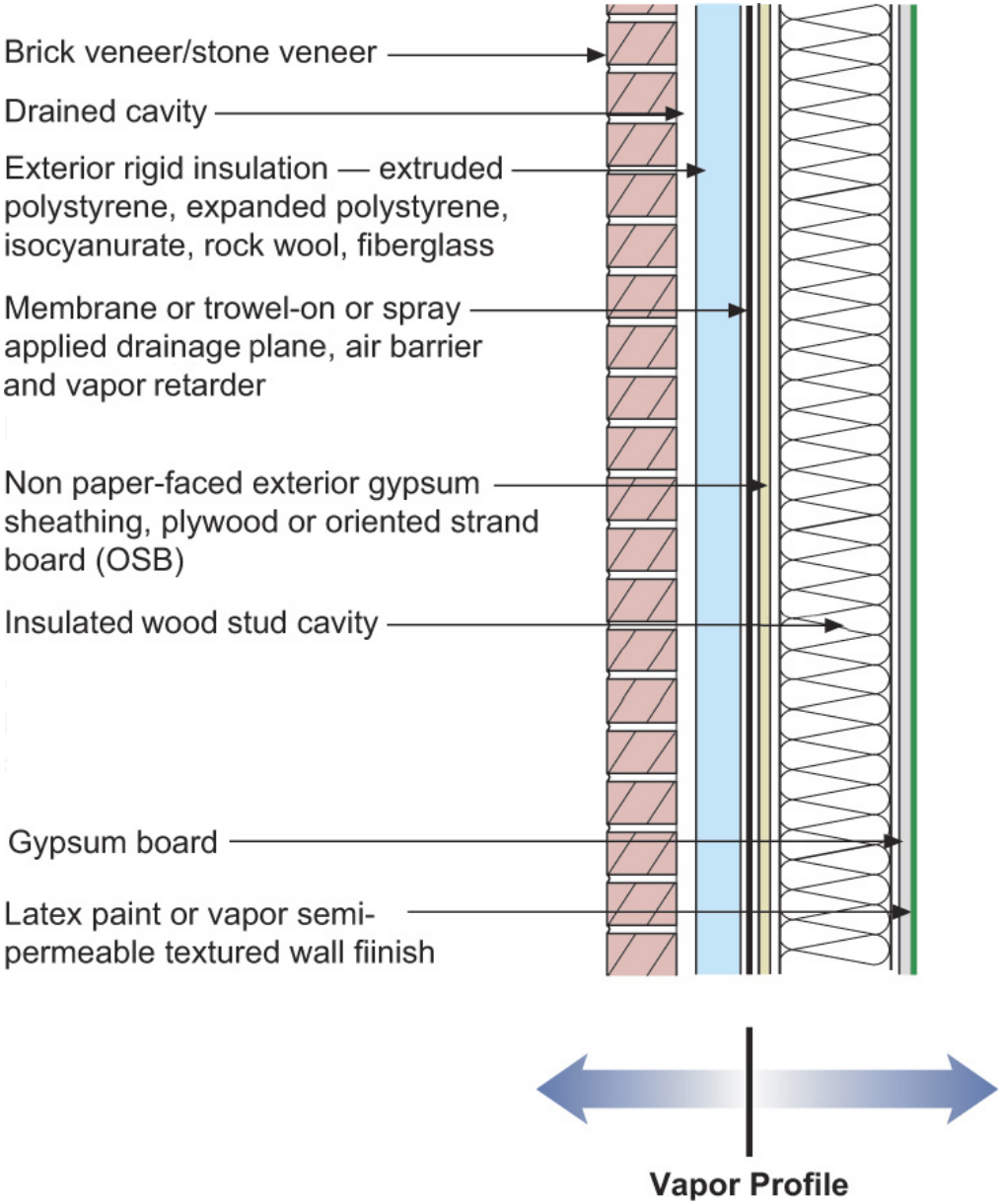

Roof
Wall
Slab

Configurations of the Perfect Wall

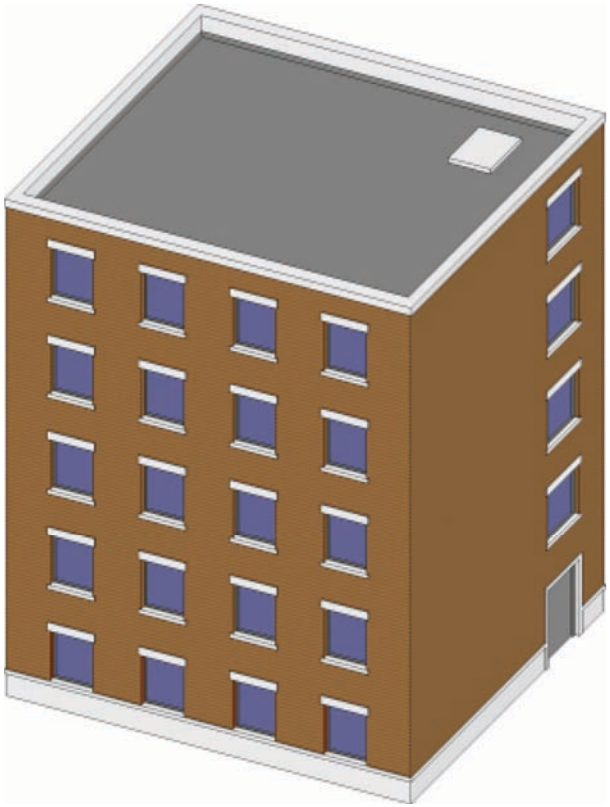

Brick veneer/stone veneer
Drained cavity
Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate, rock wool, fiberglass
Membrane or trowel-on or spray applied drainage plane, air barrier and vapor retarder
Concrete block
Metal channel or wood furring
Gypsum board
Latex paint or vapor semi-permeable textured wall fiinish
Vapor Profile


Brick veneer/stone veneer
Drained cavity
Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate, rock wool, fiberglass
Membrane or trowel-on or spray applied drainage plane, air barrier and vapor retarder
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
Vapor Profile

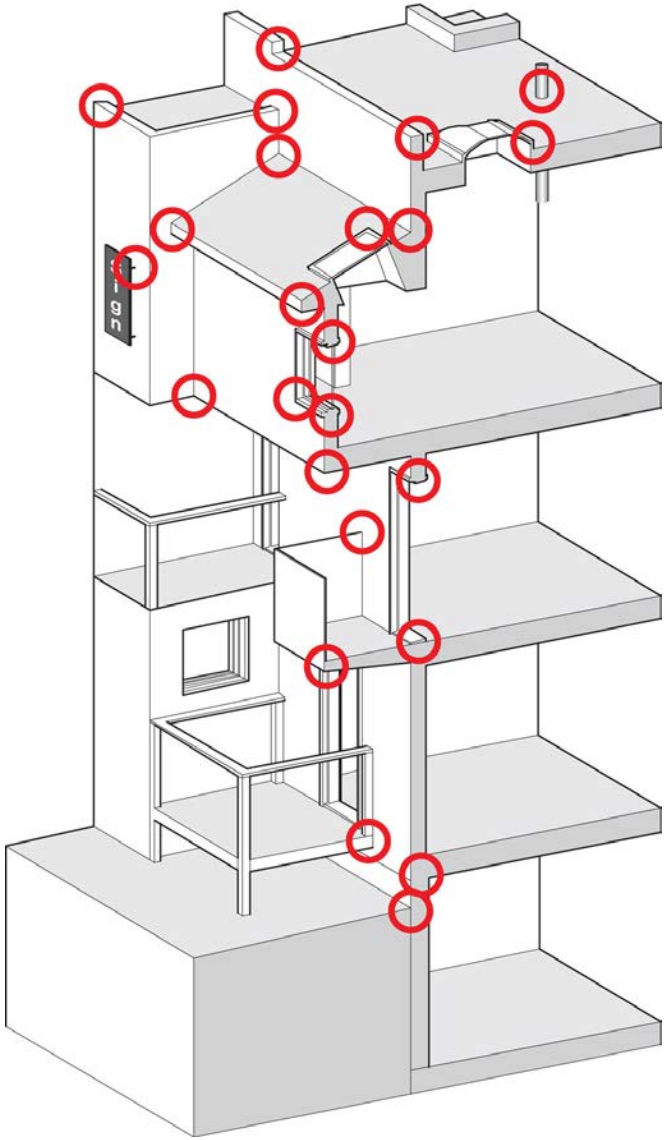


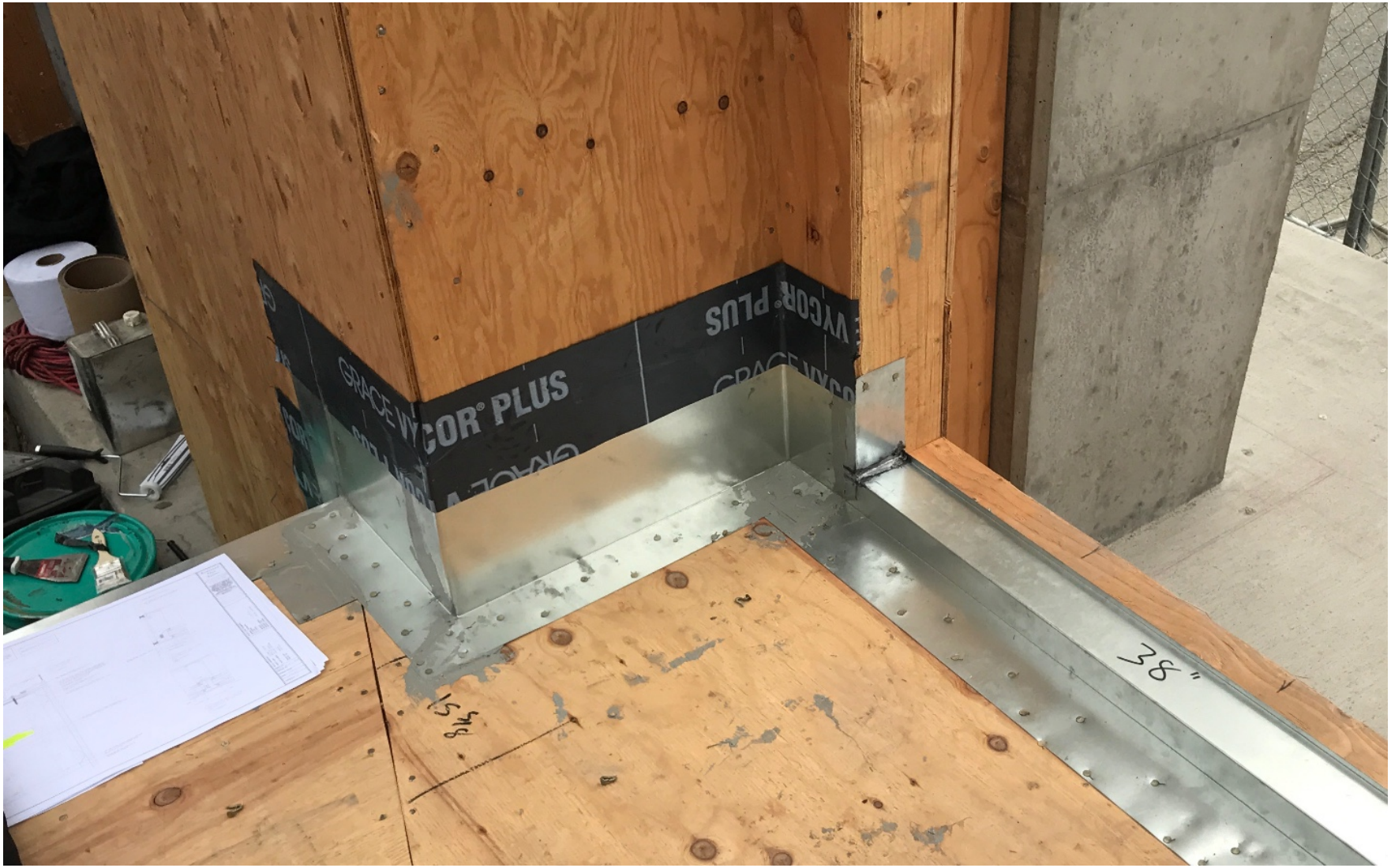

Brick veneer/stone veneer
Drained cavity
Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate, rock wool, fiberglass
Membrane or trowel-on or spray applied drainage plane, air barrier and vapor retarder
Non paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)
Insulated wood stud cavity
Gypsum board
Latex paint or vapor semi-permeable textured wall fiinish
Vapor Profile

Commercial Enclosure: Simple Layers



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

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MEL-ROL

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DUPONT

StraightFlash
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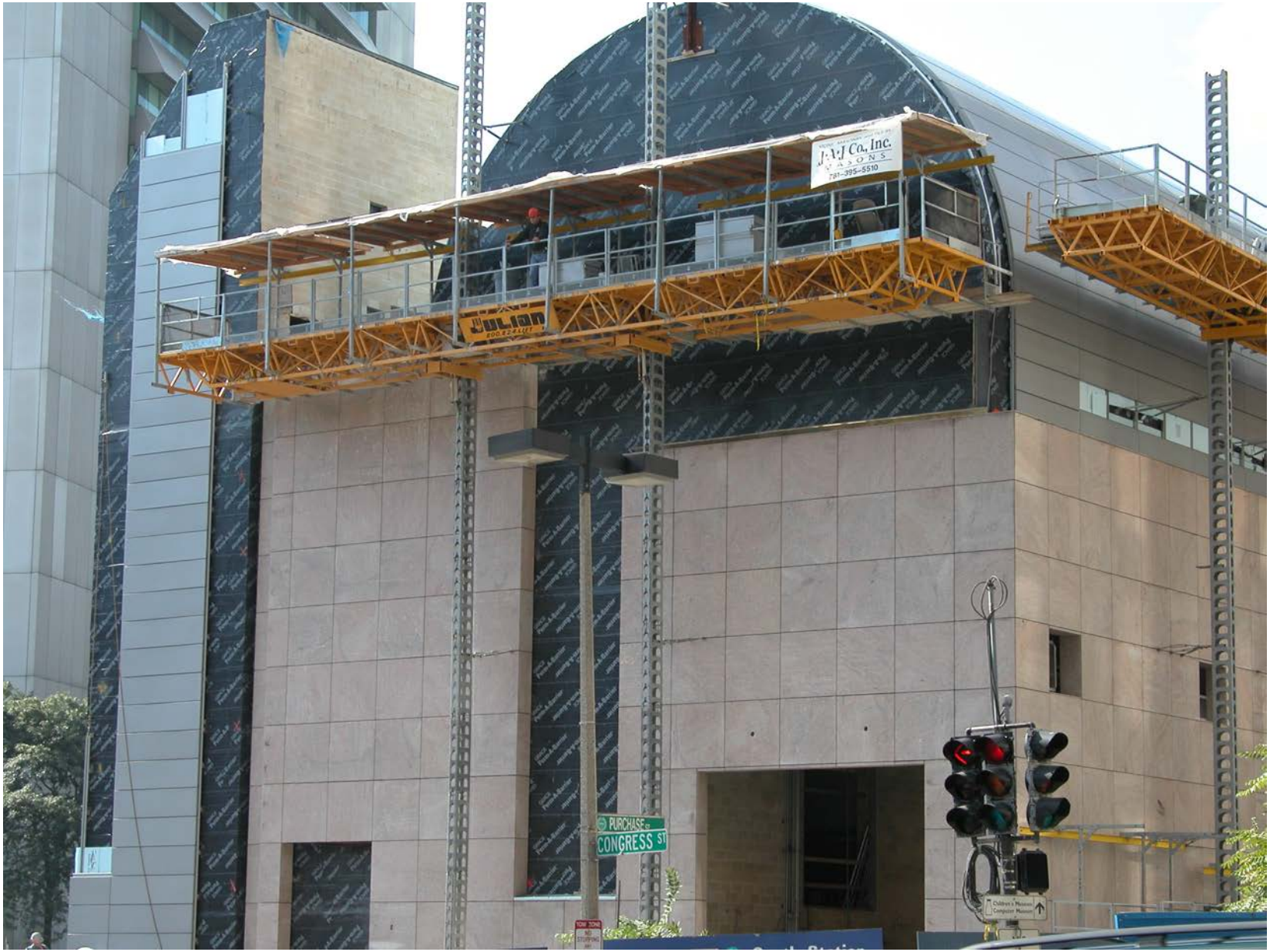
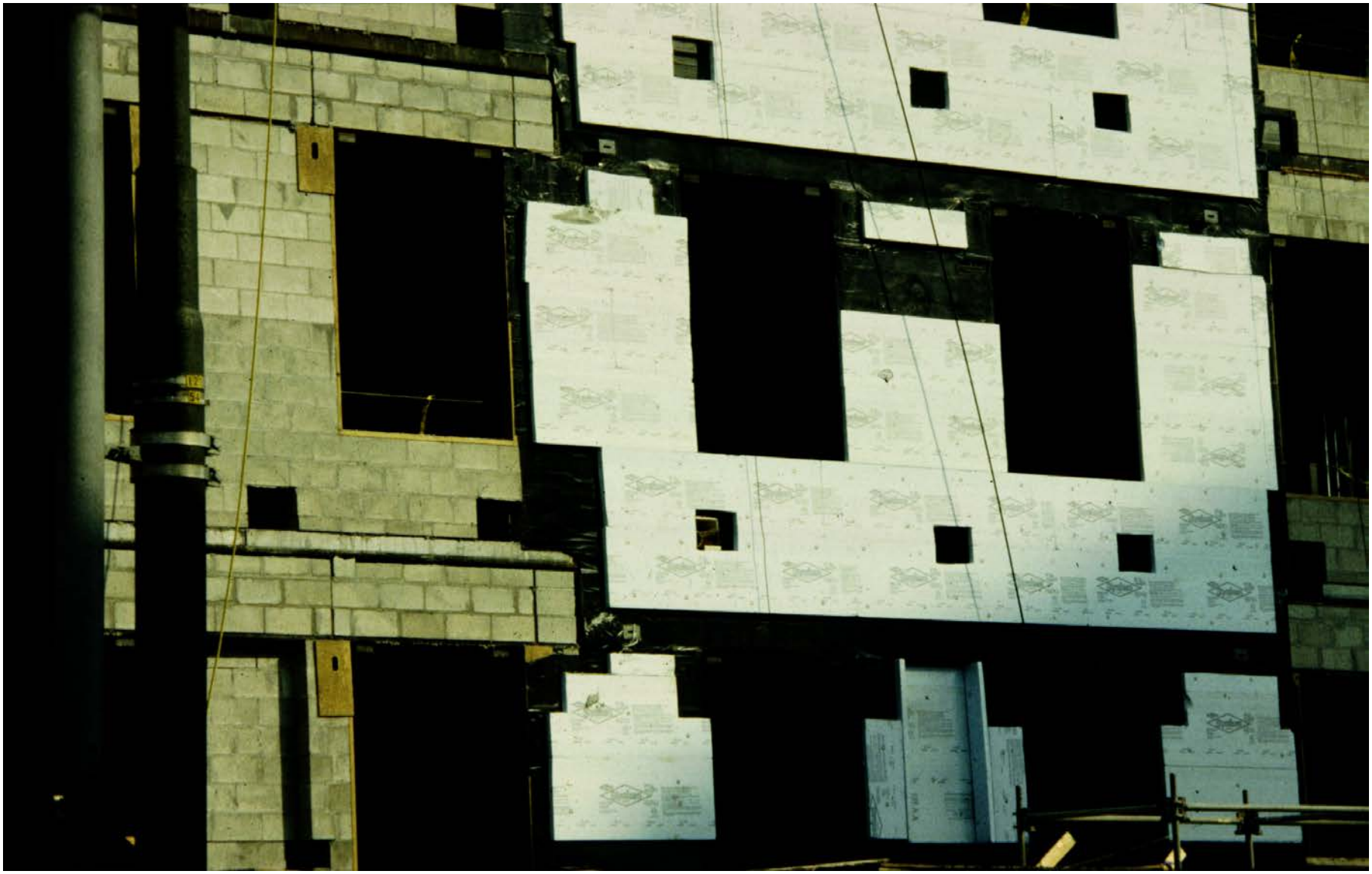
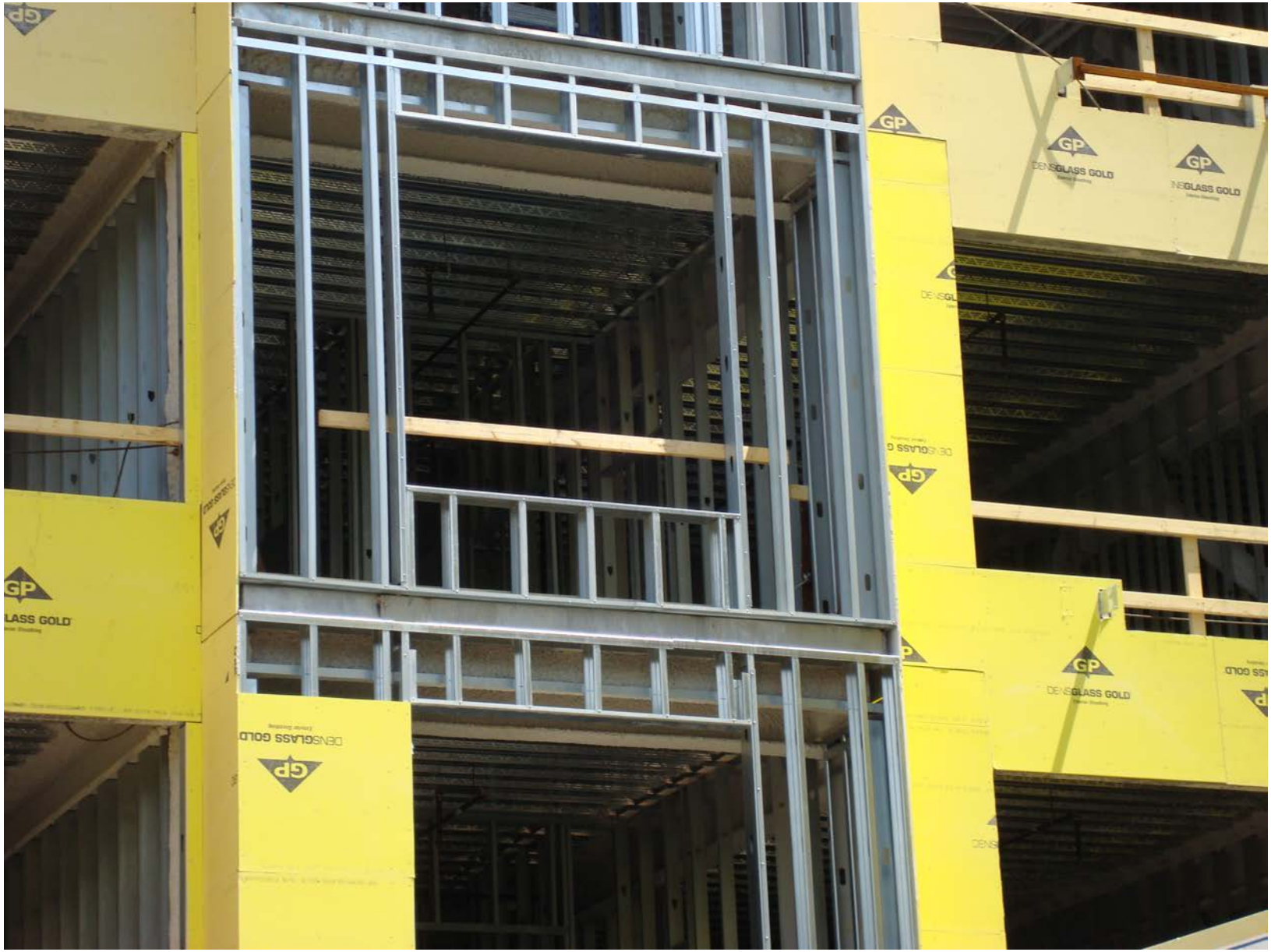

J·V·J Co., Inc.
MASONS
781-395-5510
JULIAN
PURCHASE ST
CONGRESS ST



HARVARD SCHOOL OF PUBLIC HEALTH

CAVITYMAT
CAVITYMAT

ALL VISITORS
MUST SIGN IN
AT
JOHN MORIARTY
AND ASSOCIATES
FIELD OFFICE
CAUTION
HARD HAT
AREA
WORKSITE


GP
DENSGLASS GOLD

DENSGLASS GOLD
Exterior Sheathing
DENSGLASS GOLD
Exterior Sheathing

Blueskin

Street Cleaning

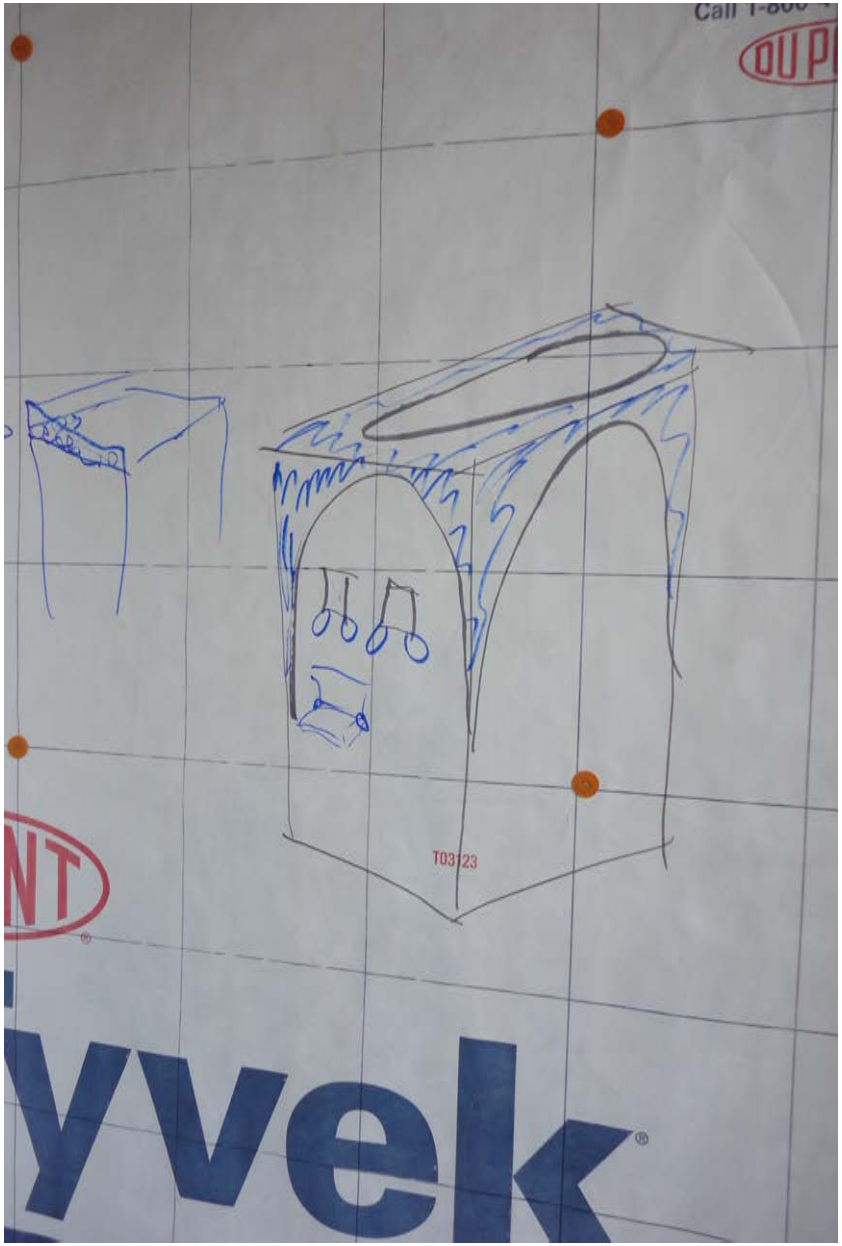
REPUBLIC

AVAILAB
978-369-4

GP
DensGlass
Sheathing

MARKET BASKET
DensGlass

Tyvek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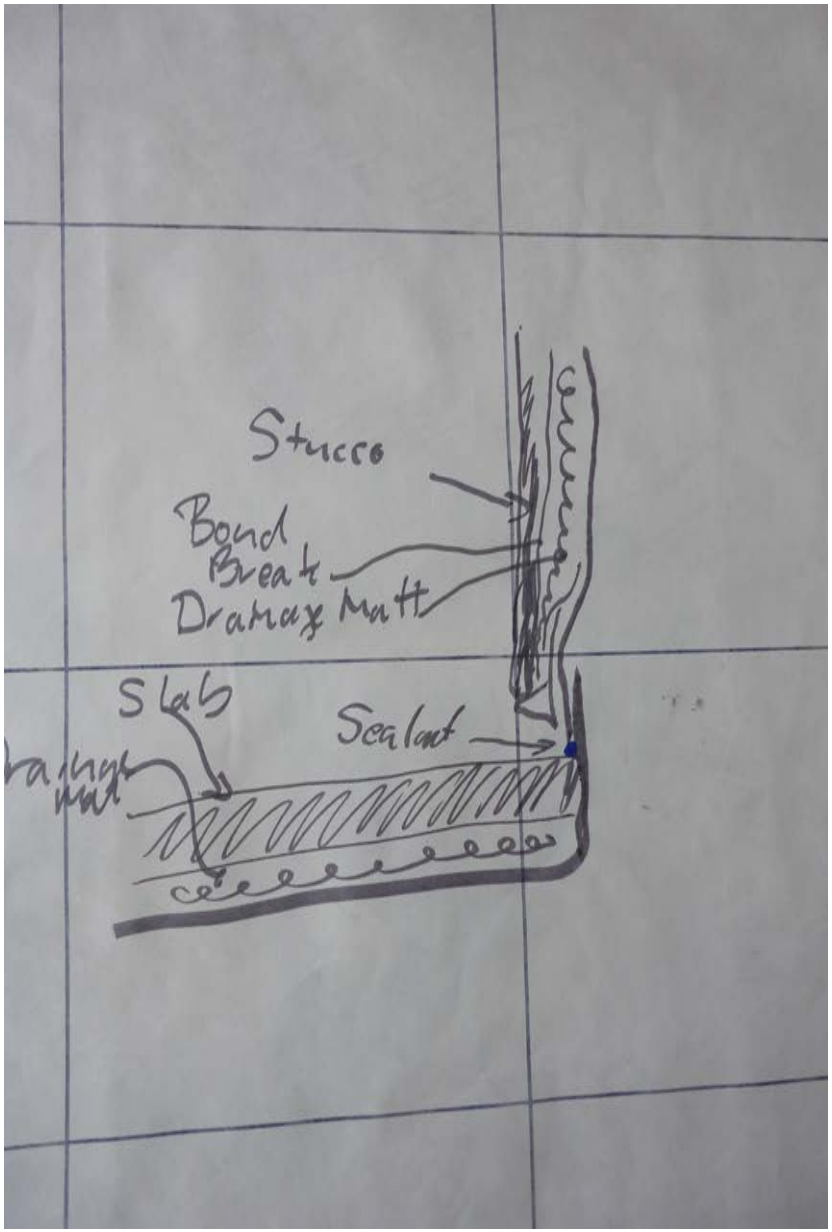
Stucco
Bond Break
Drainage Matt
Slab
Sealant

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AREA
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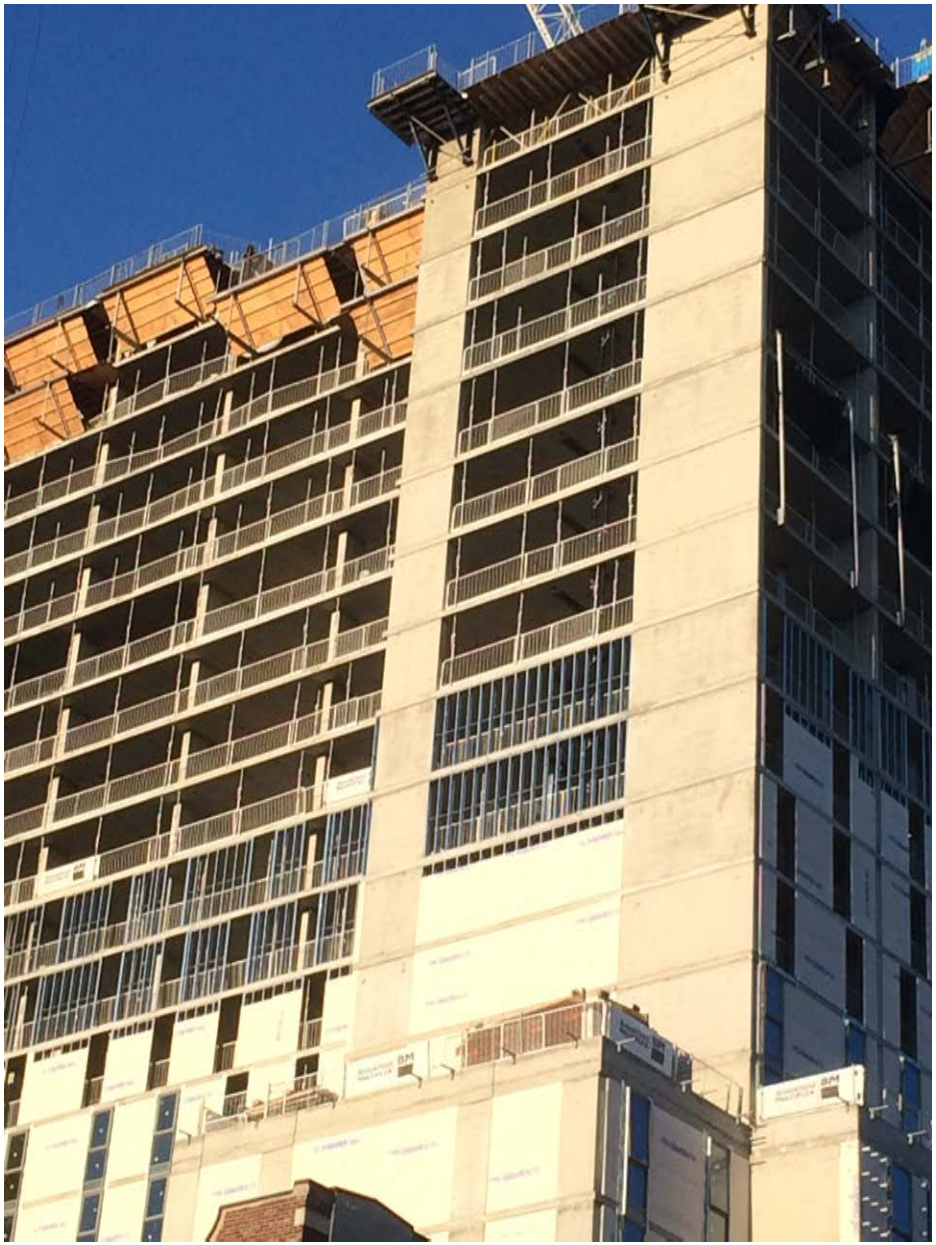
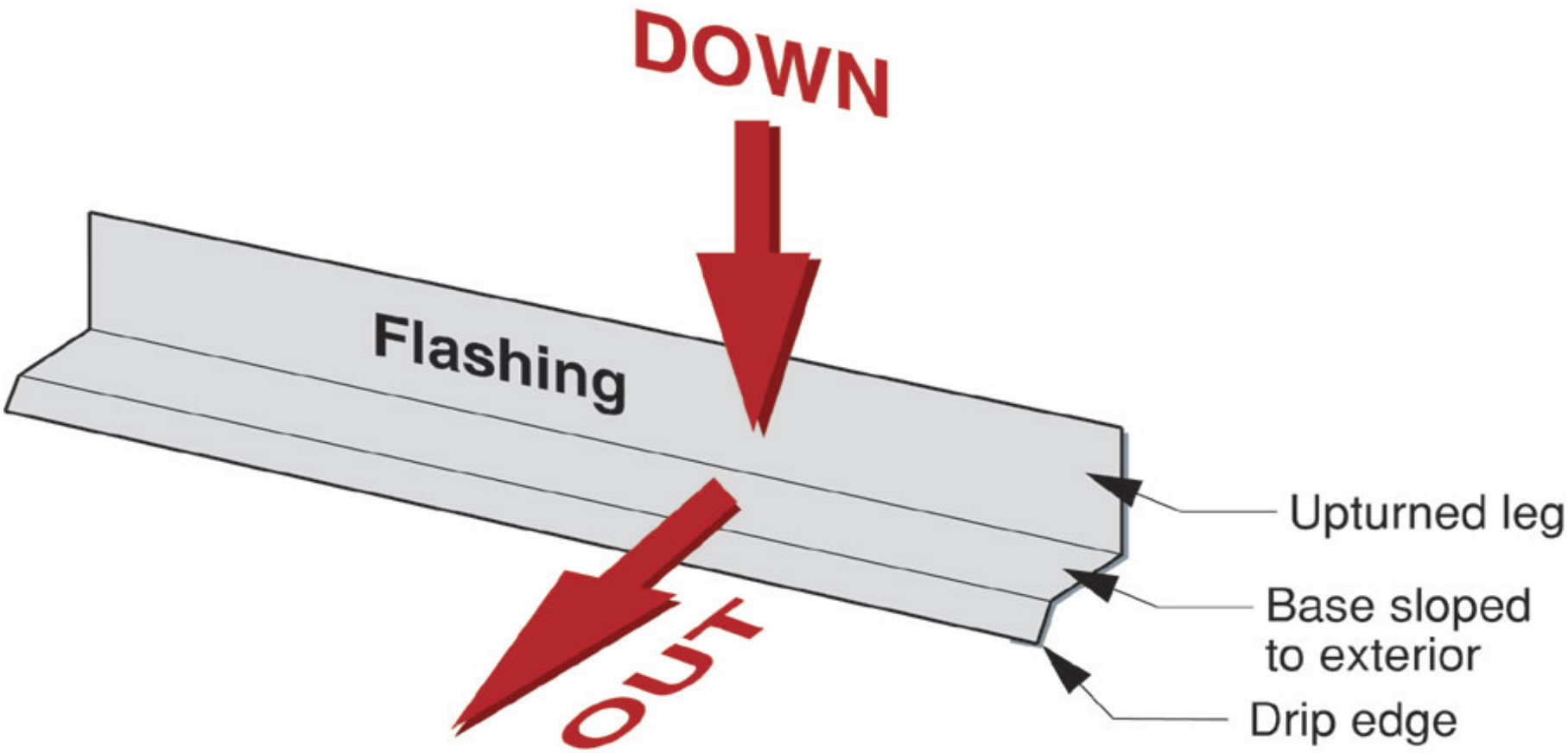
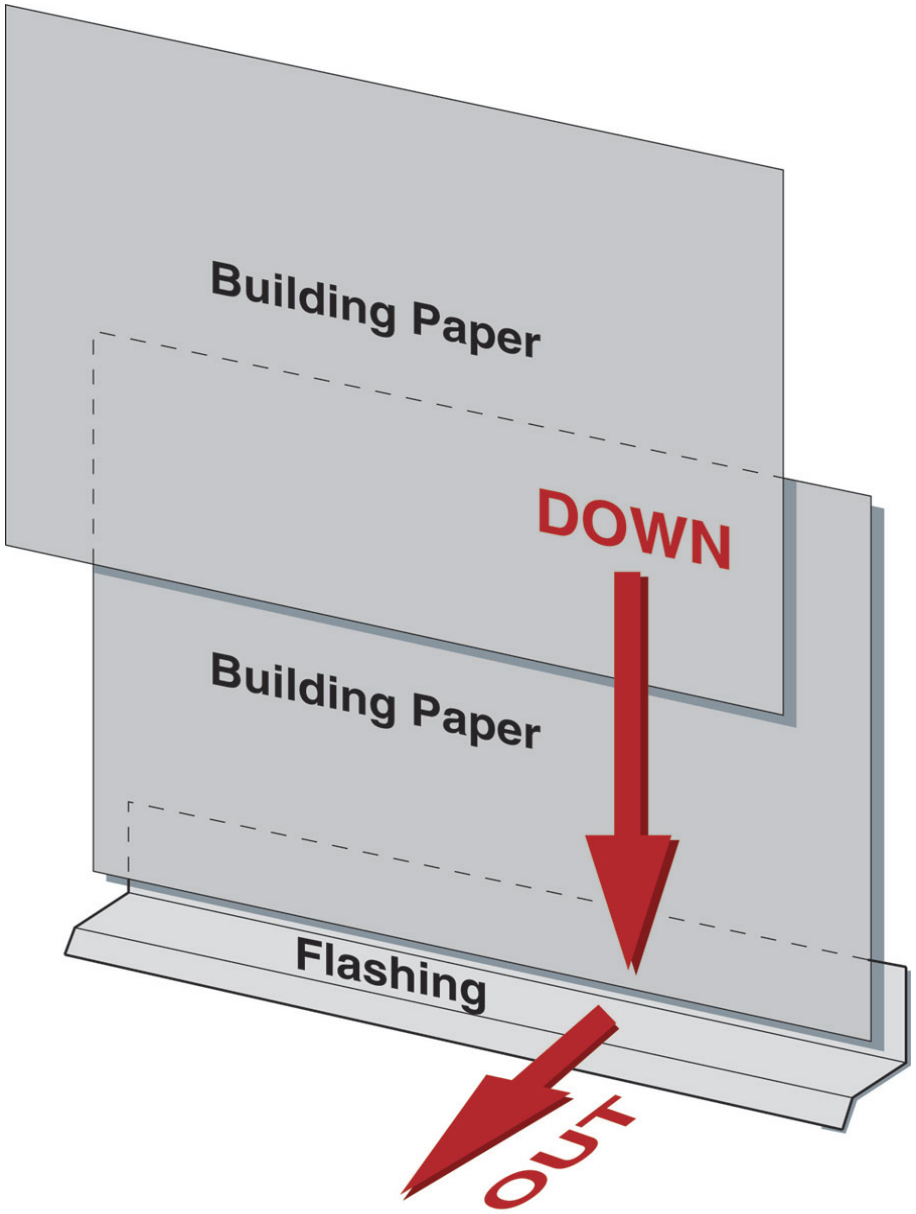
LUCIANO



Tribute
Parking
FOR LEASE
WALK-IN CLINIC

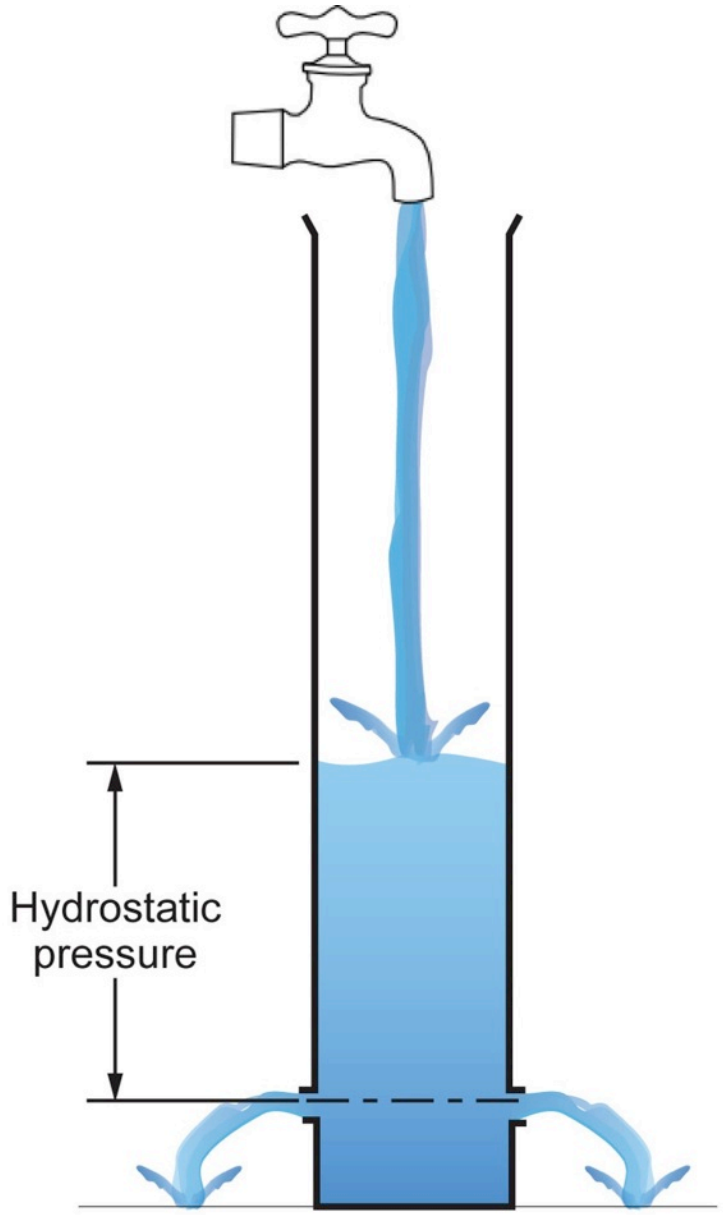
Tribute
Tribute
Tribute

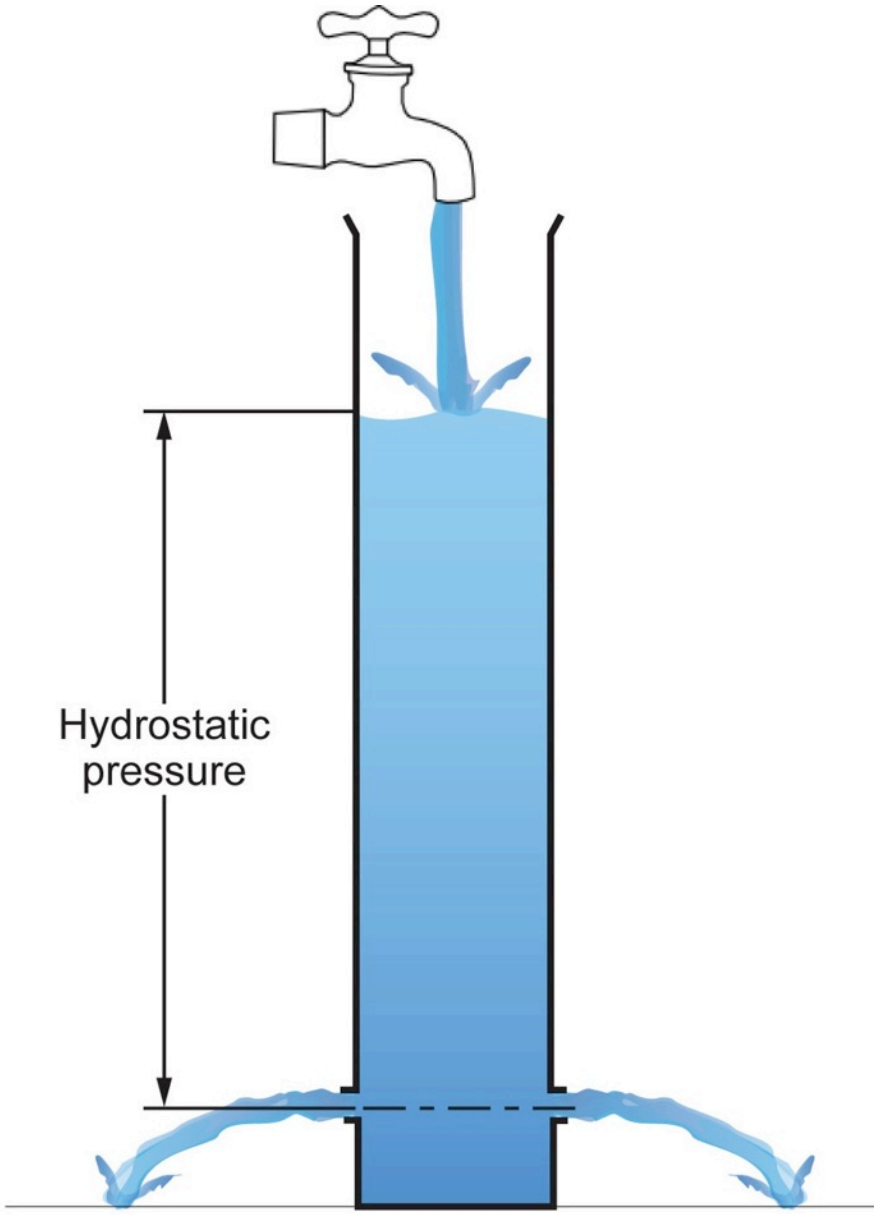

DOWN
Flashing
OUT
Upturned leg
Base sloped
to exterior
Drip edge


Building Paper
DOWN
Building Paper
Flashing
OUT

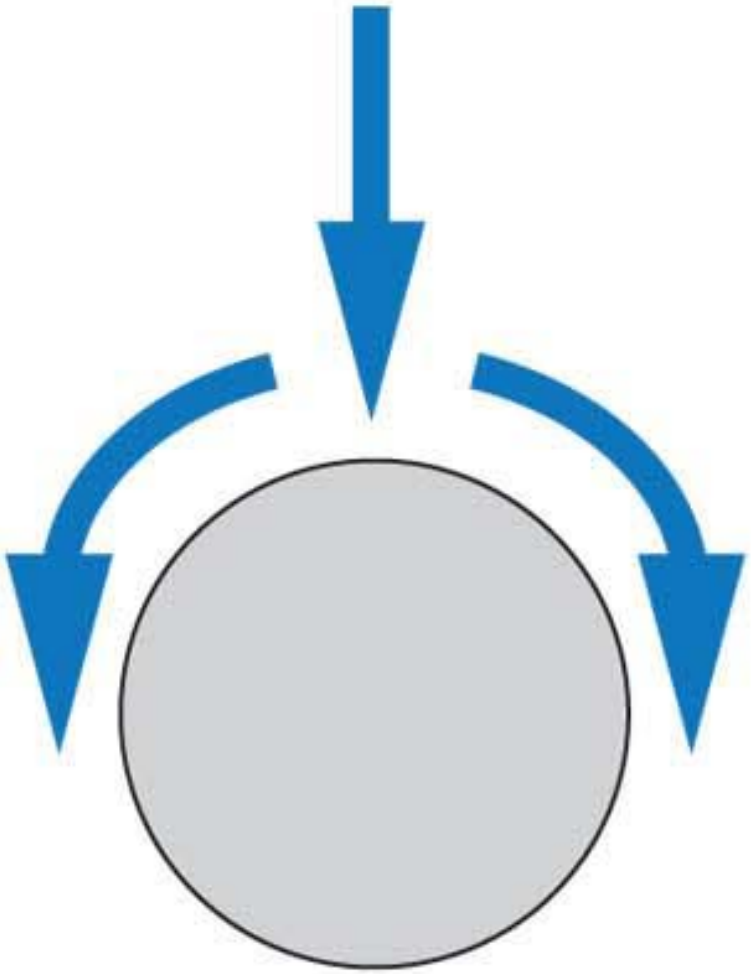
GP
sGlass™
eathing
GP
DensG
Sheathi
THIS SIDE OUT
ROOFS.

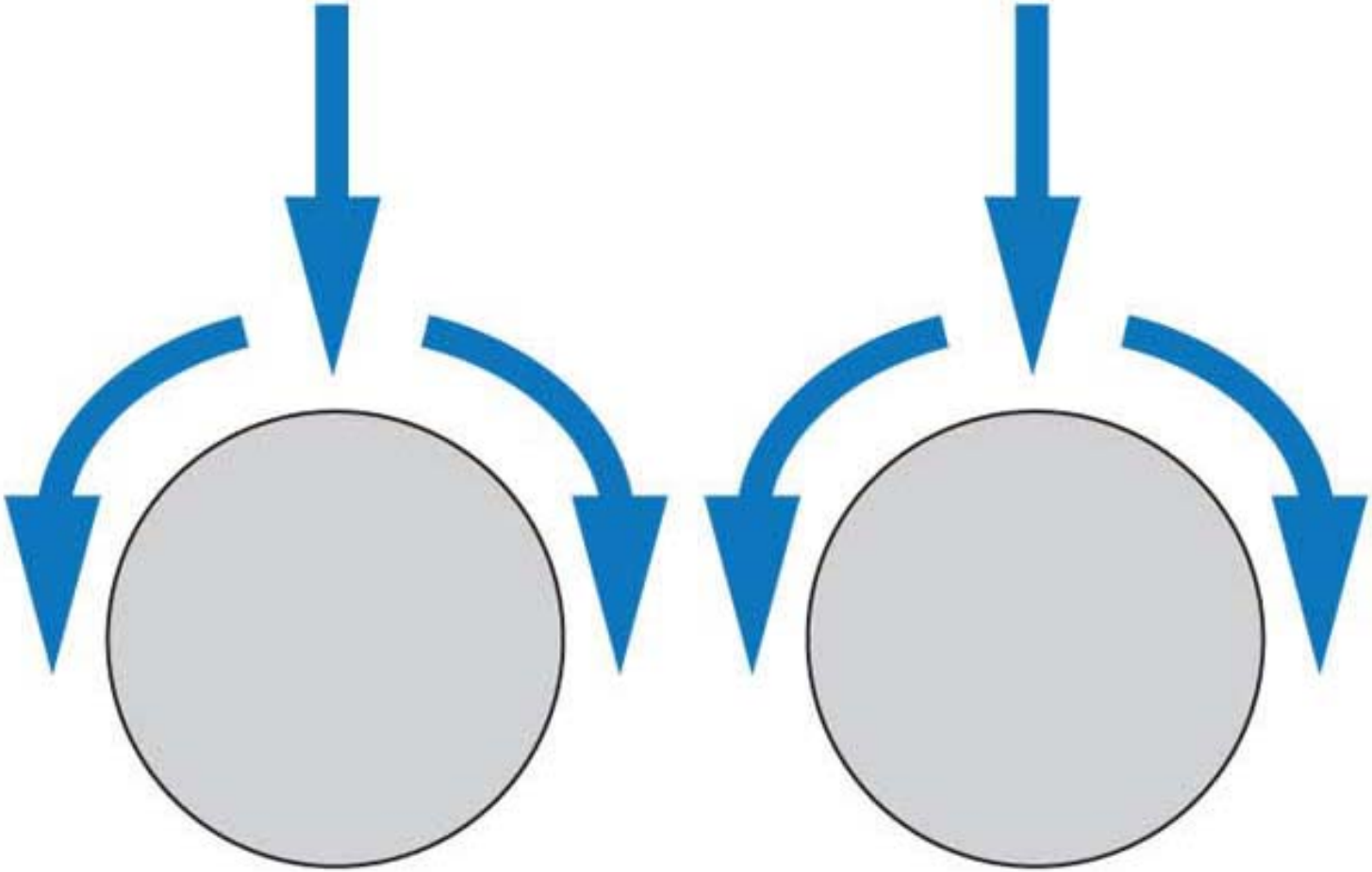
rmax ci
Isolant extérie
Thermax ci
Aislamiento Ext
THERM X ci

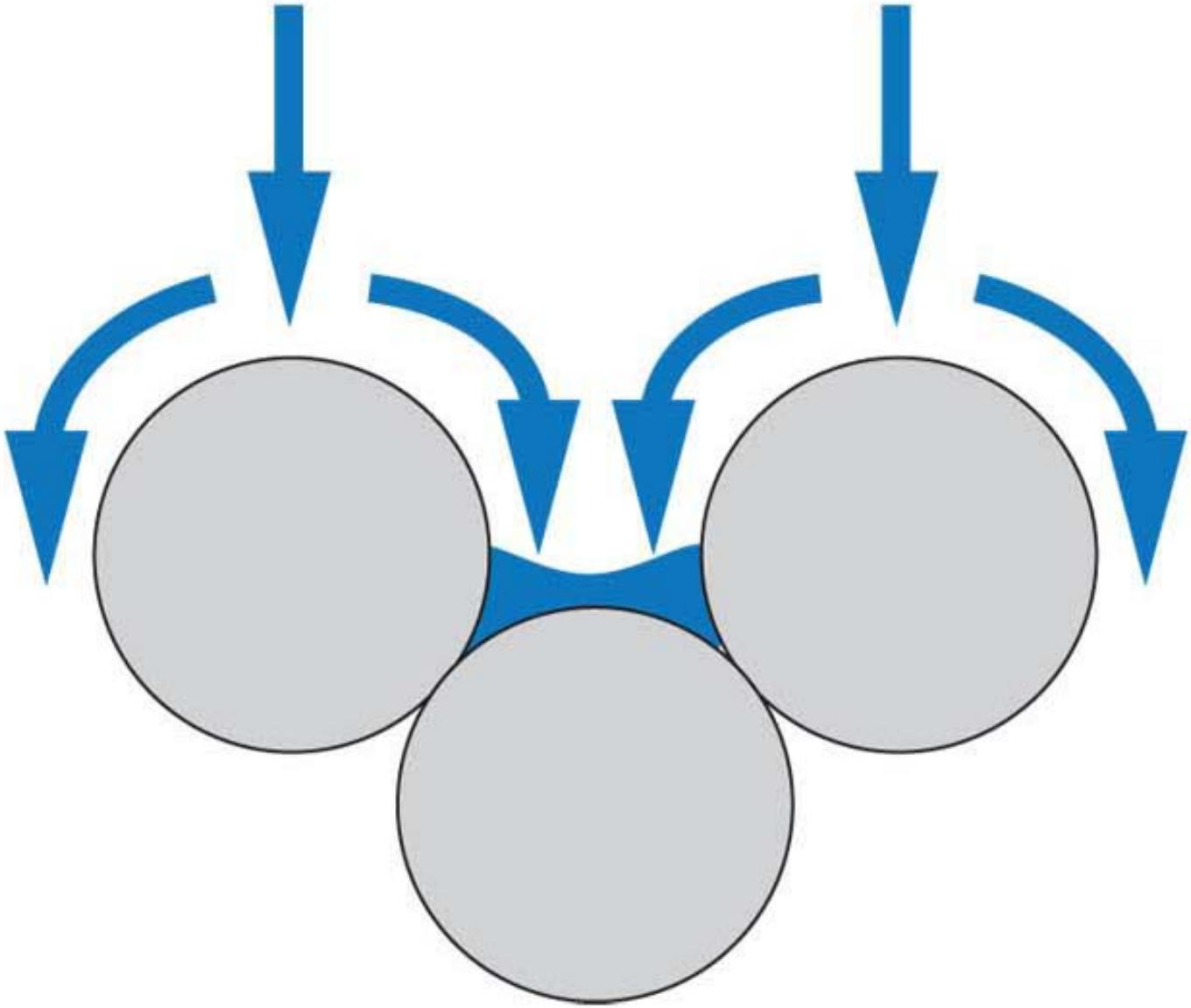

Hydrostatic
pressure

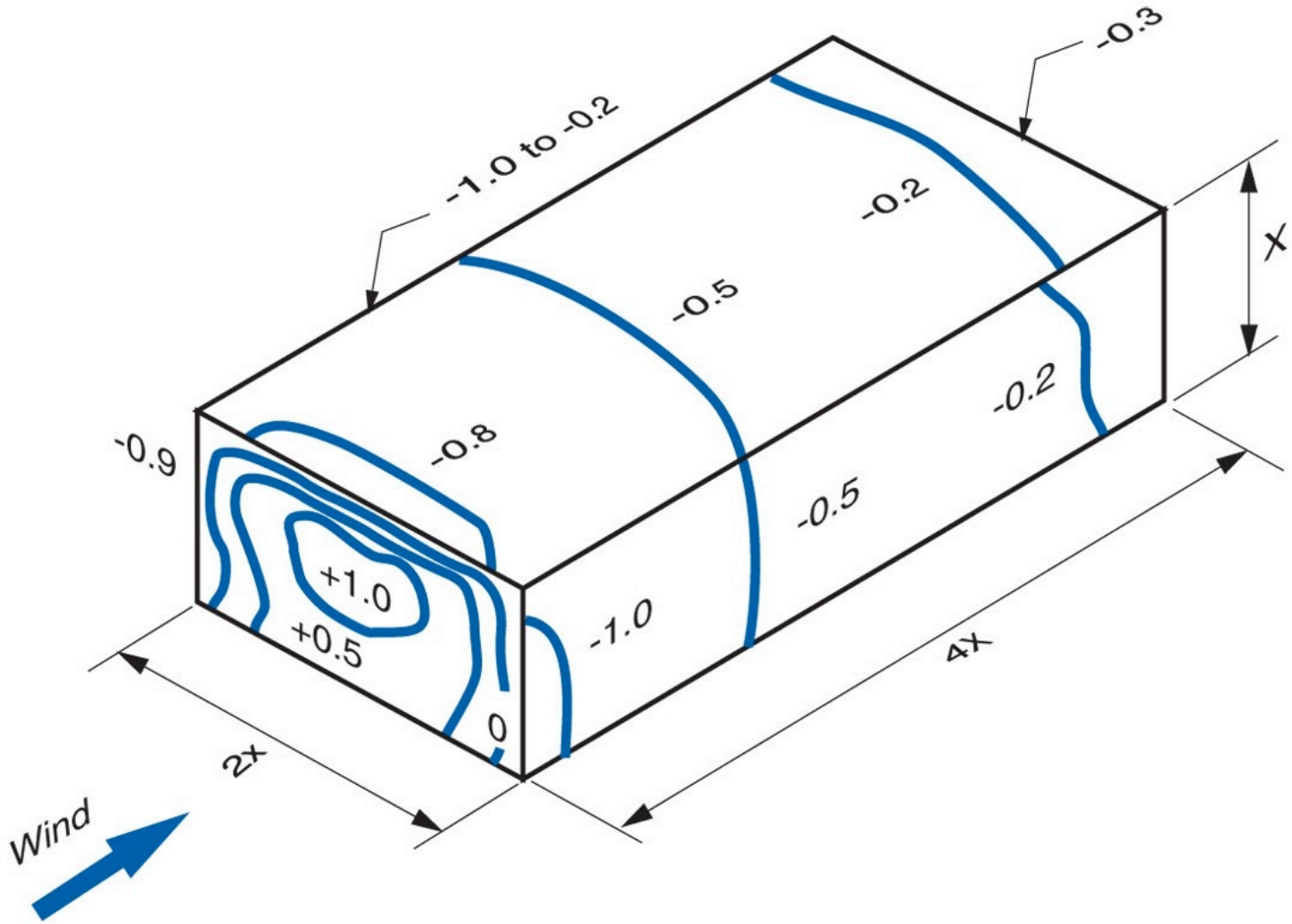

Hydrostatic
pressure

PUBLIC

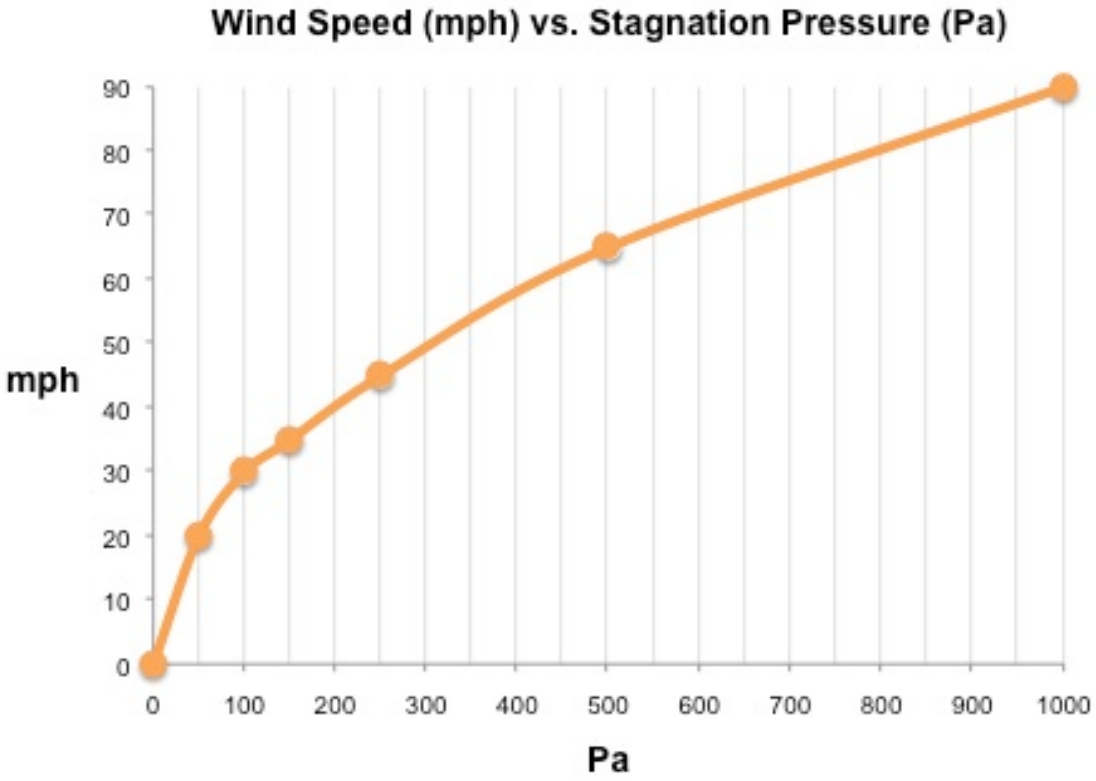






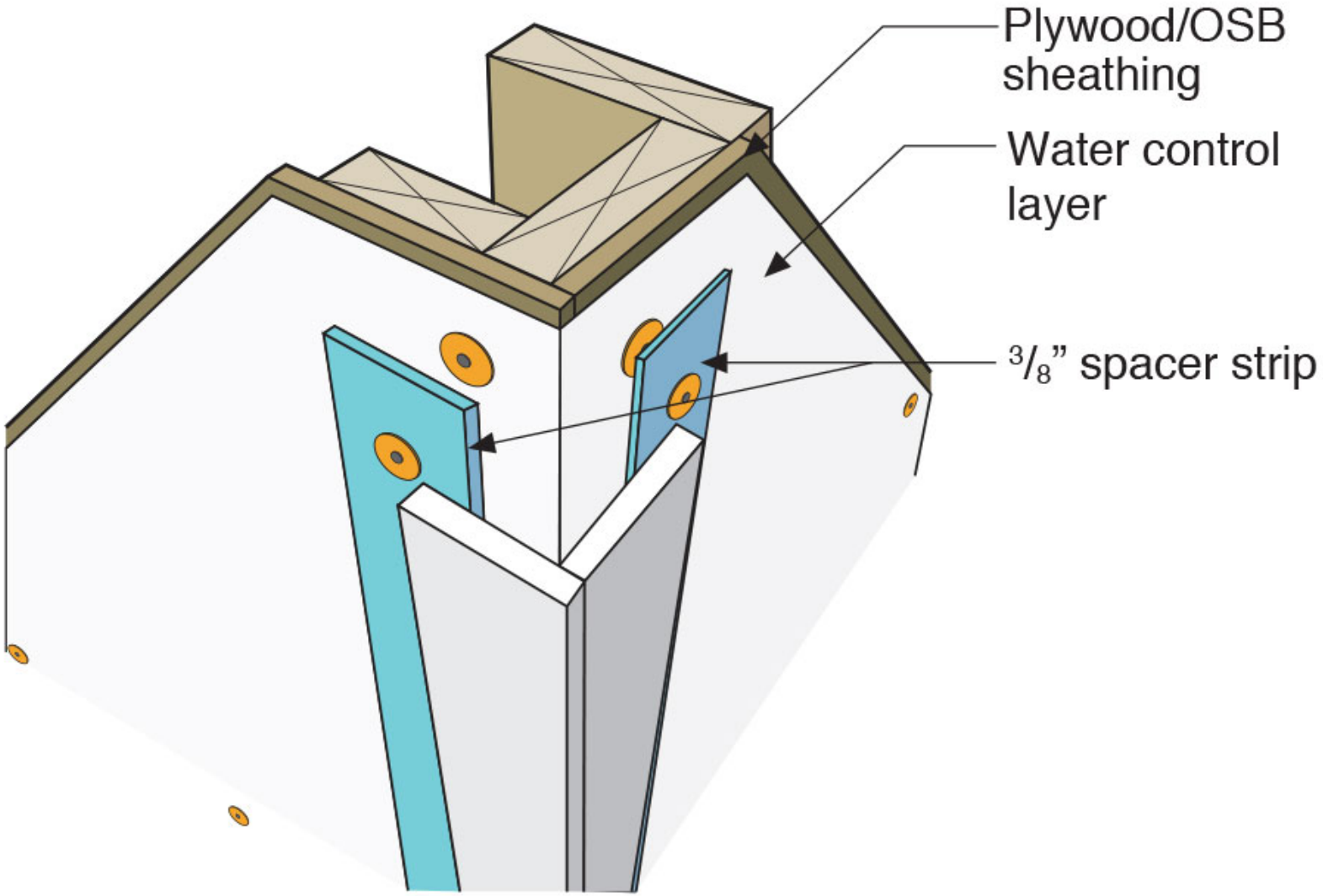

-0.3
-1.0 to -0.2
-0.2
-0.5
-0.2
-0.9
-0.8
-0.5
+1.0
+0.5
-1.0
0
X
2X
4X
Wind

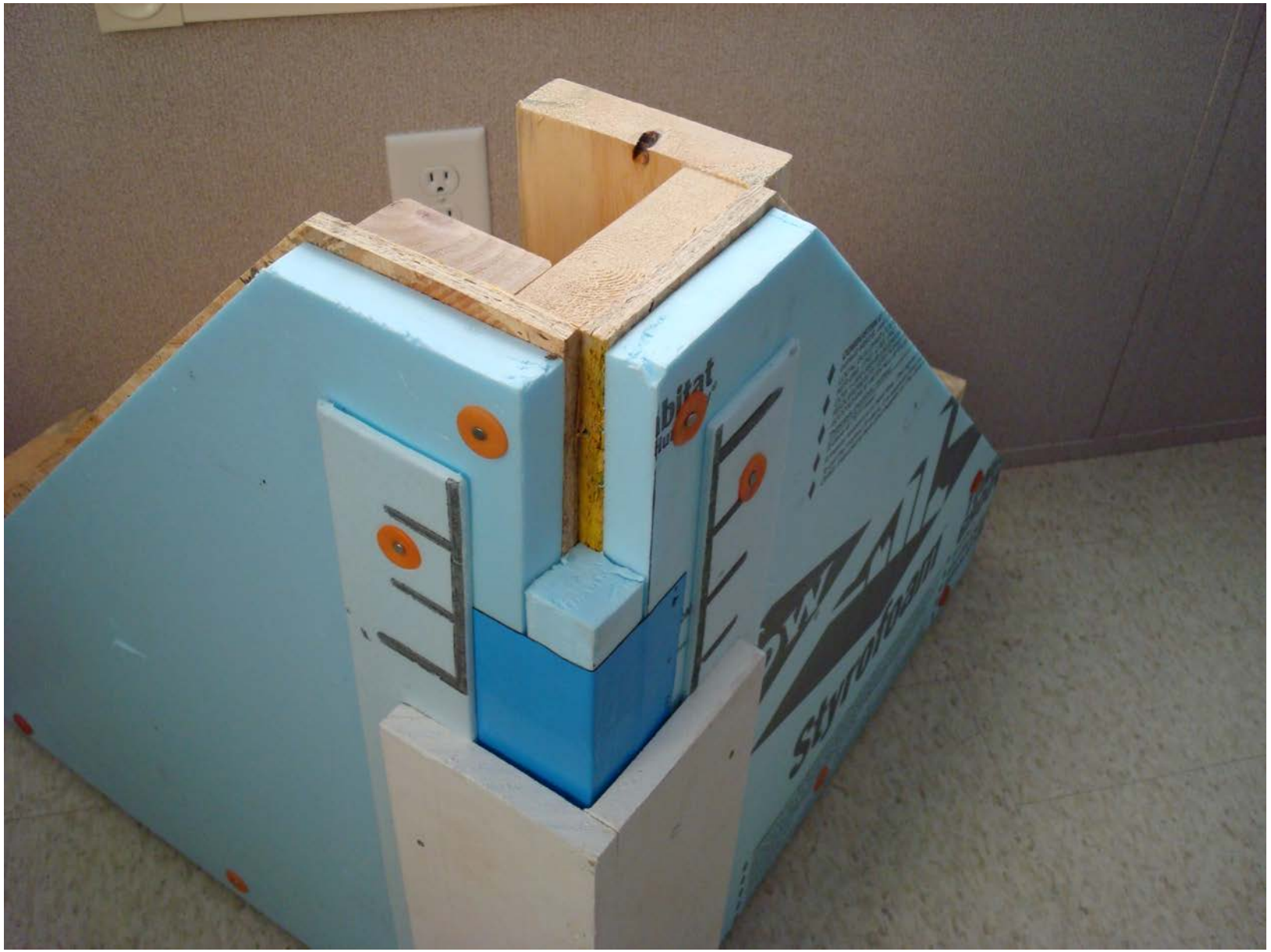
Pascals		mph
50	Pa =	20 mph
100	Pa =	30 mph
150	Pa =	35 mph
250	Pa =	45 mph
500	Pa =	65 mph
1,000	Pa =	90 mph



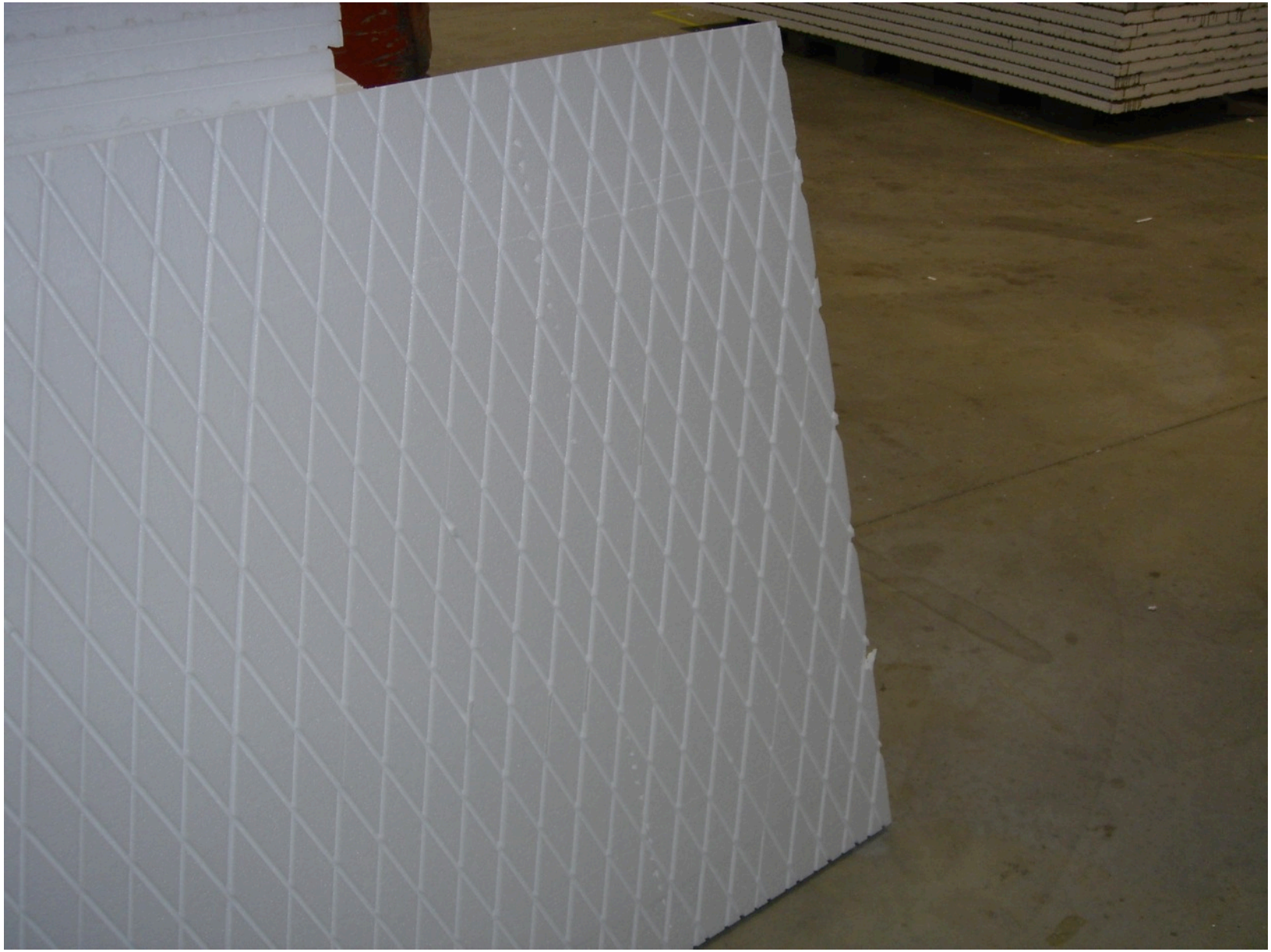
DUPONT

Call 1-800-44TYVEK
WWW.TYVEK.COM

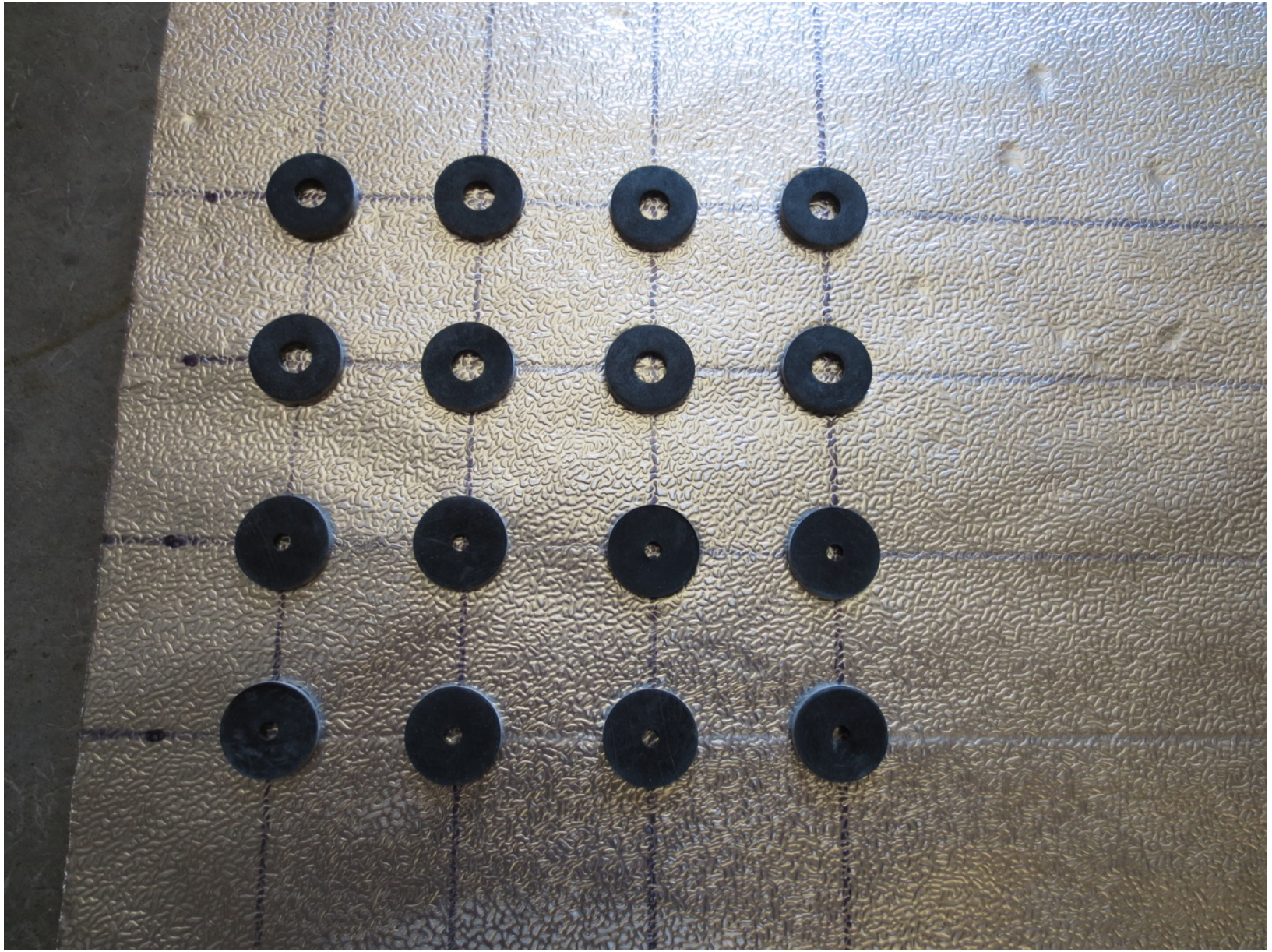

Plywood/OSB sheathing
Water control layer
3/8" spacer strip


Styrofoam

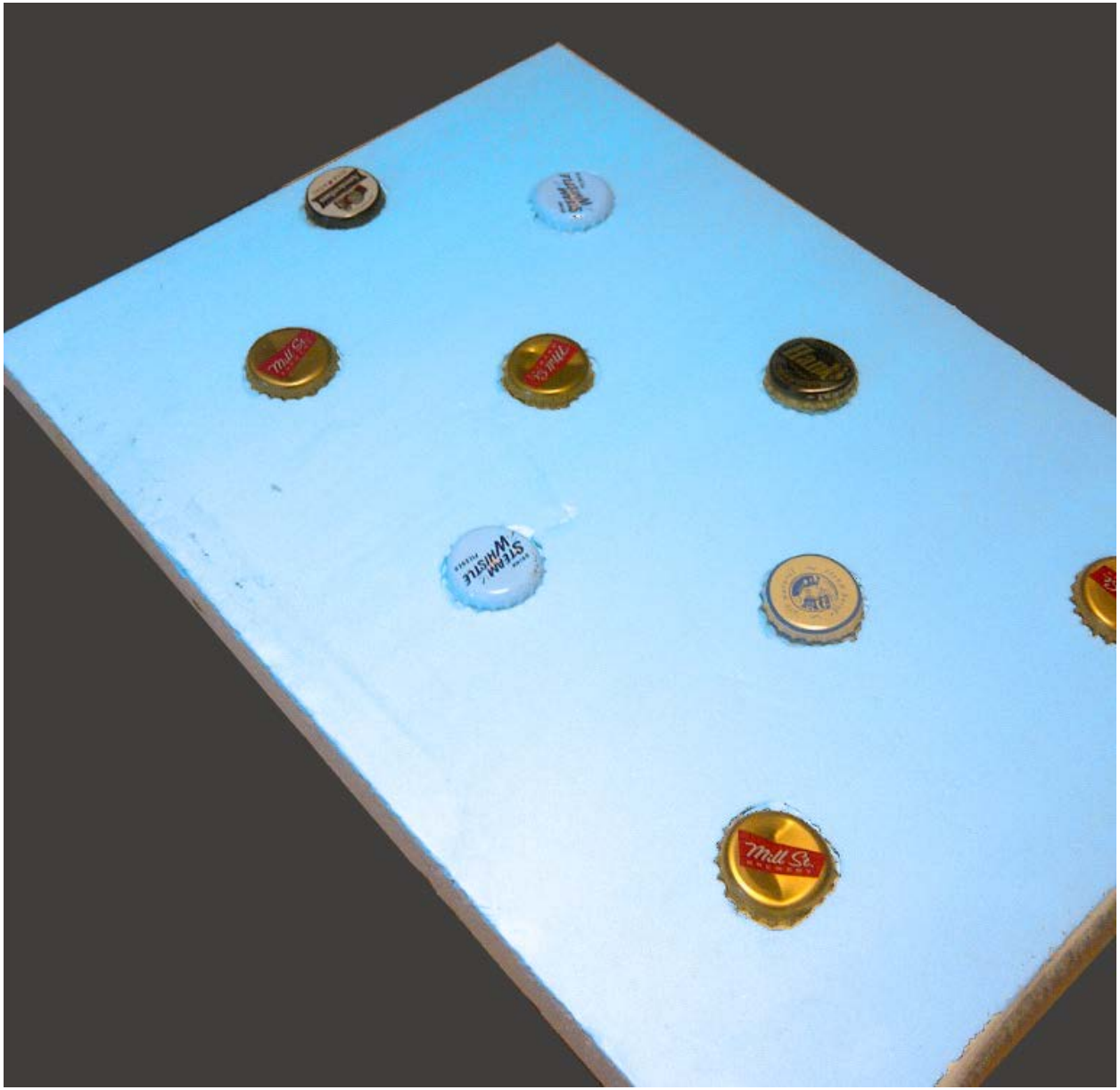
DuPont
Tyvek
Tape
DuPont
Tyvek
Tape

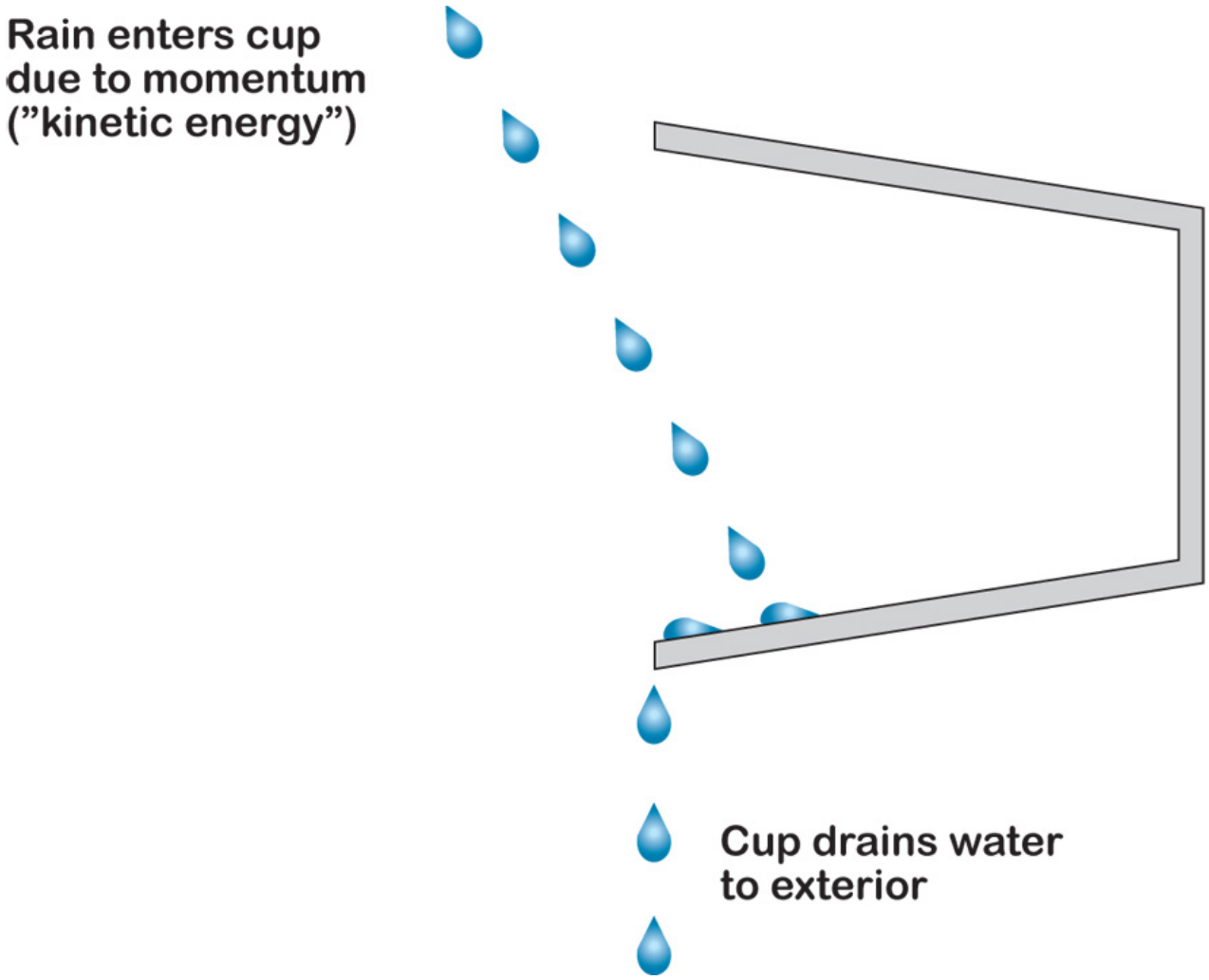


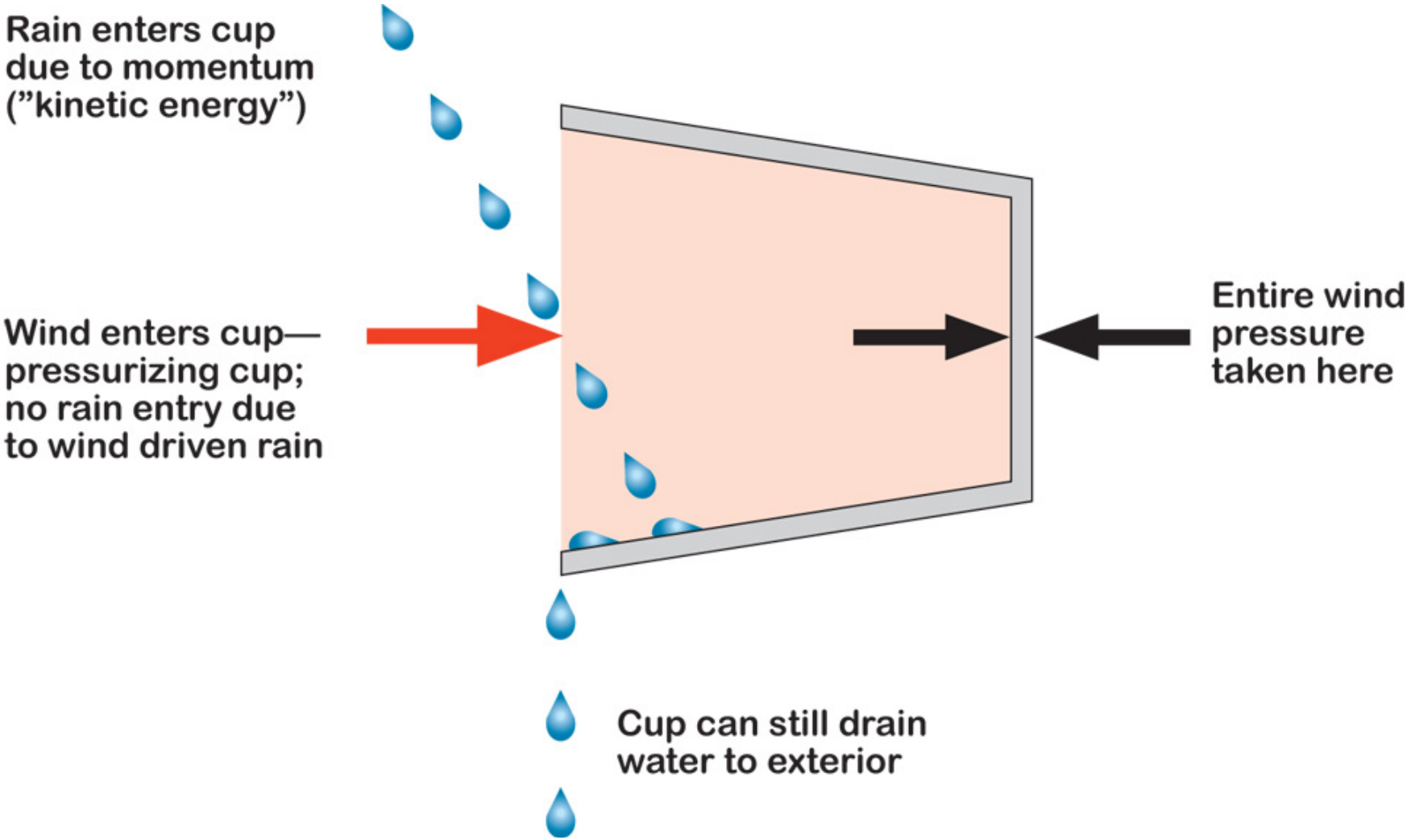
Rain Screen

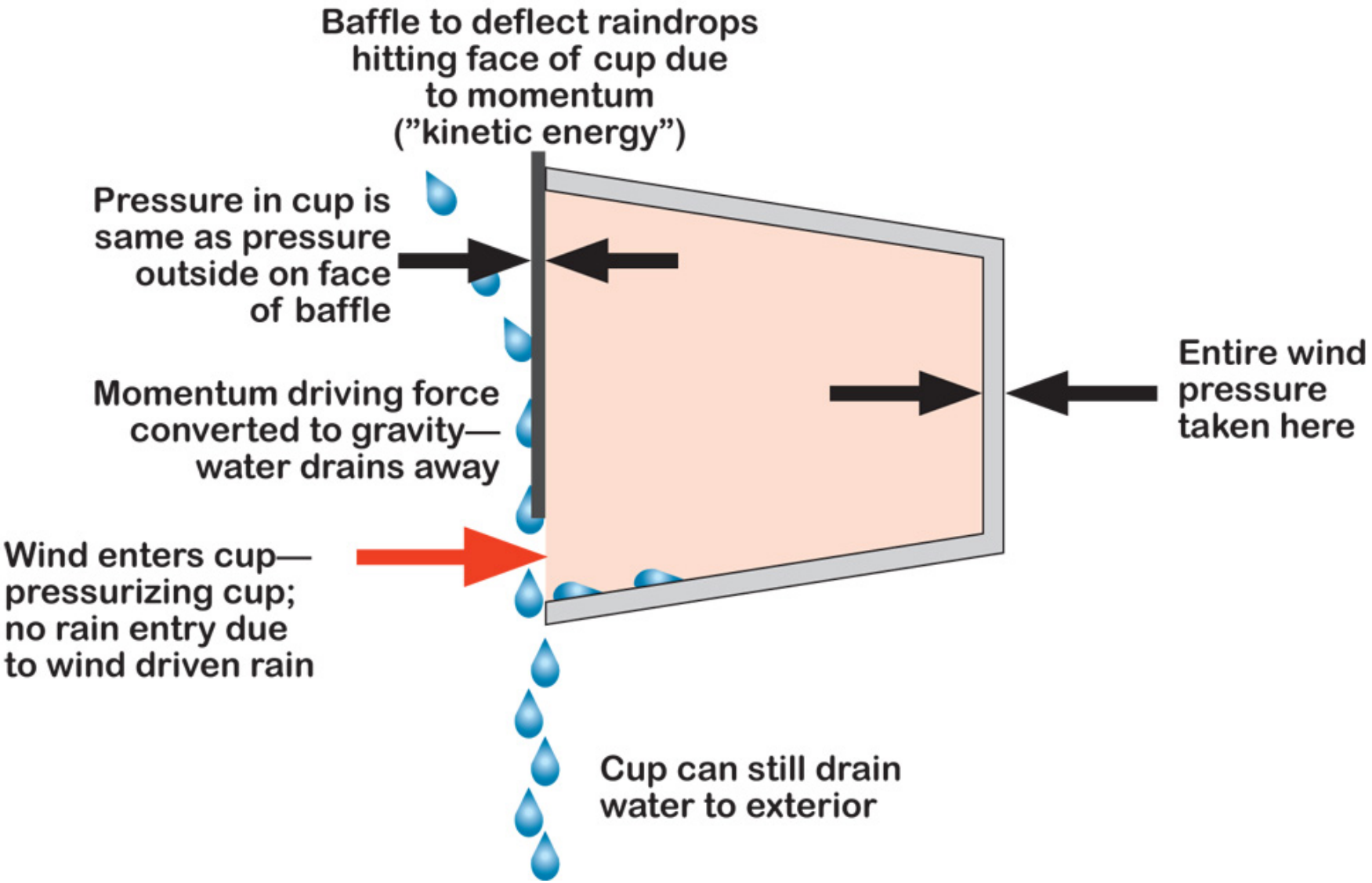


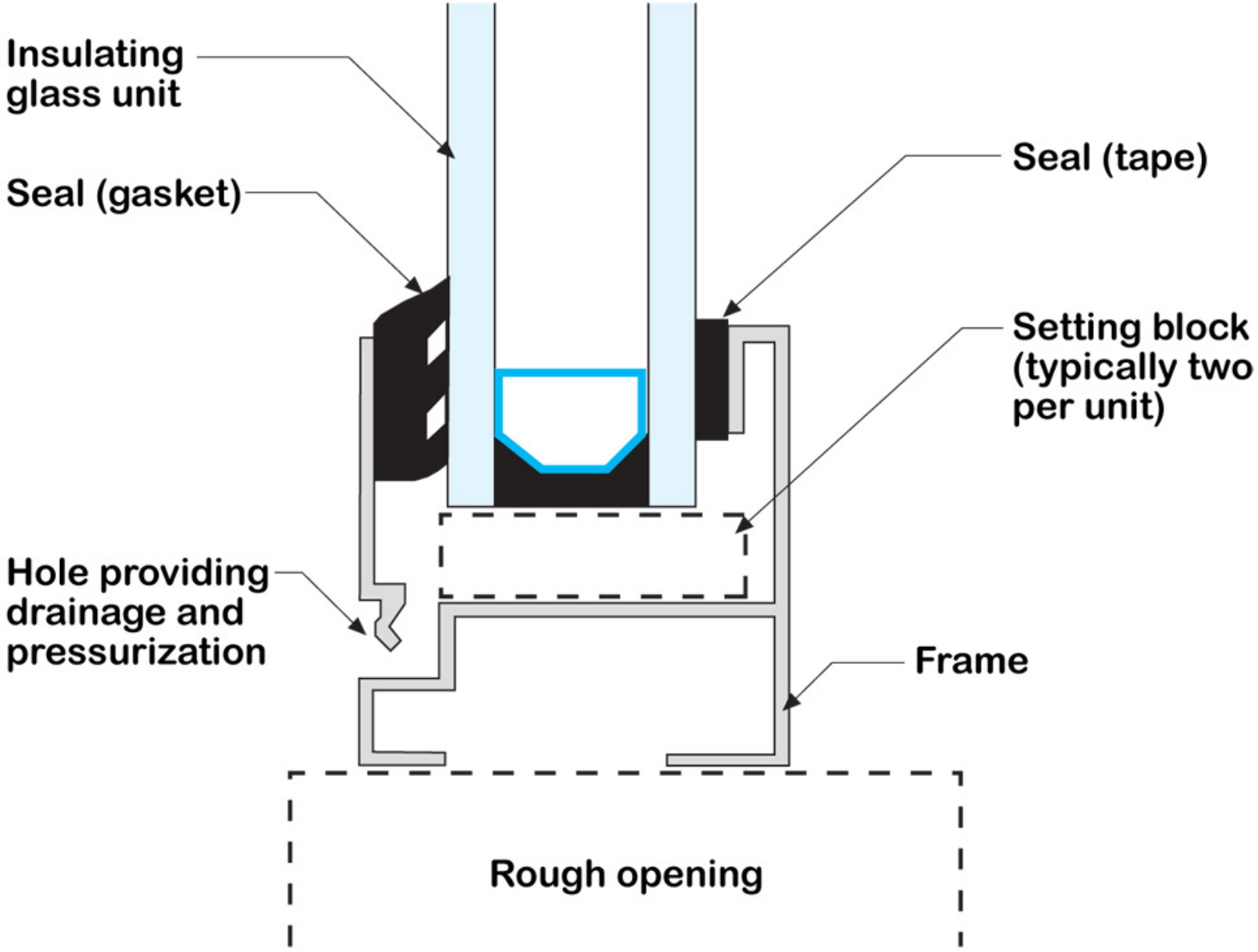
Beer Screen?

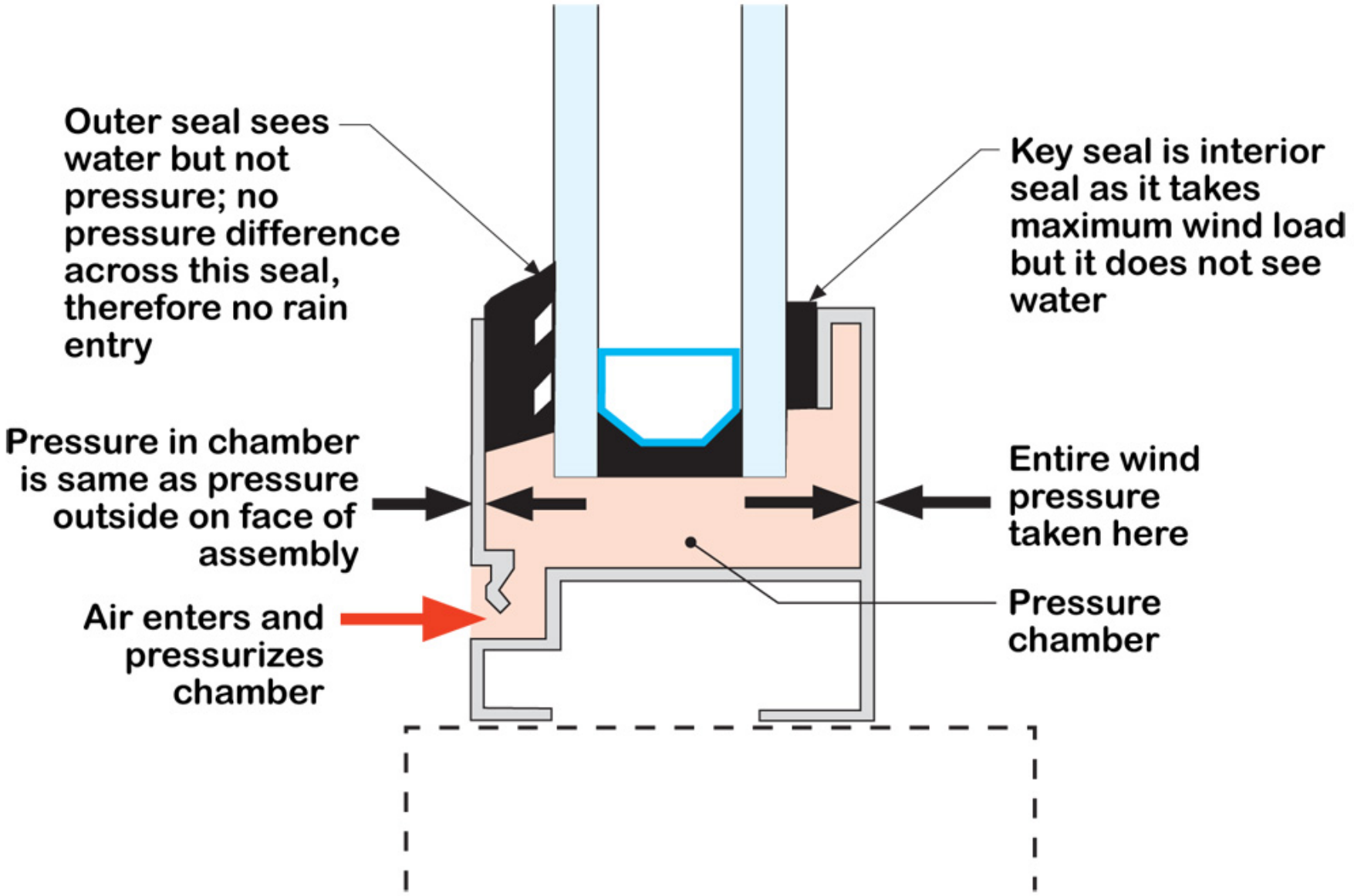

Mill St.
Steam Whistle
Mill St.

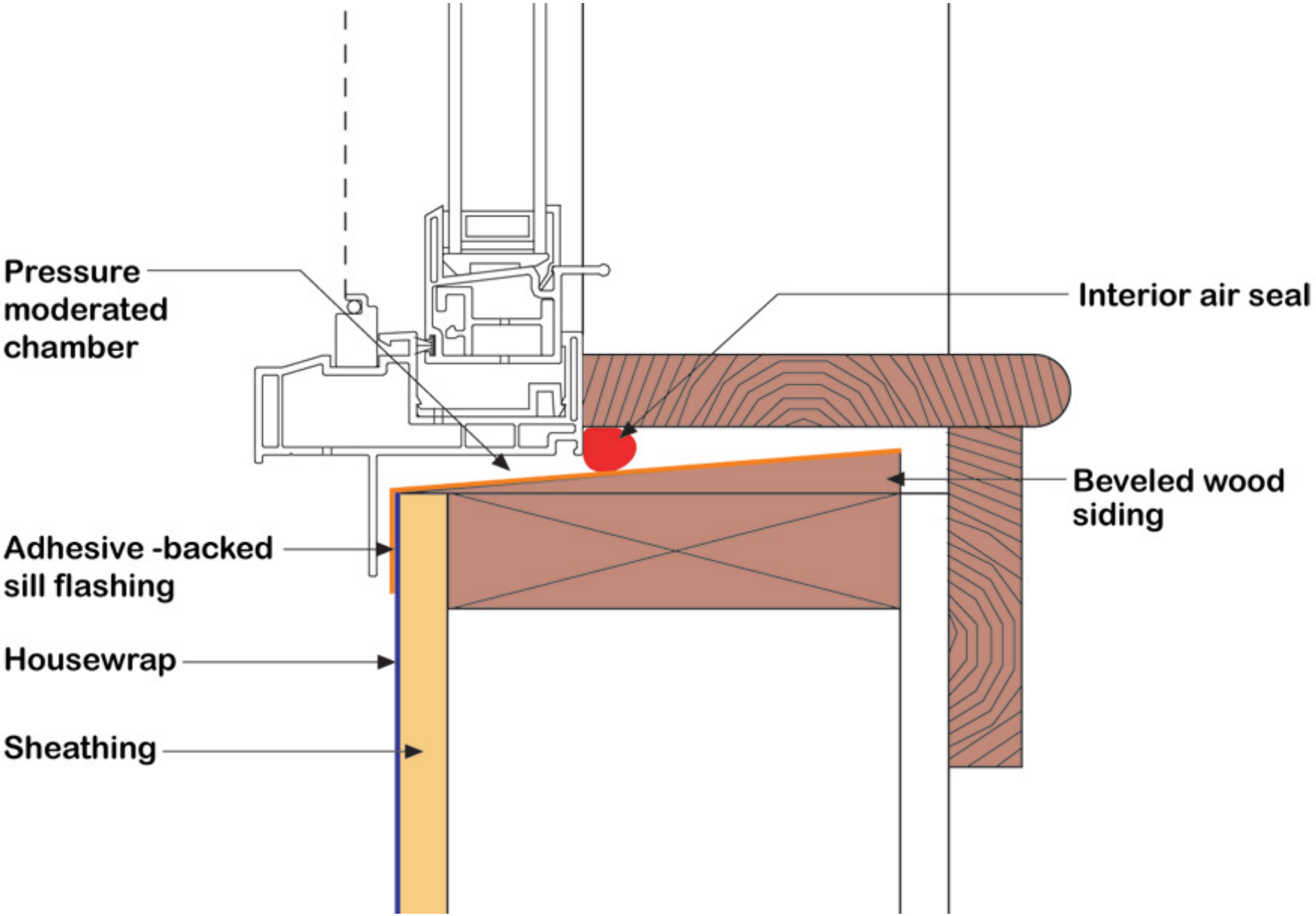

Rain enters cup
due to momentum
("kinetic energy")
Cup drains water
to exterior


Rain enters cup due to momentum ("kinetic energy")
Wind enters cup— pressurizing cup; no rain entry due to wind driven rain
Entire wind pressure taken here
Cup can still drain water to exterior


Baffle to deflect raindrops hitting face of cup due to momentum ("kinetic energy")
Pressure in cup is same as pressure outside on face of baffle
Momentum driving force converted to gravity— water drains away
Wind enters cup— pressurizing cup; no rain entry due to wind driven rain
Entire wind pressure taken here
Cup can still drain water to exterior

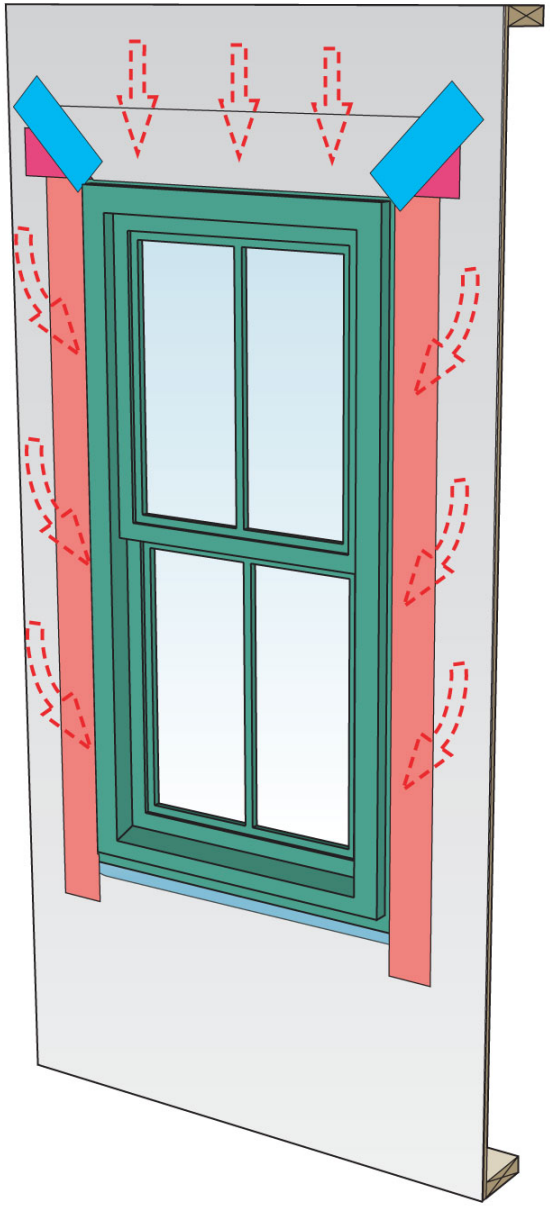

Insulating glass unit
Seal (gasket)
Seal (tape)
Setting block (typically two per unit)
Hole providing drainage and pressurization
Frame
Rough opening

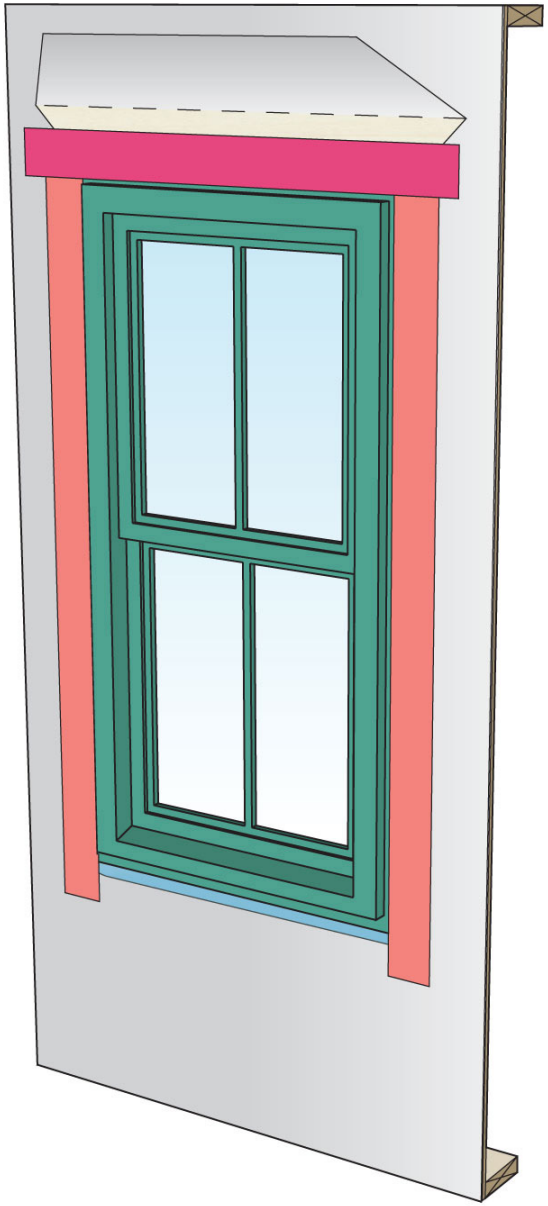

Outer seal sees water but not pressure; no pressure difference across this seal, therefore no rain entry
Key seal is interior seal as it takes maximum wind load but it does not see water
Pressure in chamber is same as pressure outside on face of assembly
Entire wind pressure taken here
Air enters and pressurizes chamber
Pressure chamber

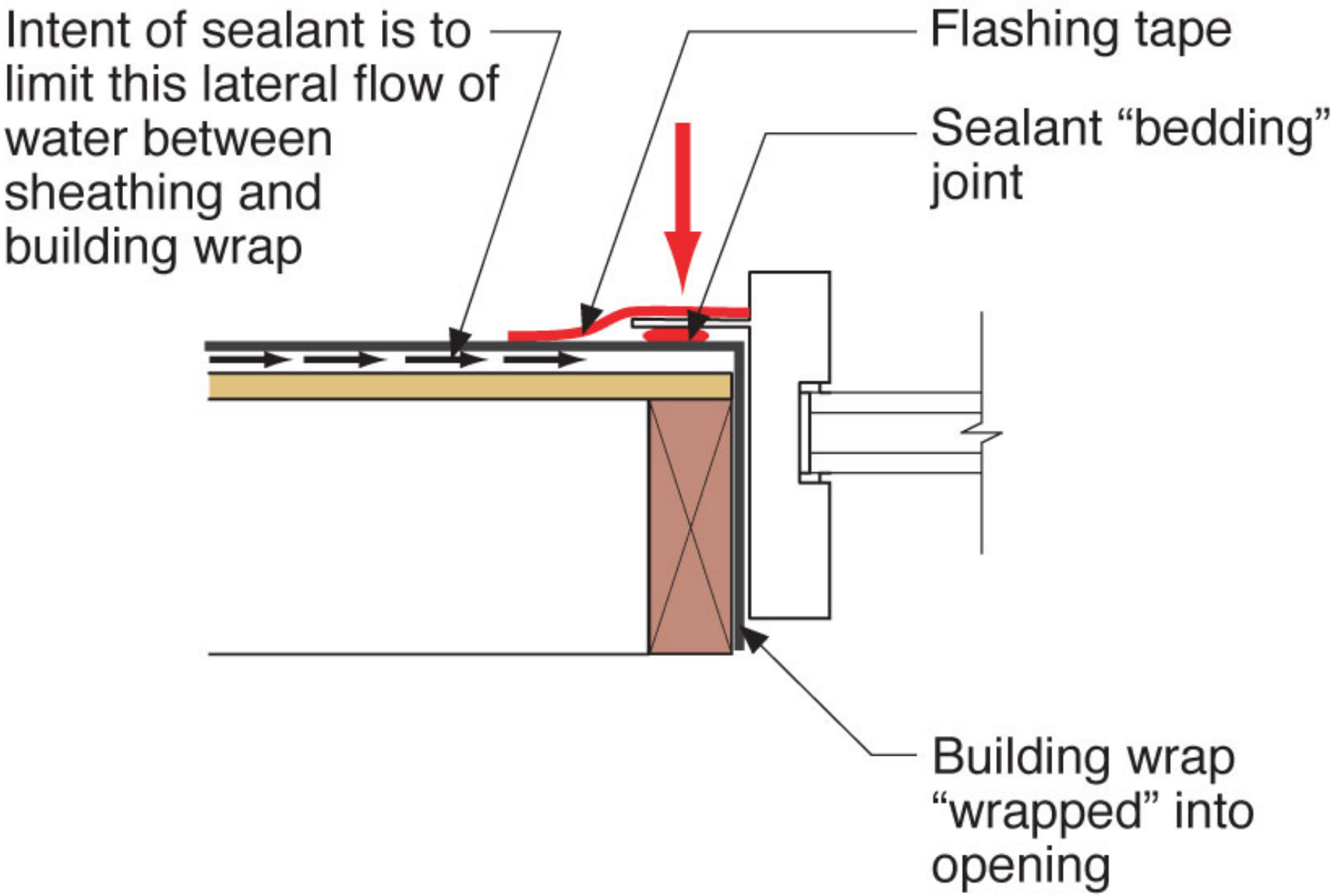

Pressure moderated chamber
Interior air seal
Beveled wood siding
Adhesive -backed sill flashing
Housewrap
Sheathing

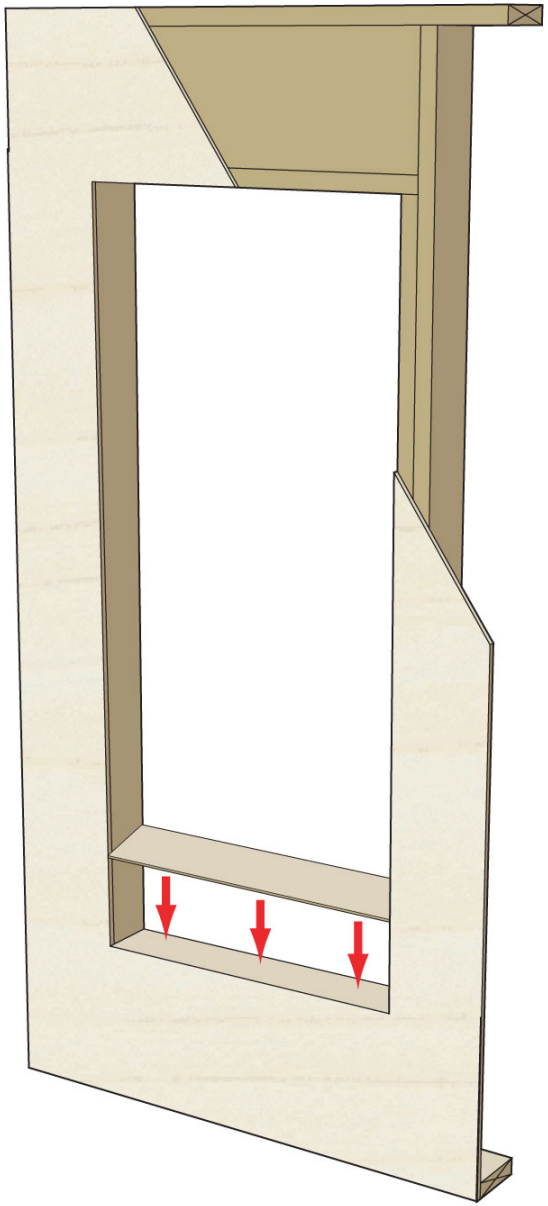
ightFlash

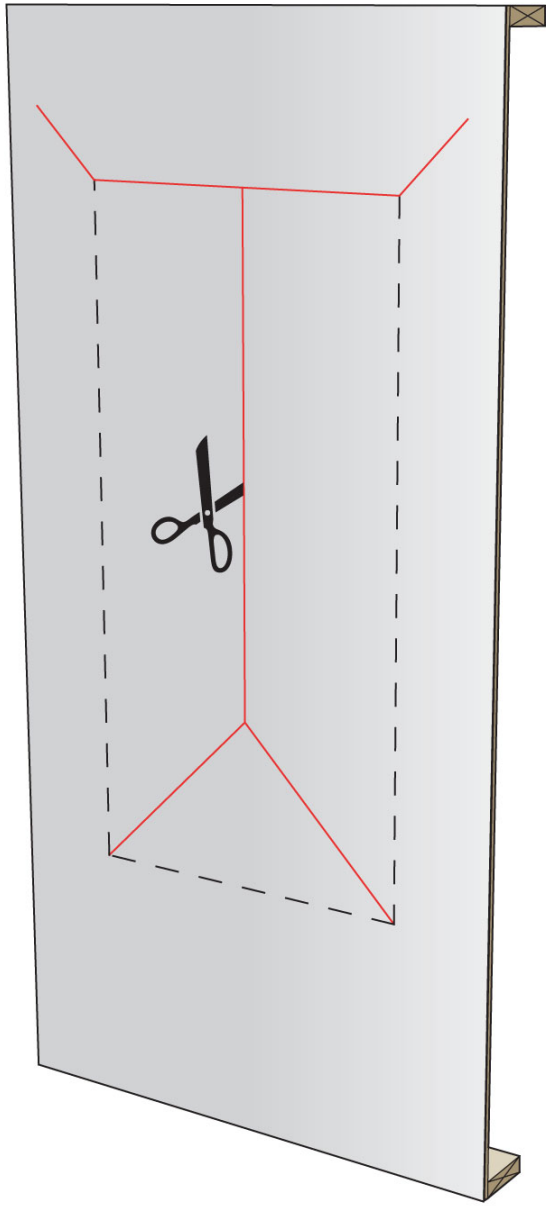
DOW
Styrofoam

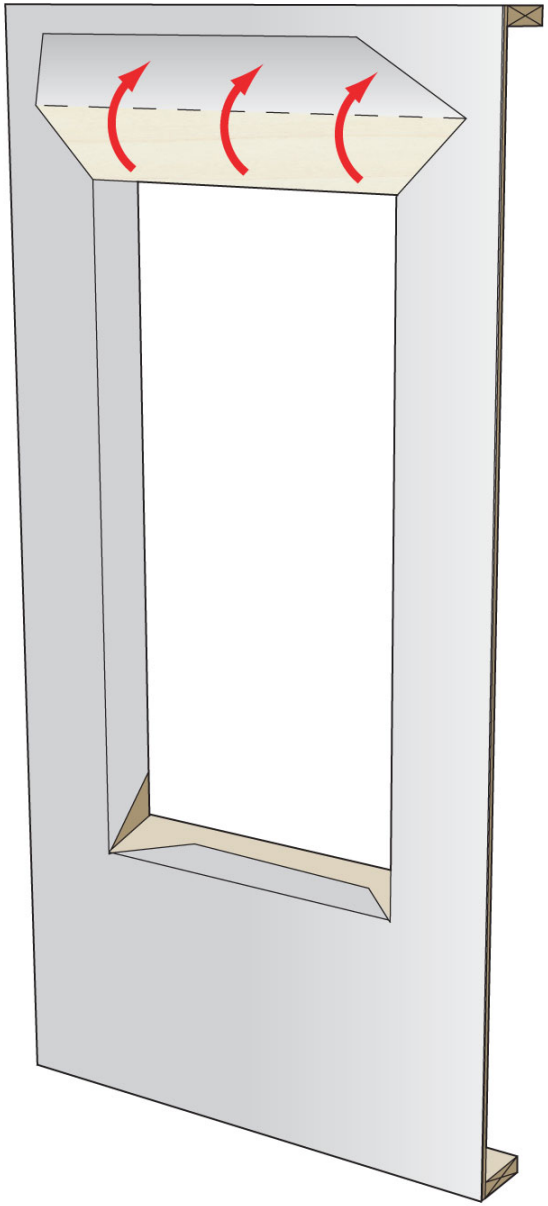


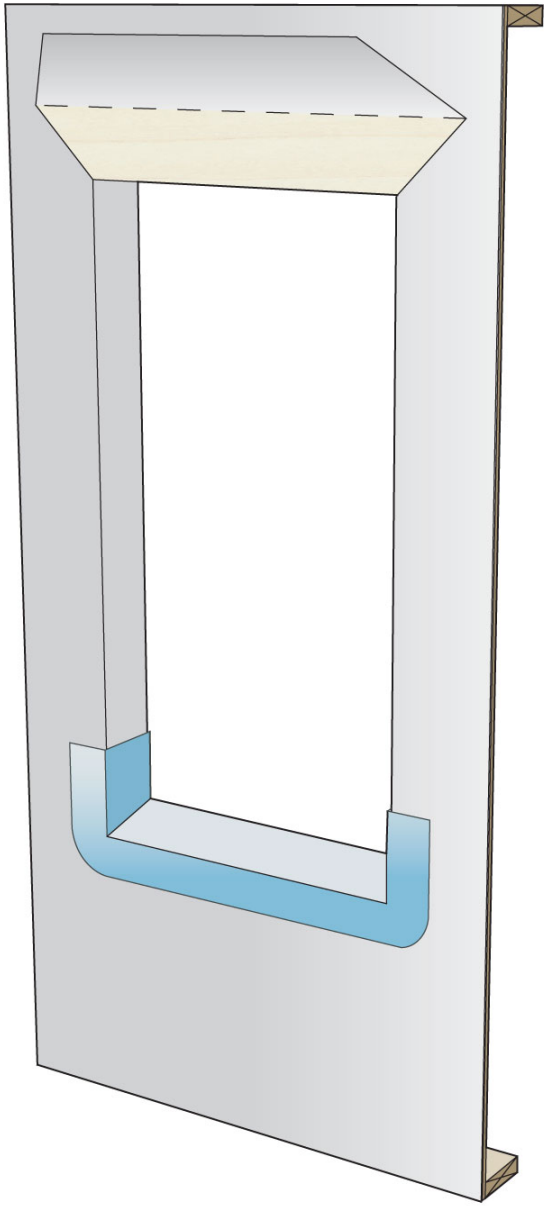


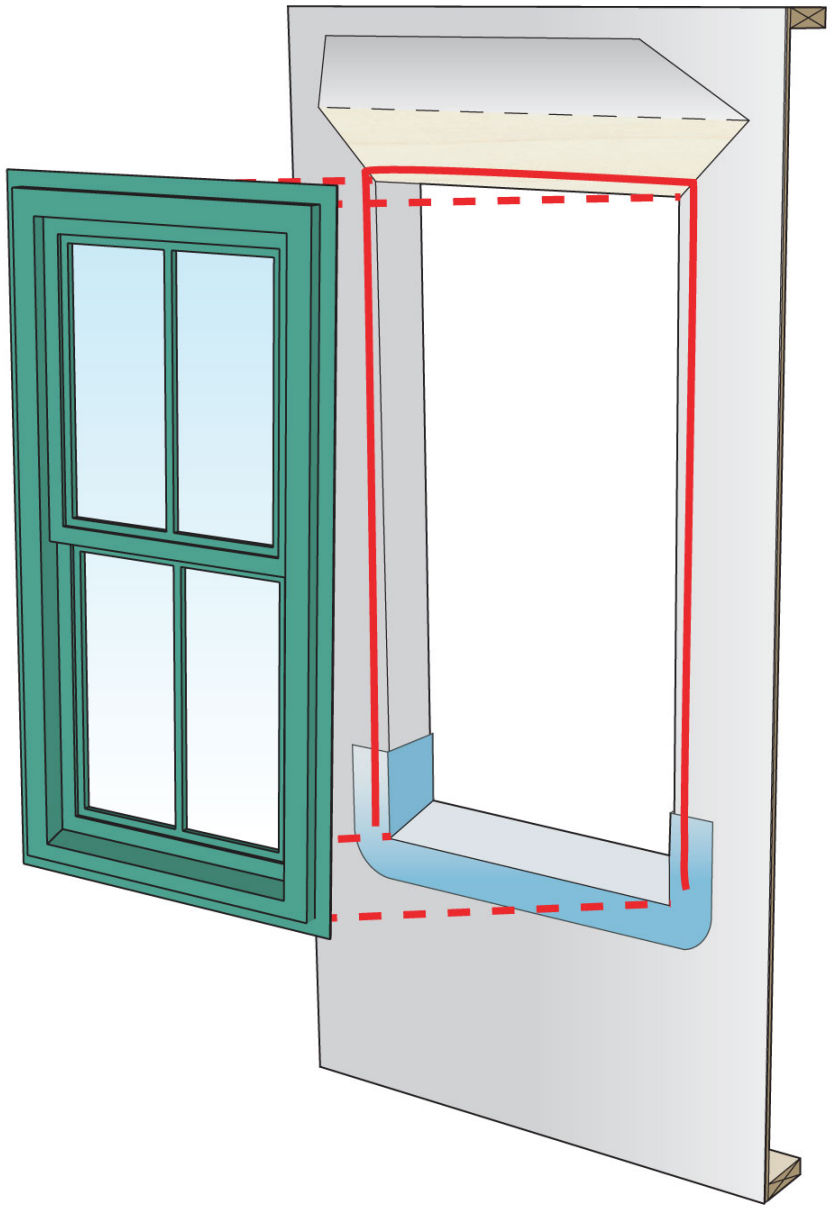

Intent of sealant is to limit this lateral flow of water between sheathing and building wrap
Flashing tape
Sealant “bedding” joint
Building wrap “wrapped” into opening

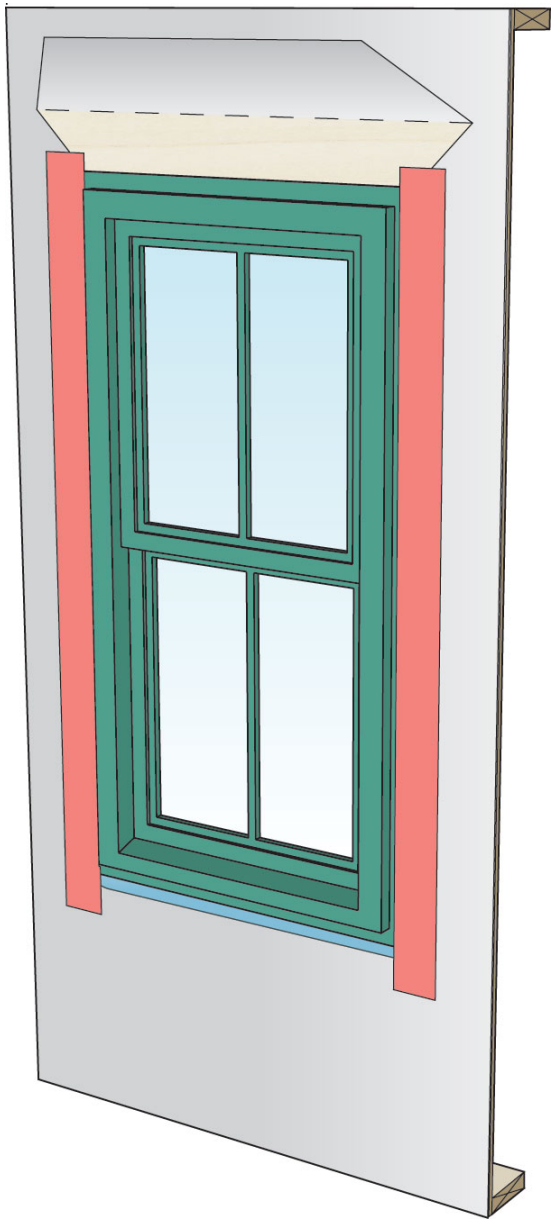


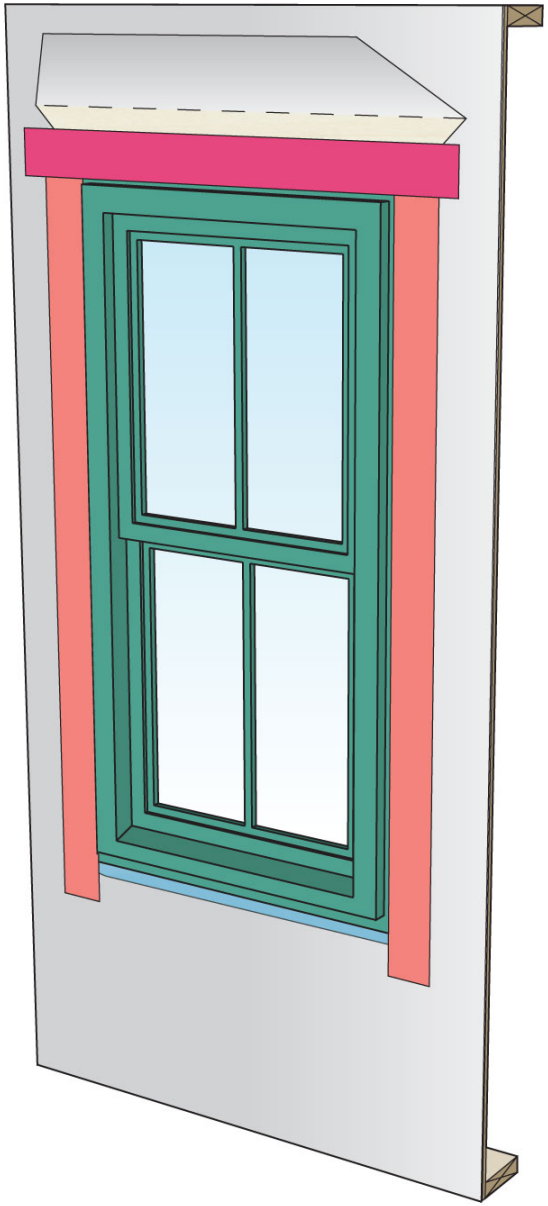


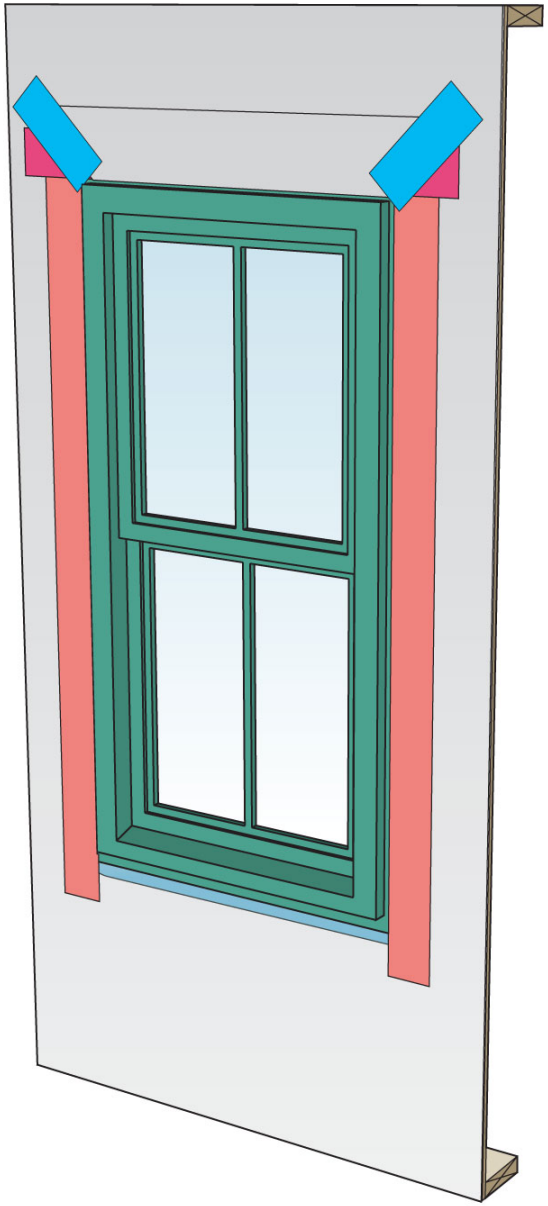


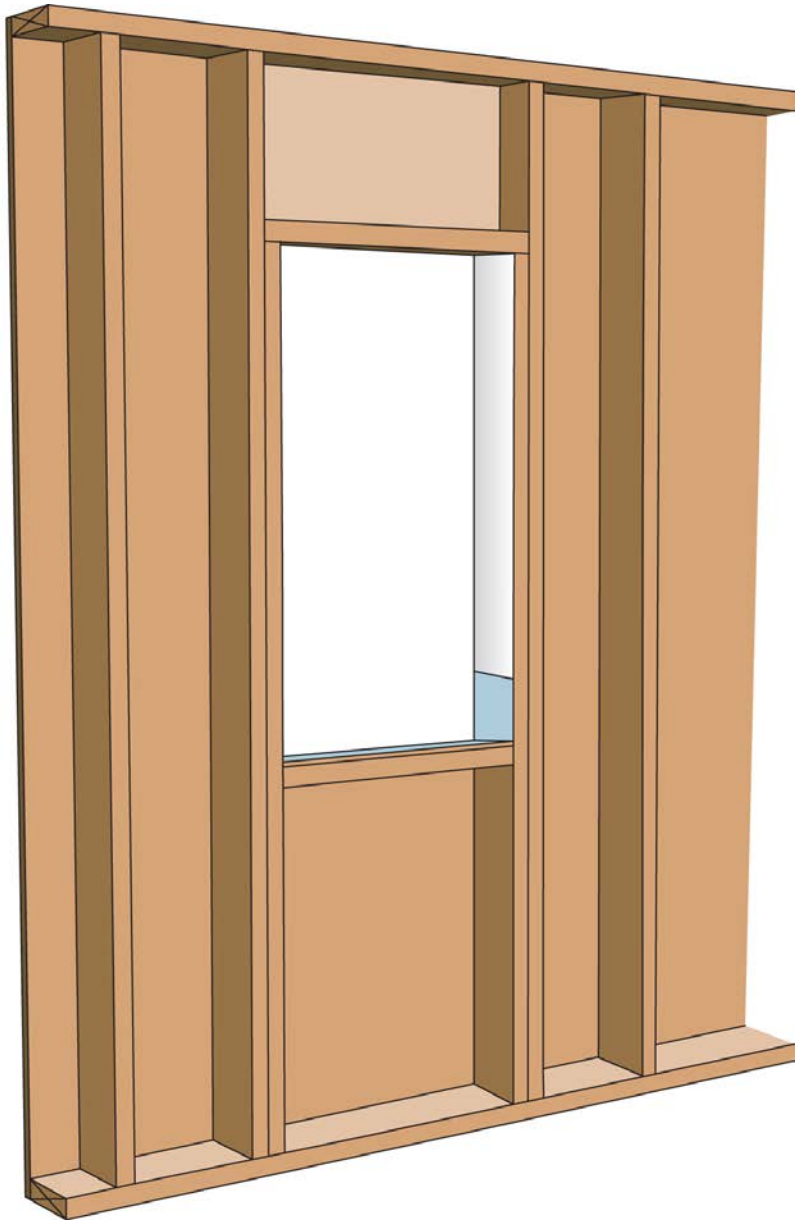




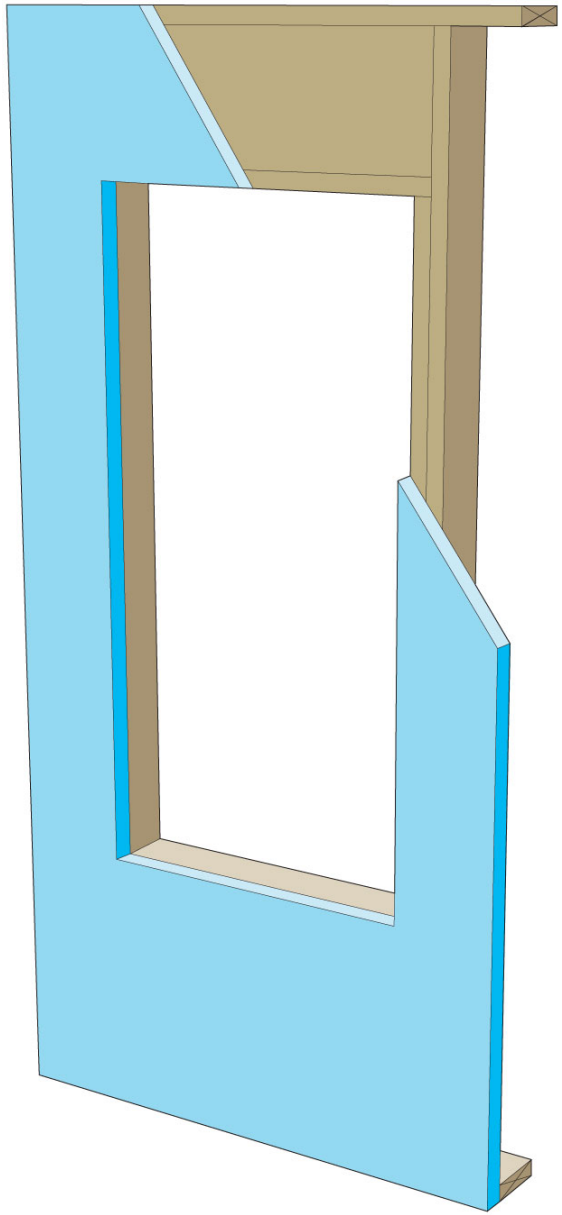


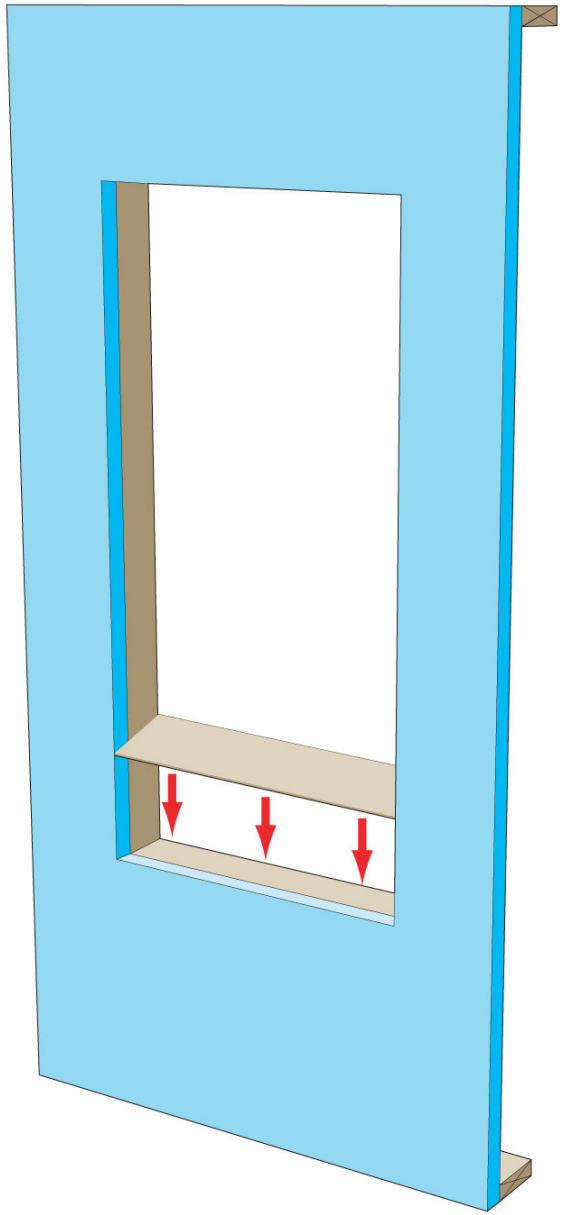


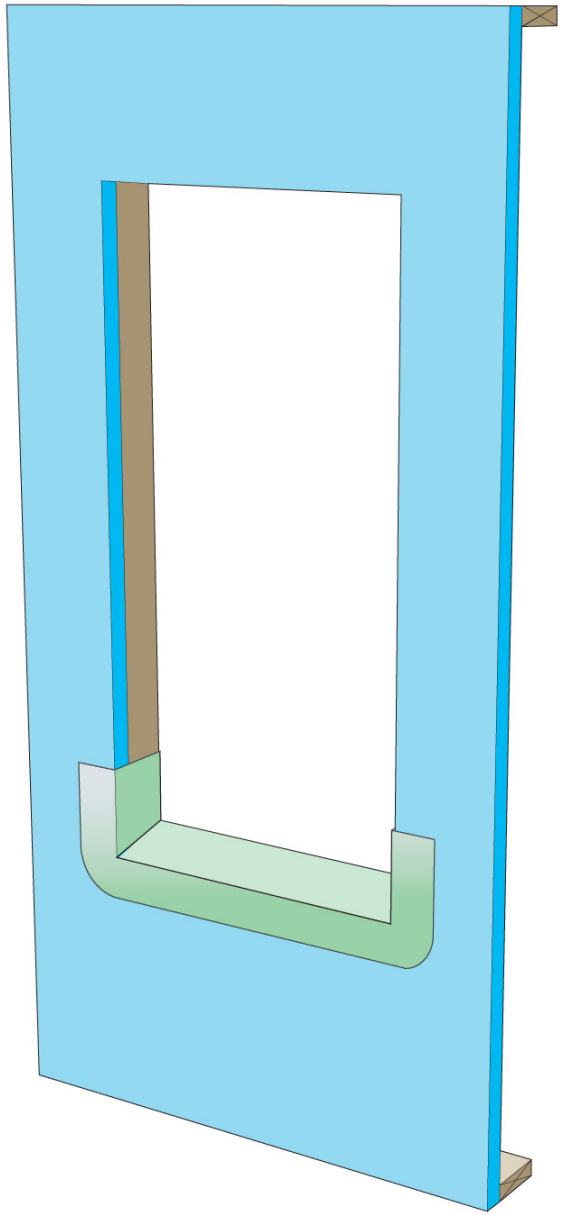


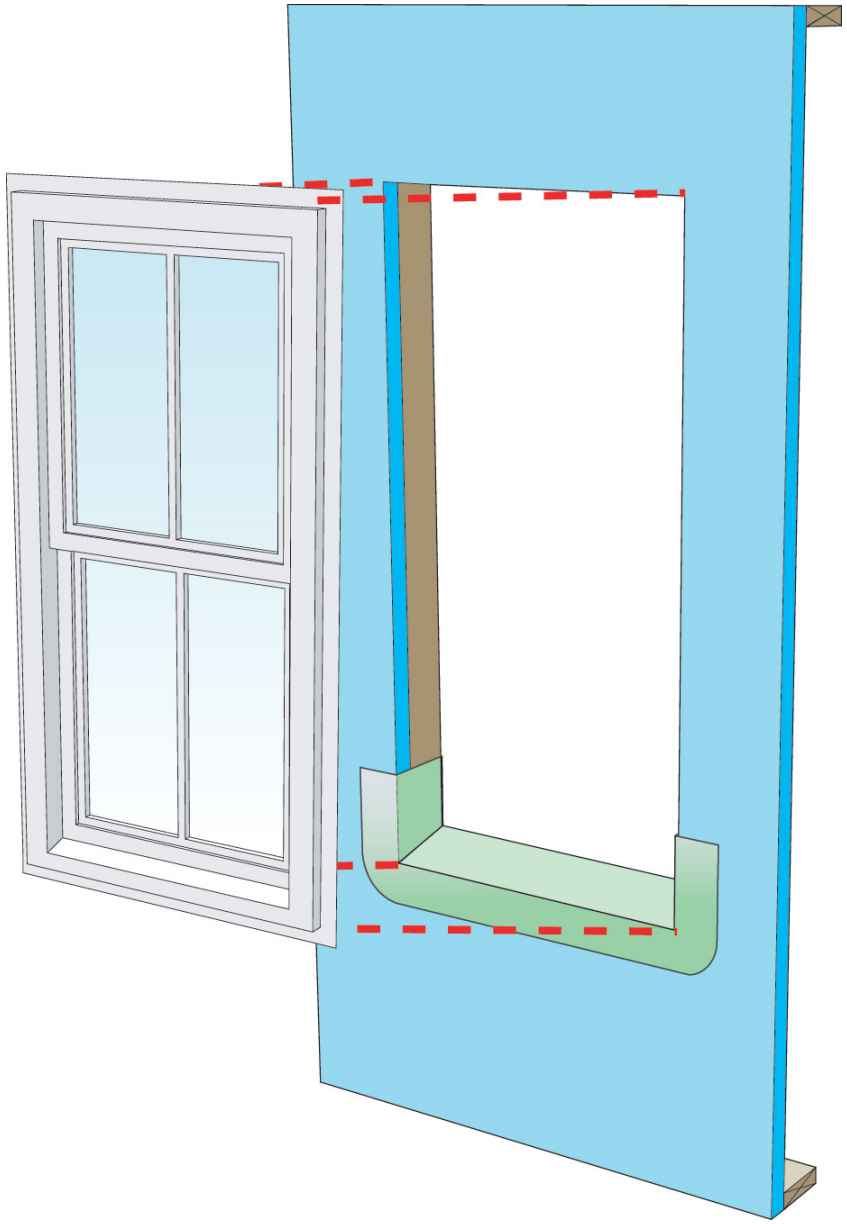


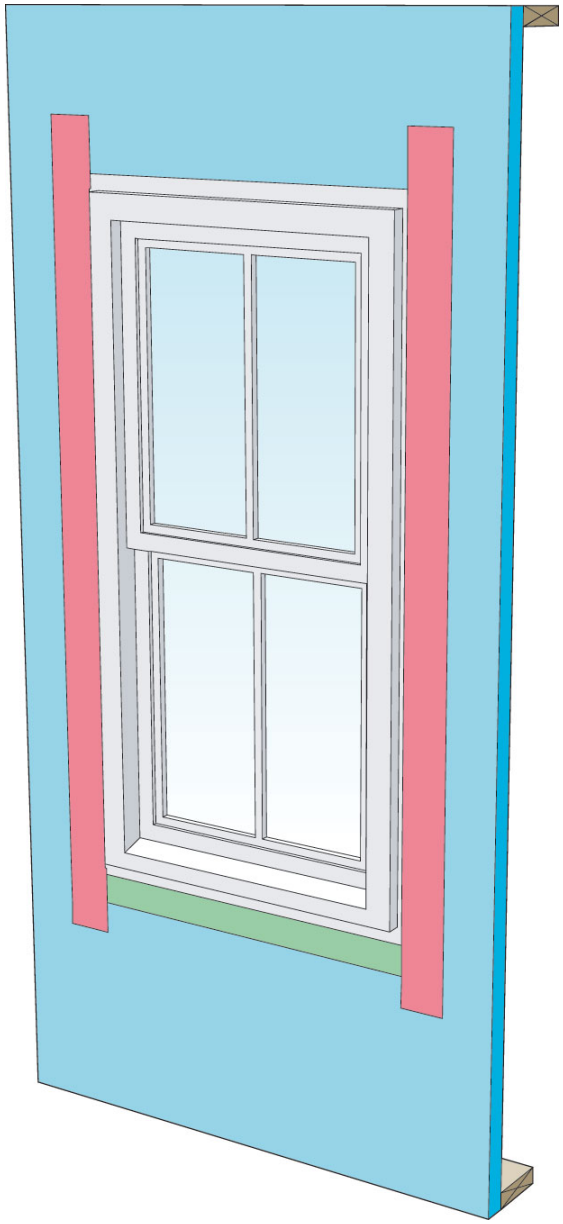
RCI
WARNING: DuPont™ Tyvek®
AVERTISSEMENT: Le matériau
stalled as an air barrier ac

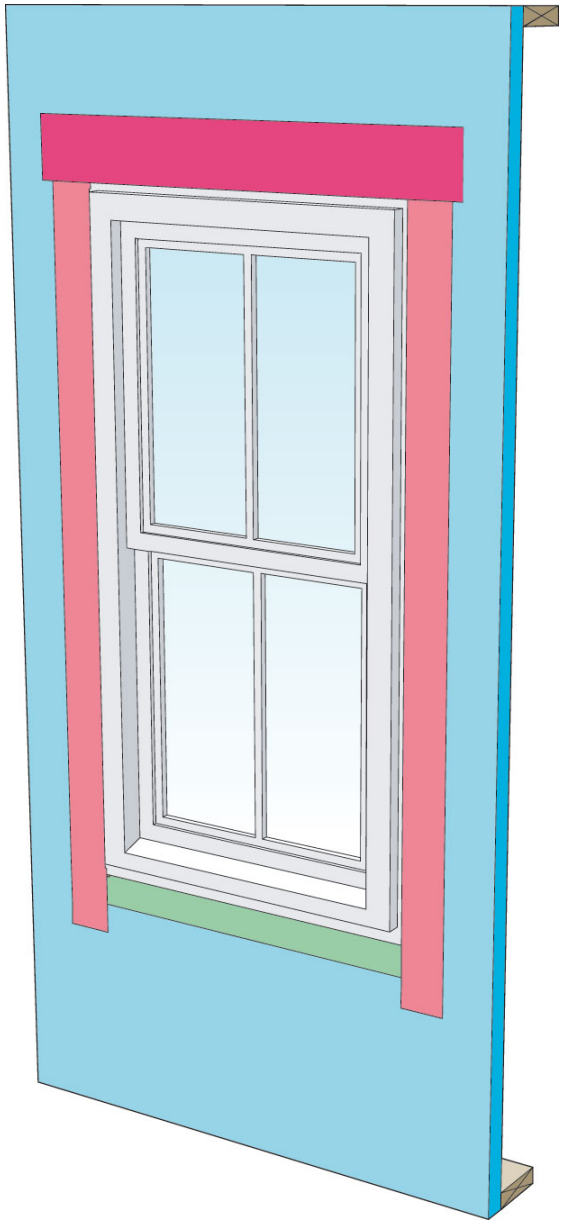


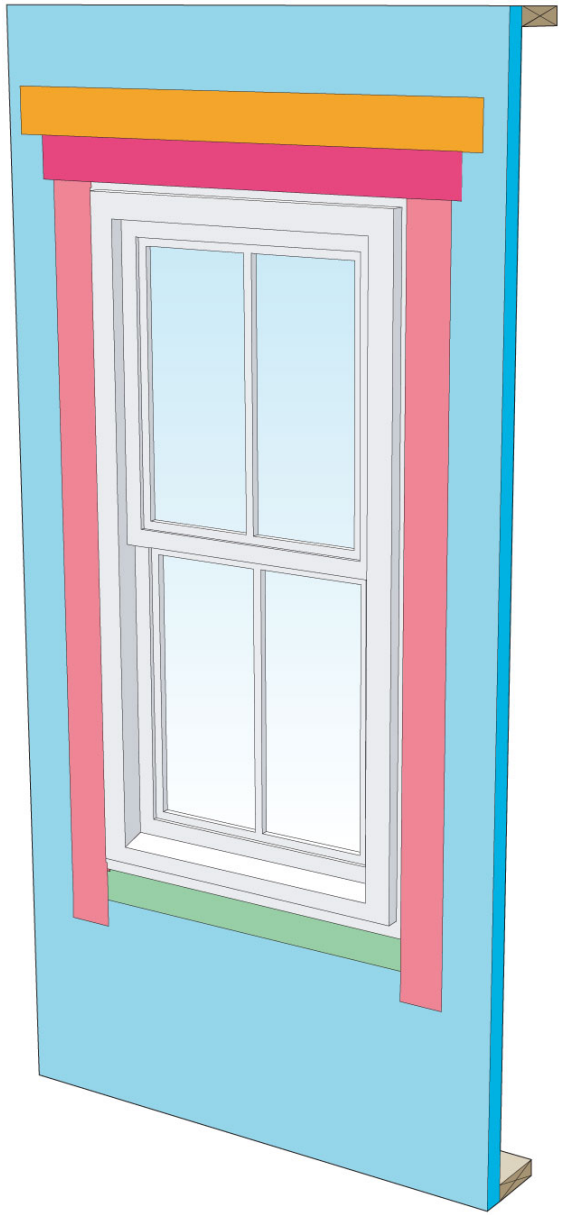


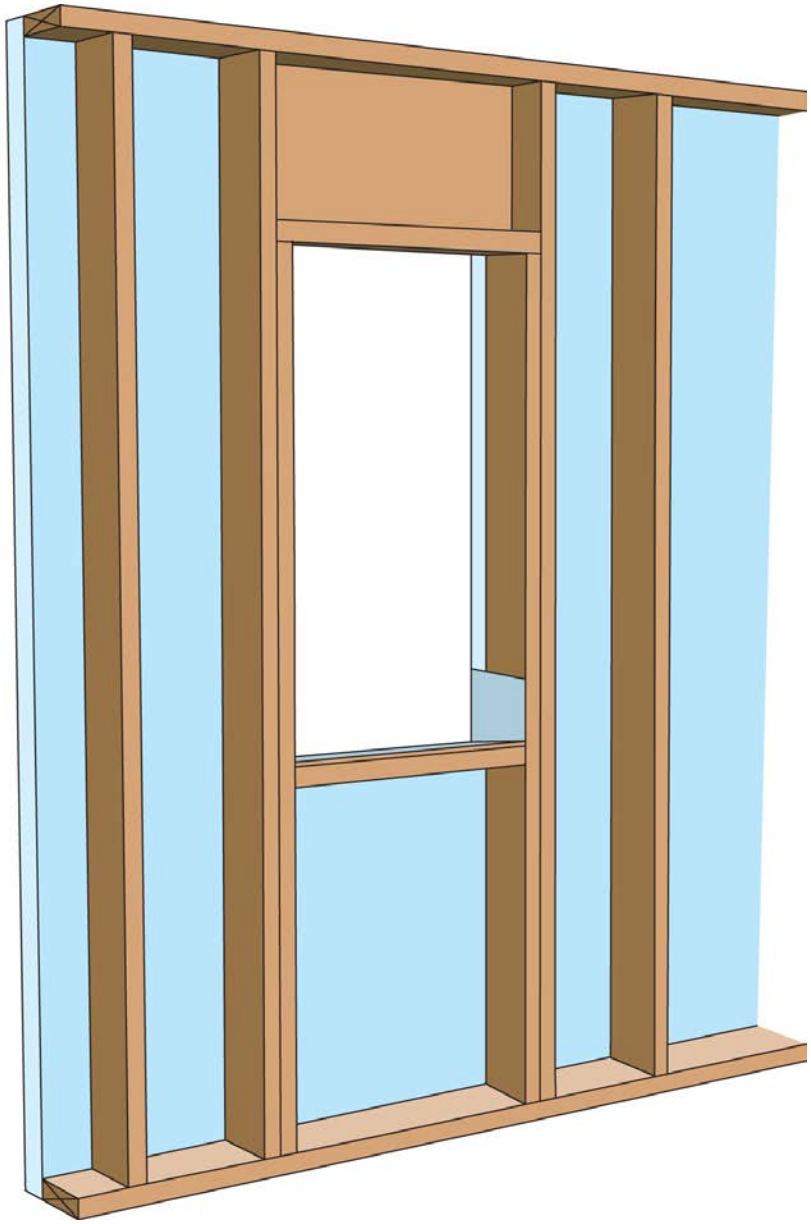


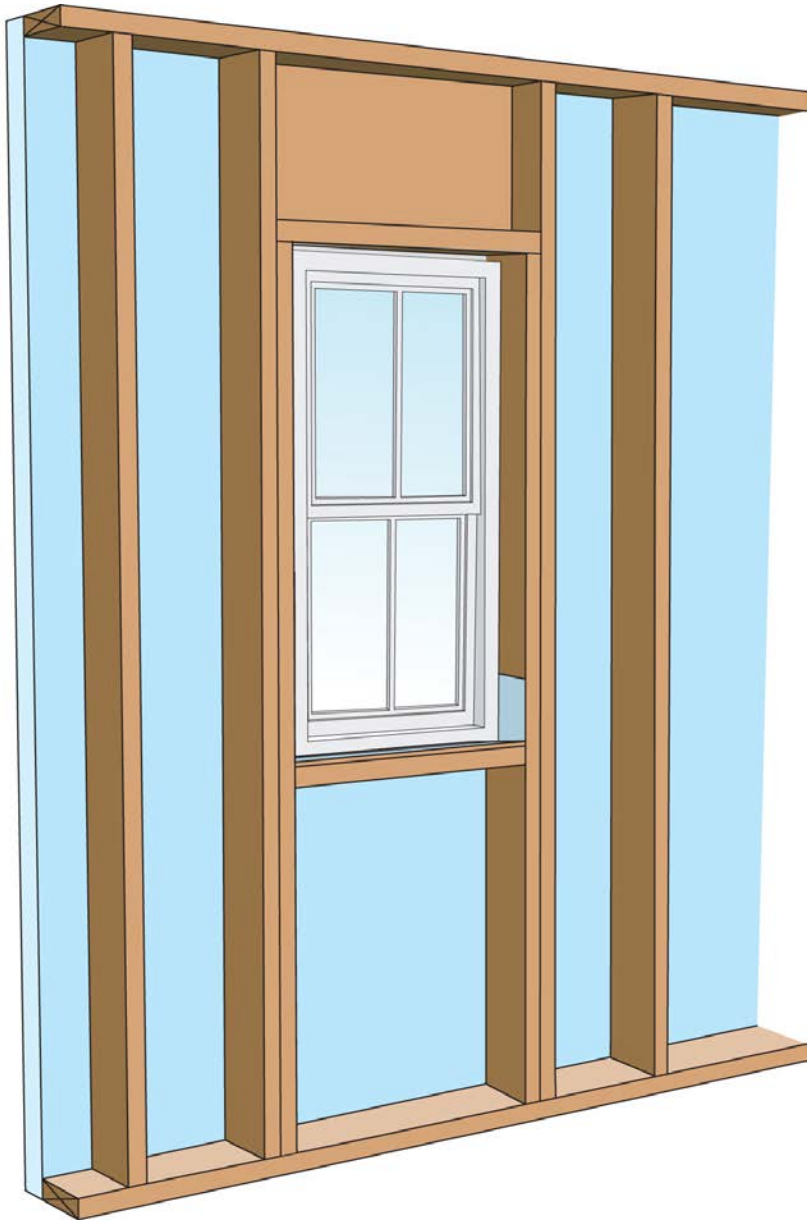


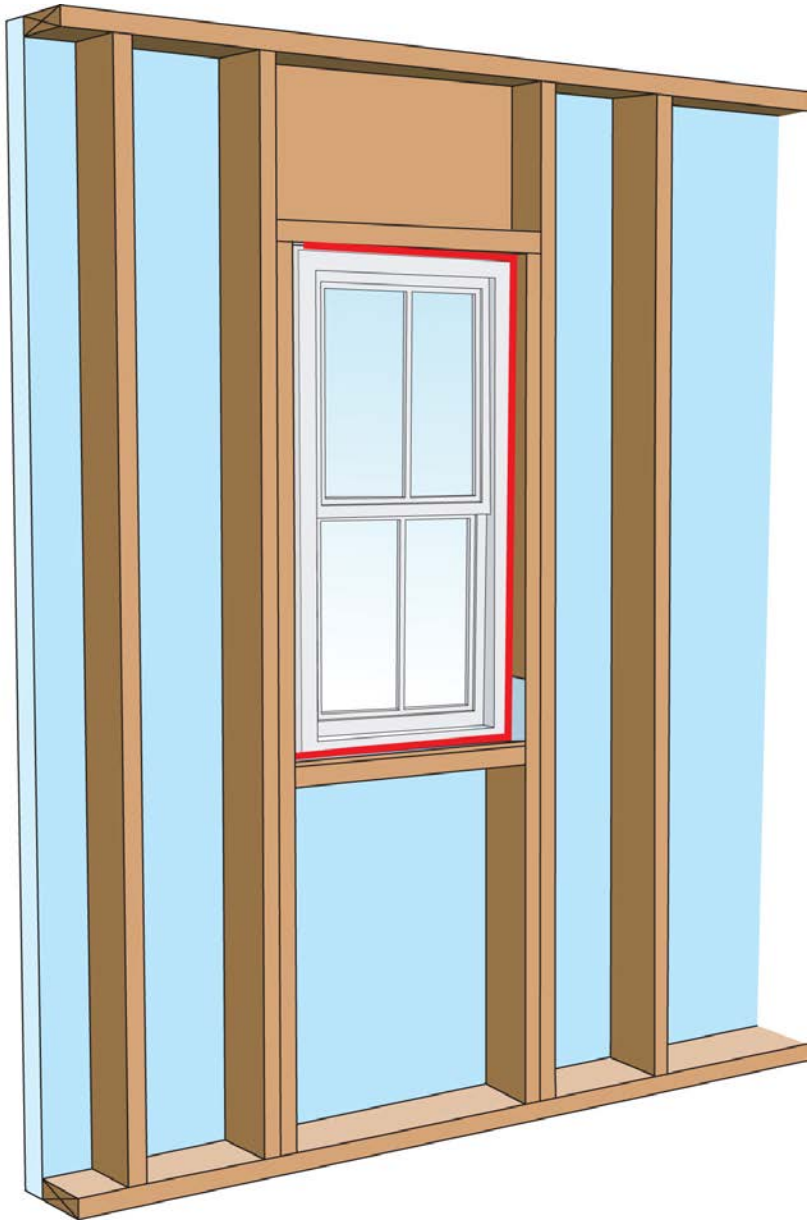




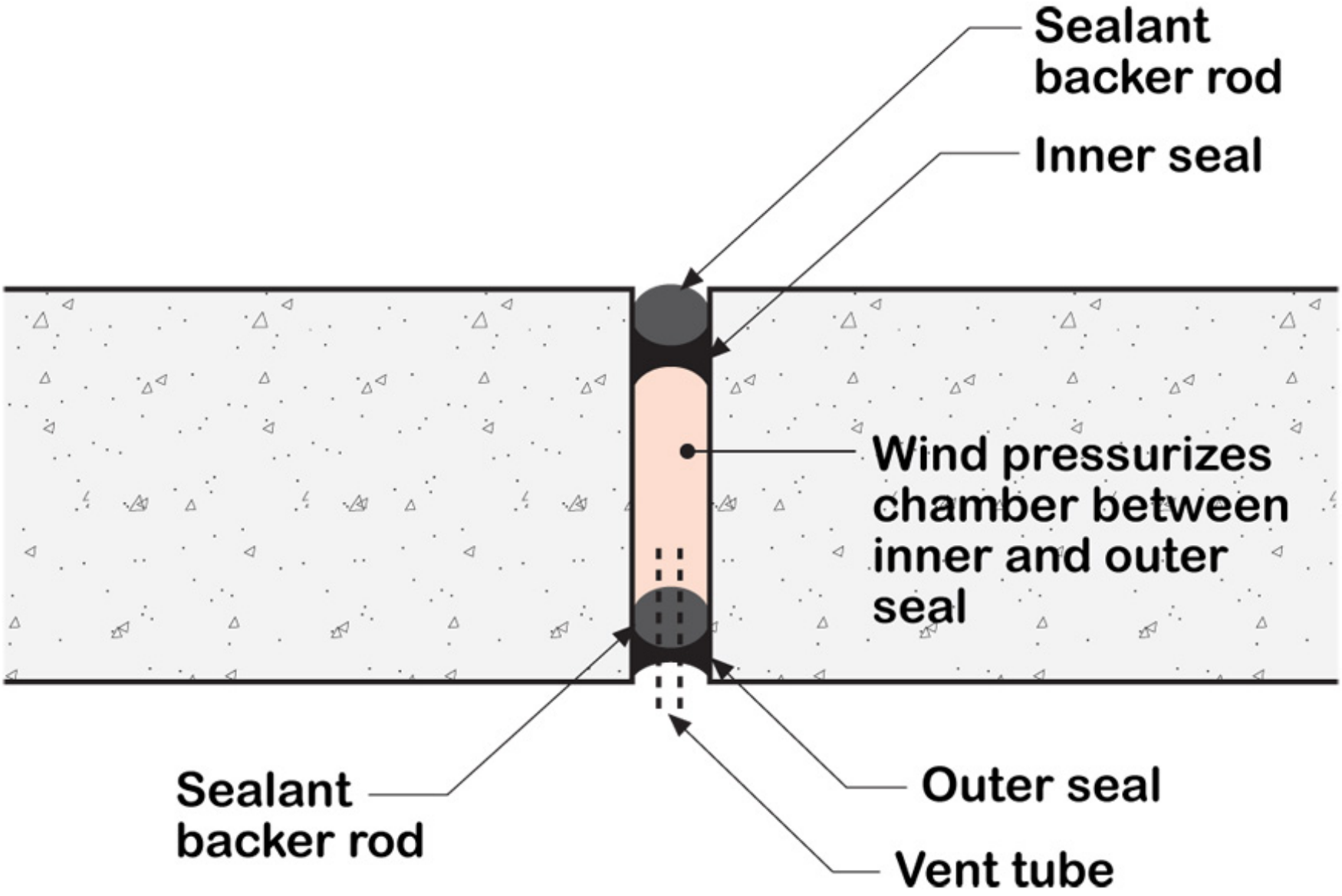


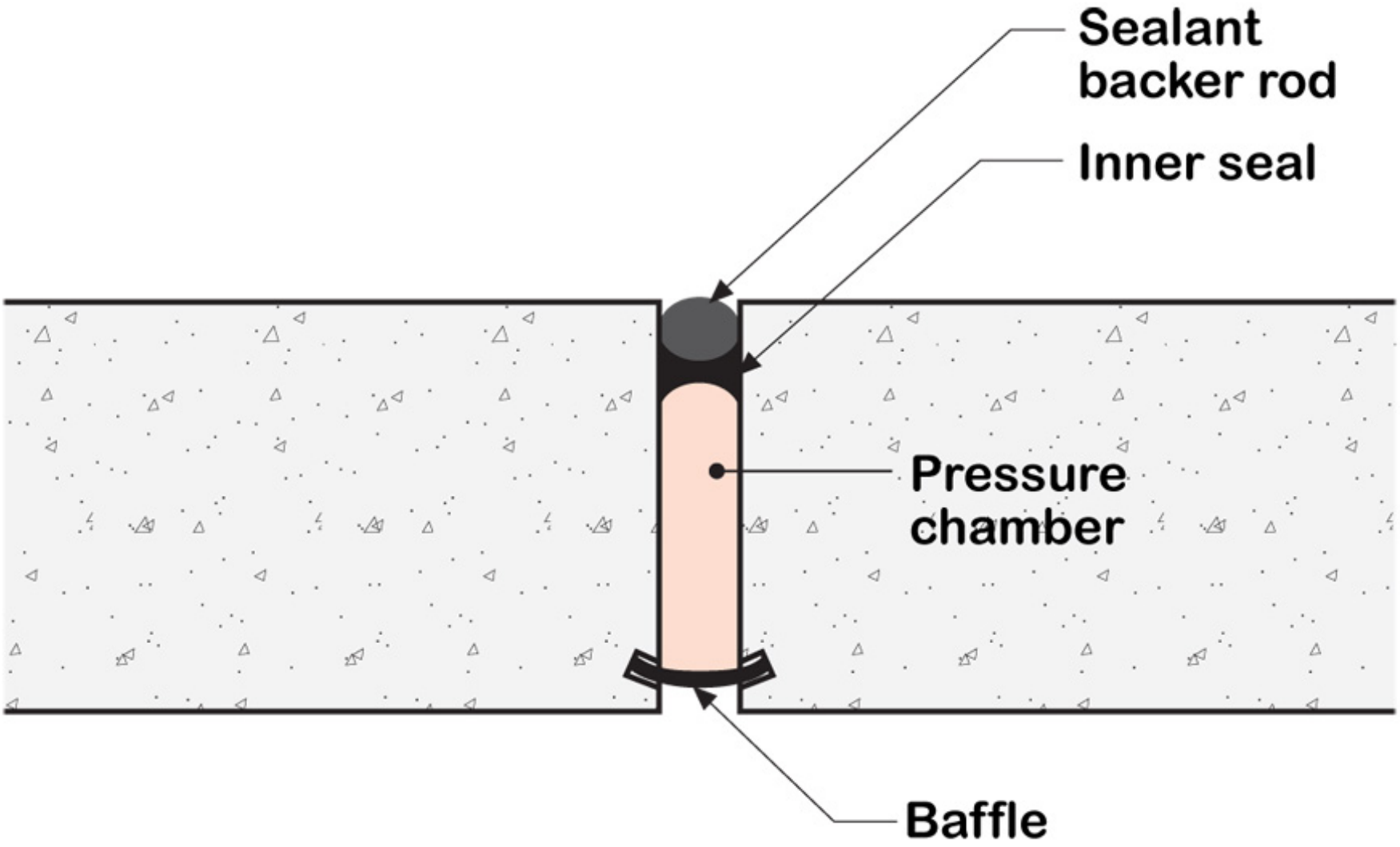


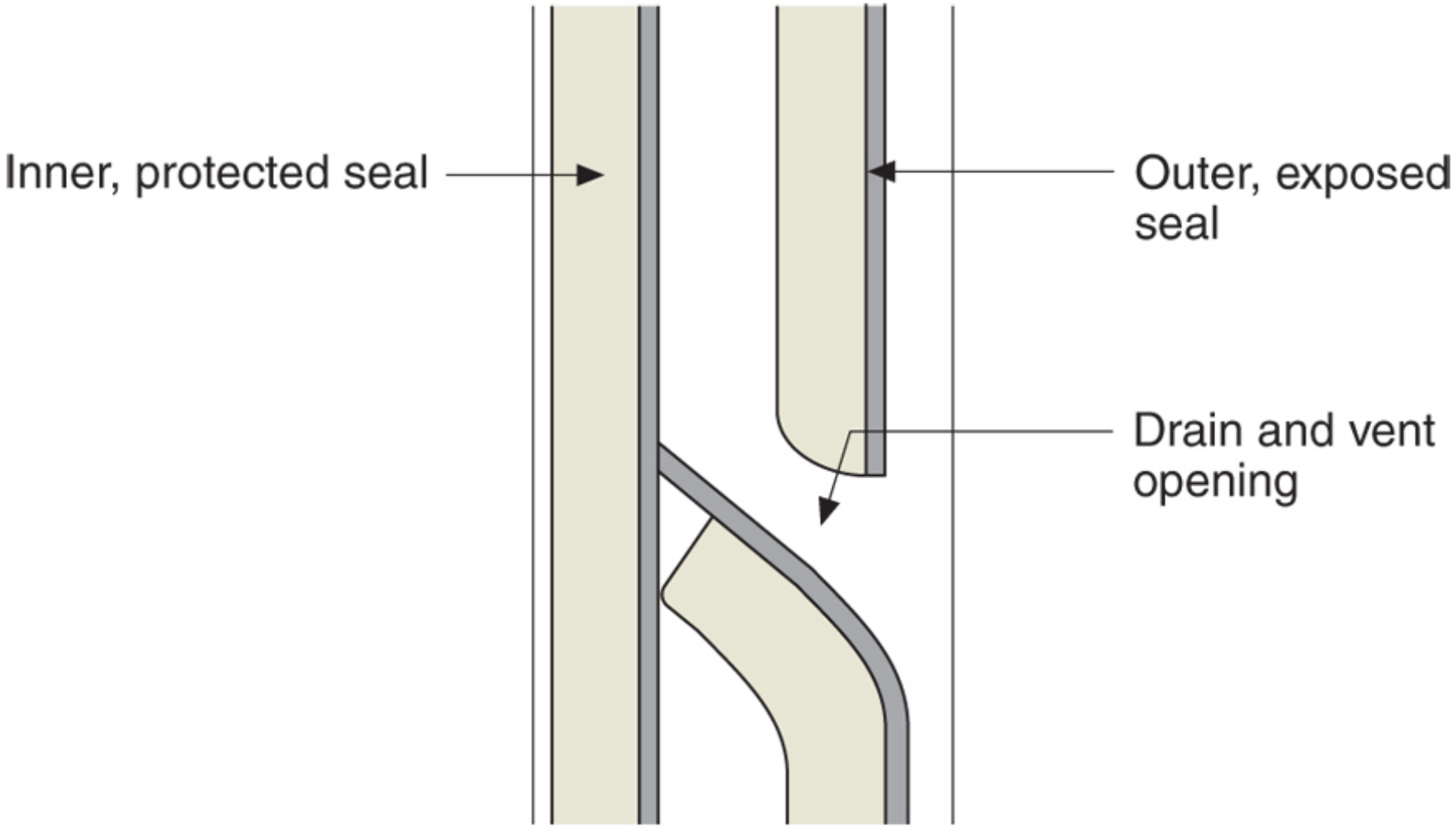


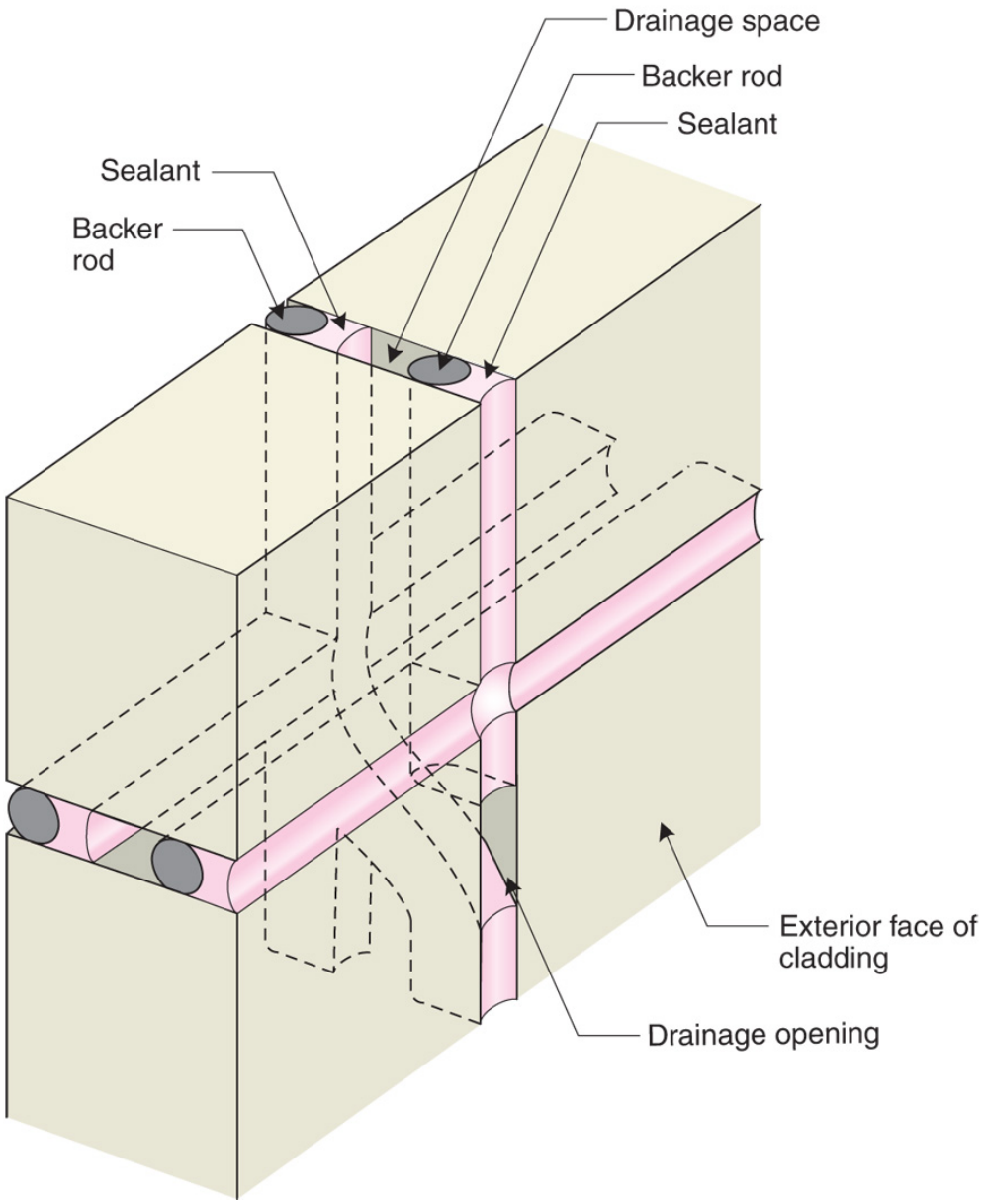


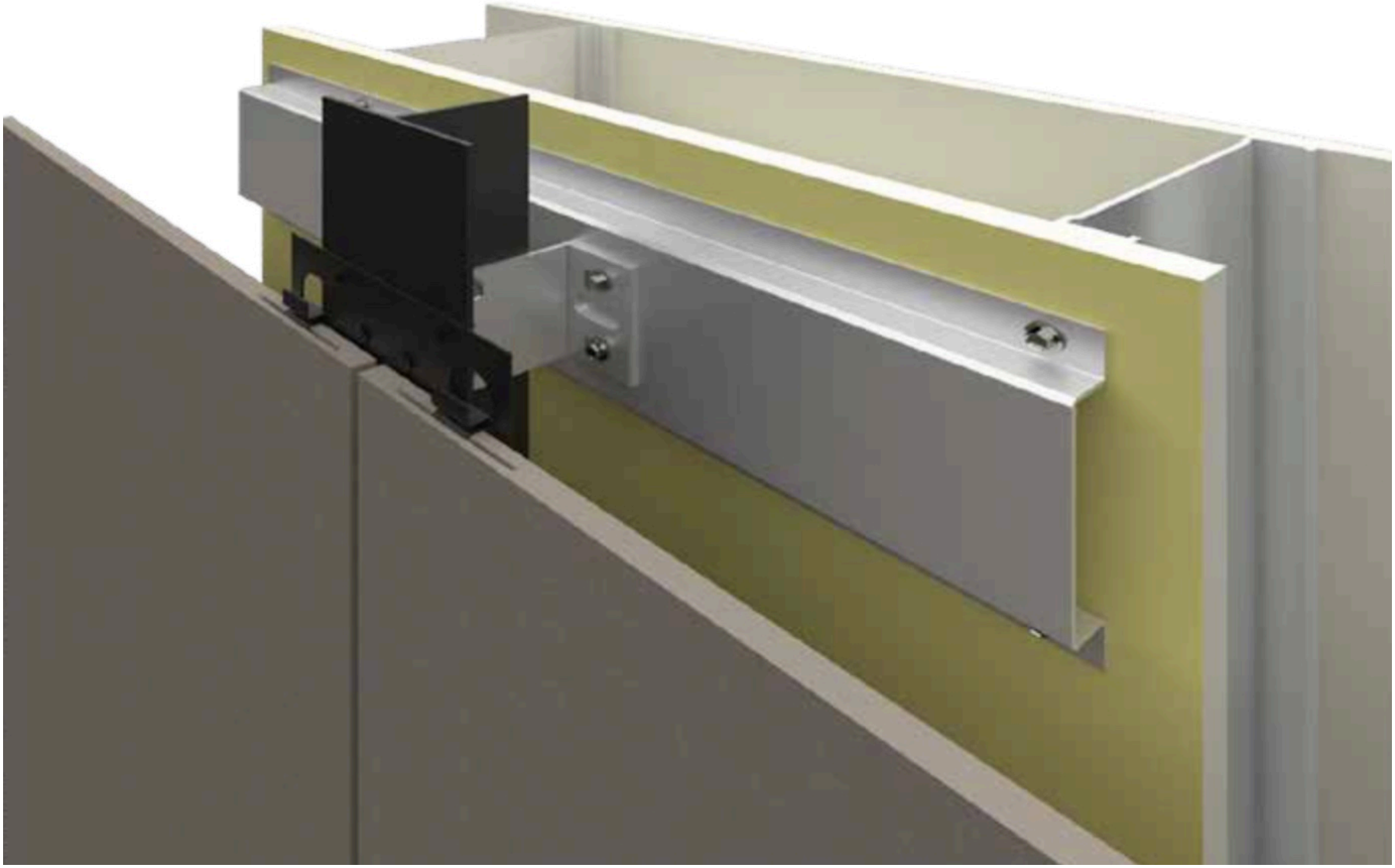
DERMACON

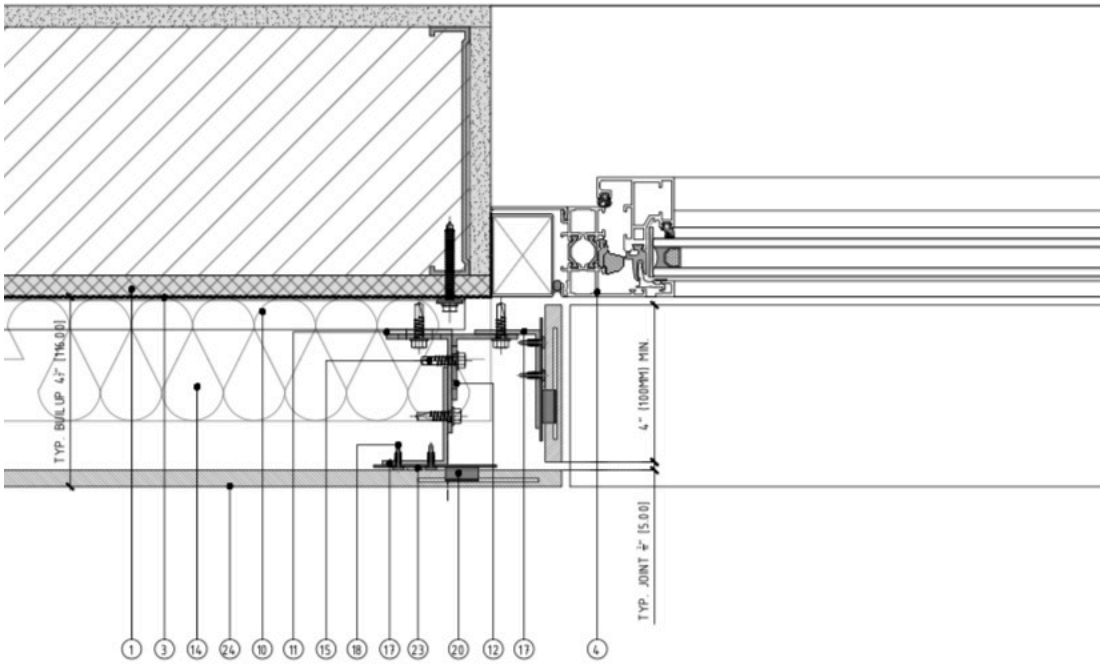

Sealant backer rod
Inner seal
Wind pressurizes chamber between inner and outer seal
Sealant backer rod
Outer seal
Vent tube


Sealant
backer rod
Inner seal
Pressure
chamber
Baffle


Inner, protected seal
Outer, exposed seal
Drain and vent opening


Drainage space
Backer rod
Sealant
Sealant
Backer rod
Exterior face of cladding
Drainage opening




TYP. BUILUP 4½" [116.00]
4" [100MM] MIN.
TYP. JOINT ¼" [5.00]
1
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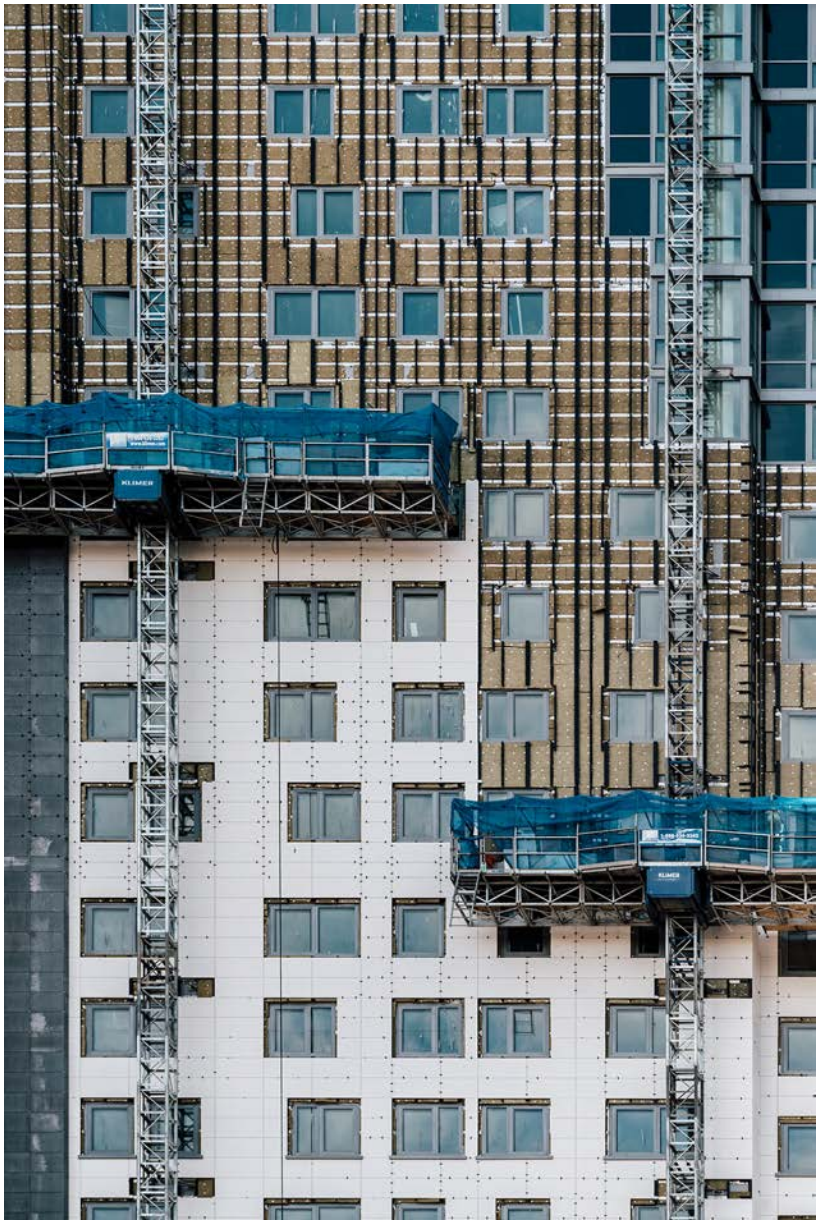
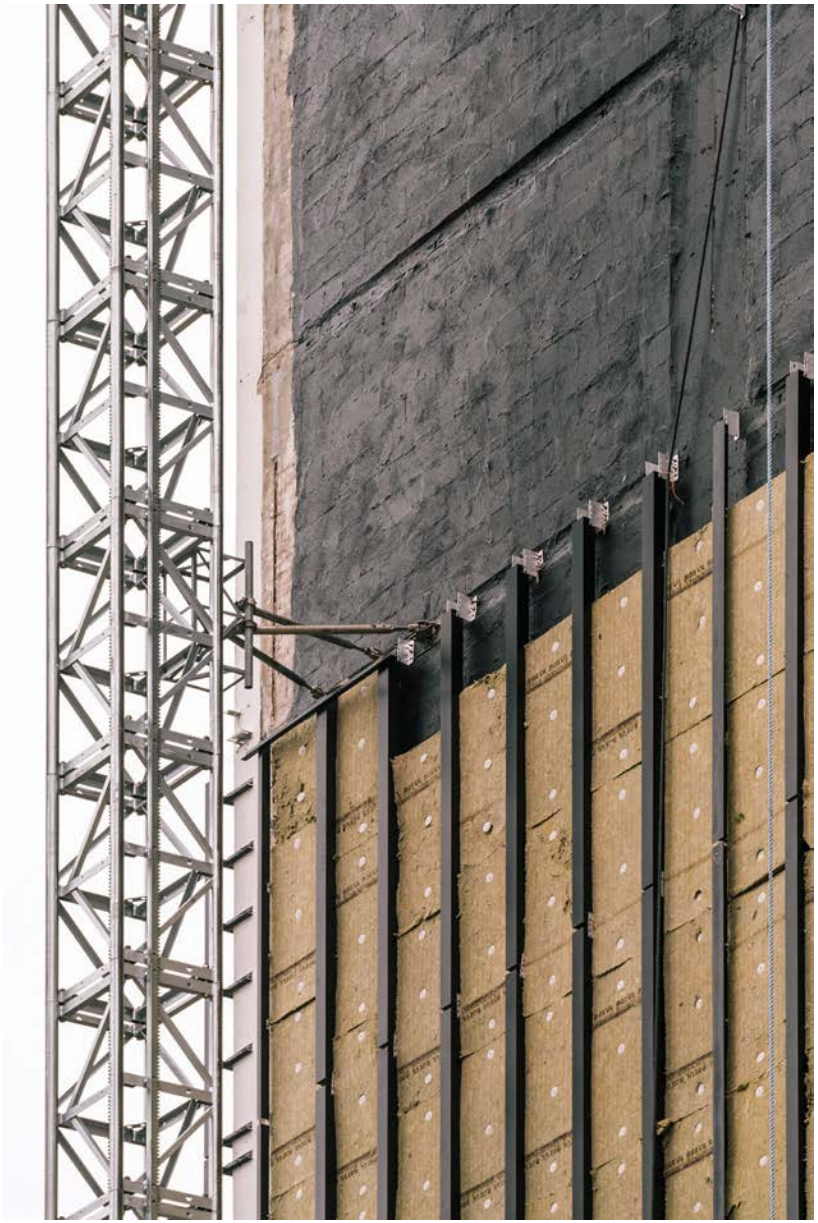
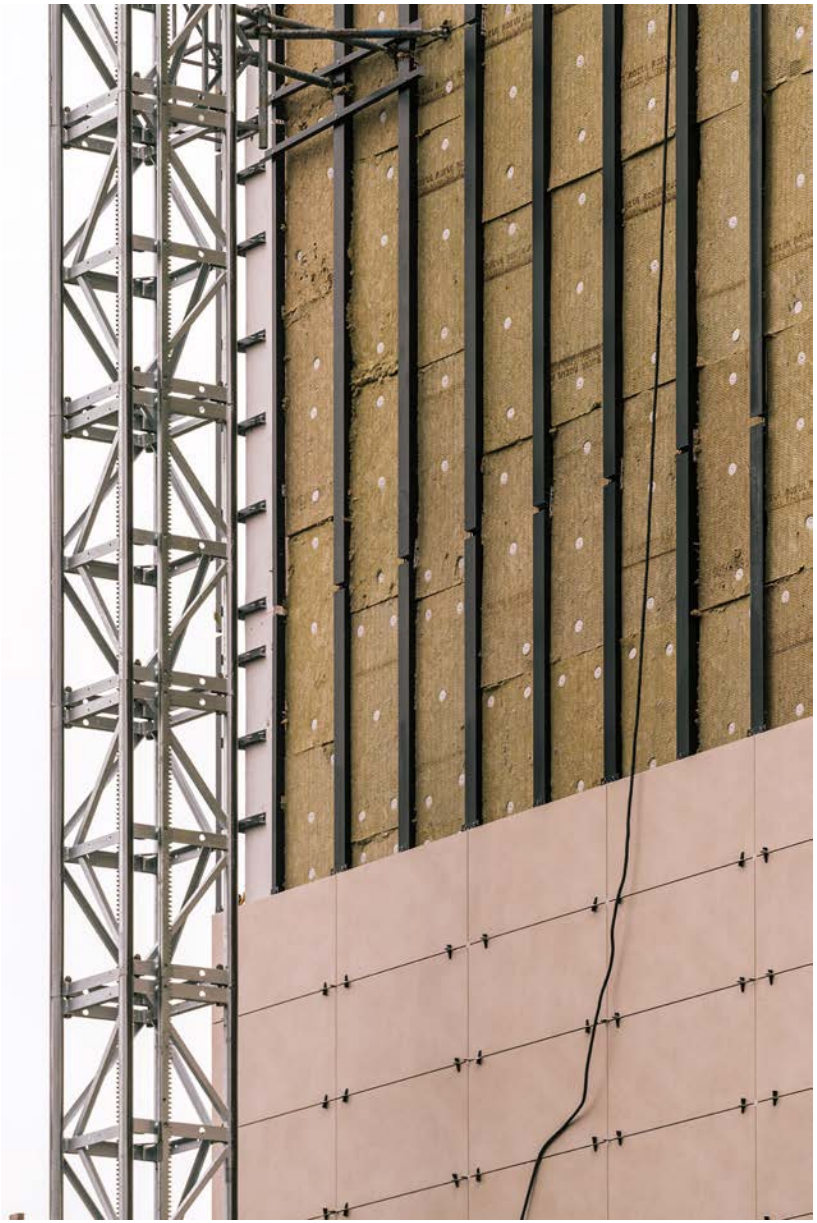
AC HOTELS
AC HOTELS



wework
With Love
PINK
Do What You Love



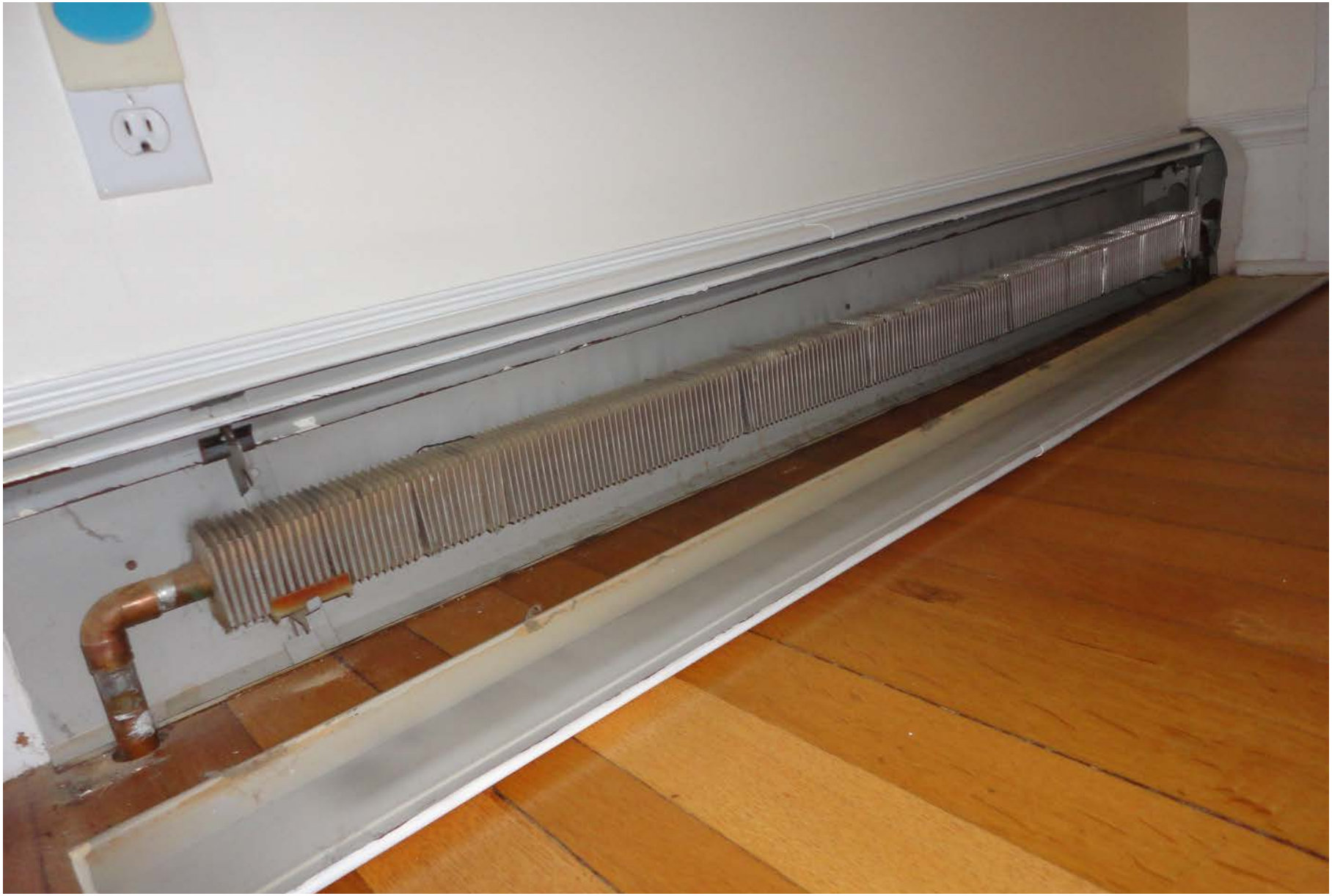


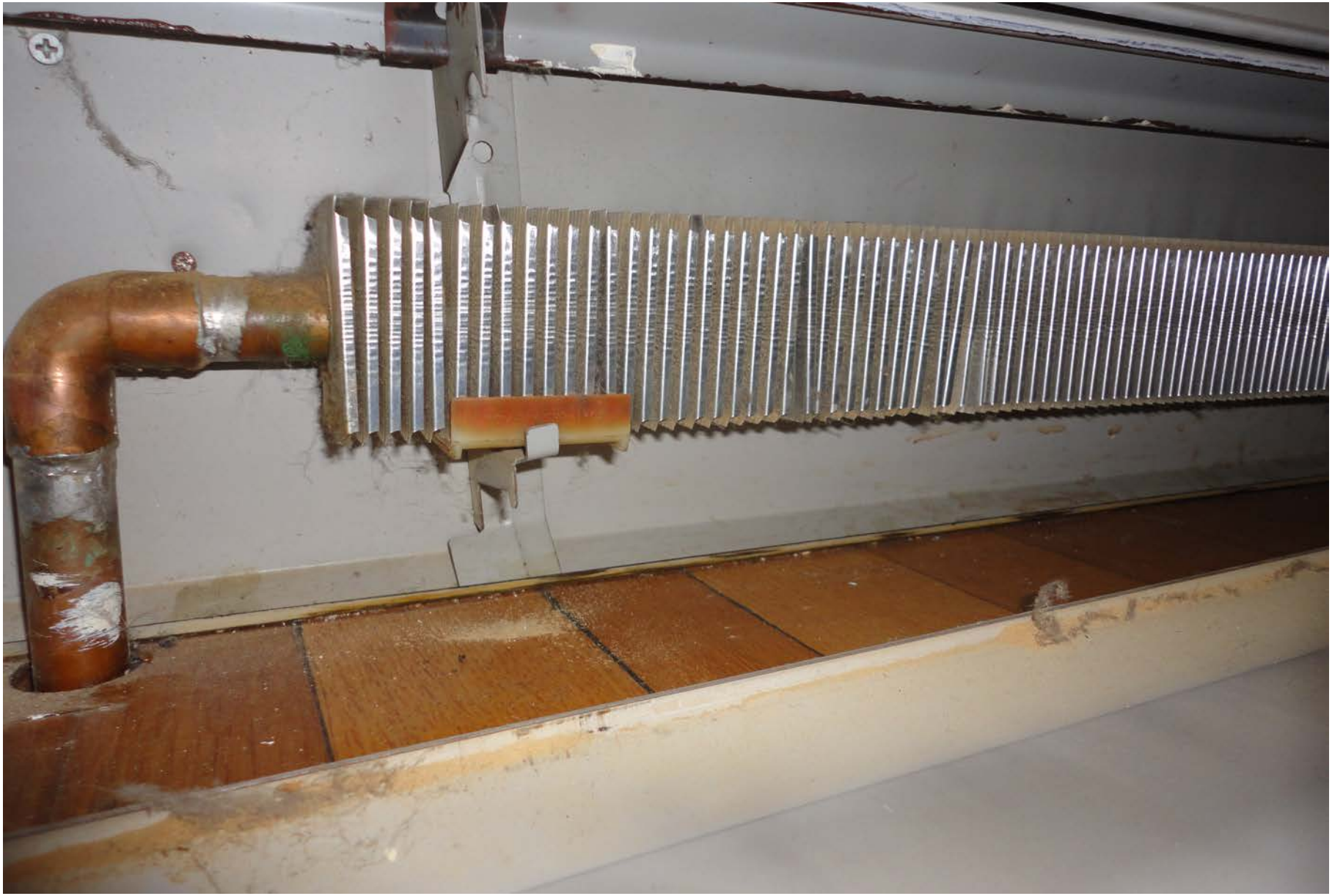
Life is Tough Enough As it Is…

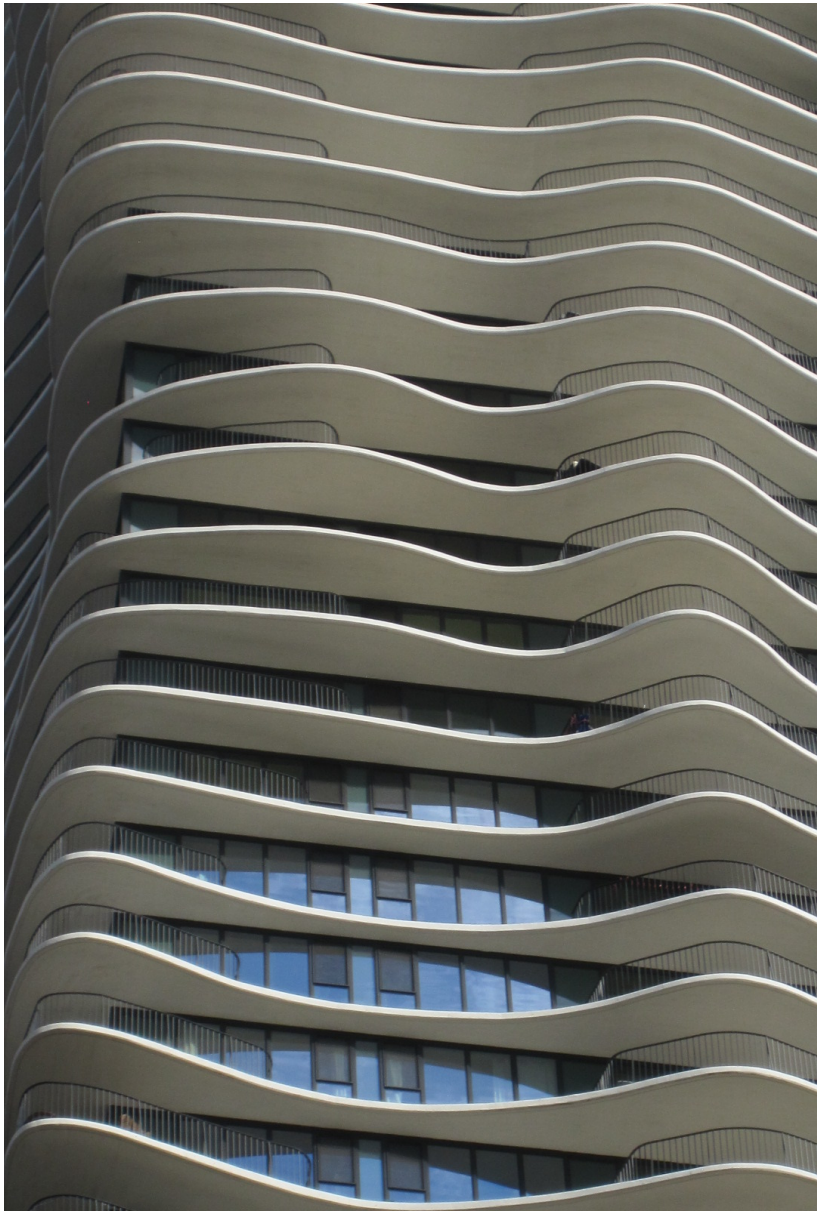
Life is Tough Enough As it Is…

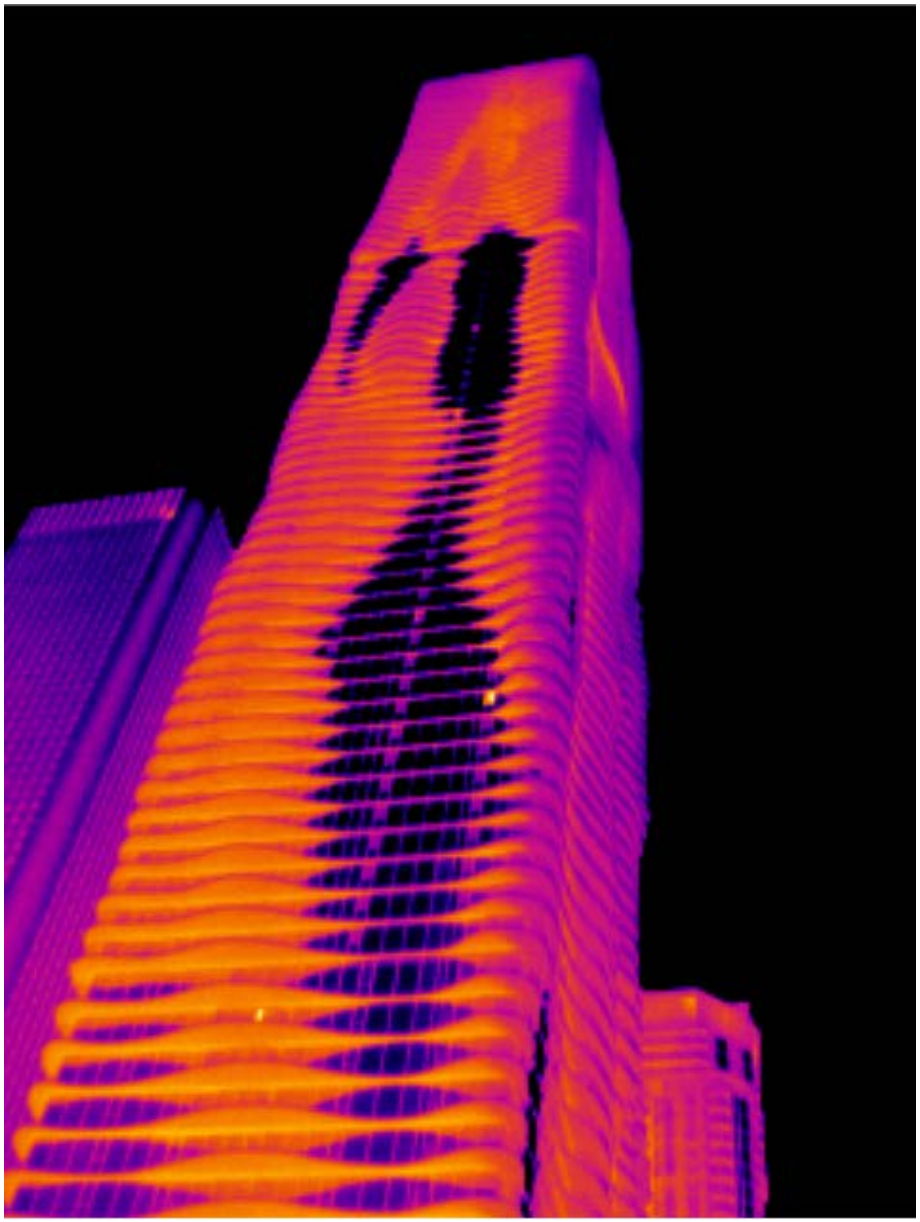
It’s Harder When You Are Stupid

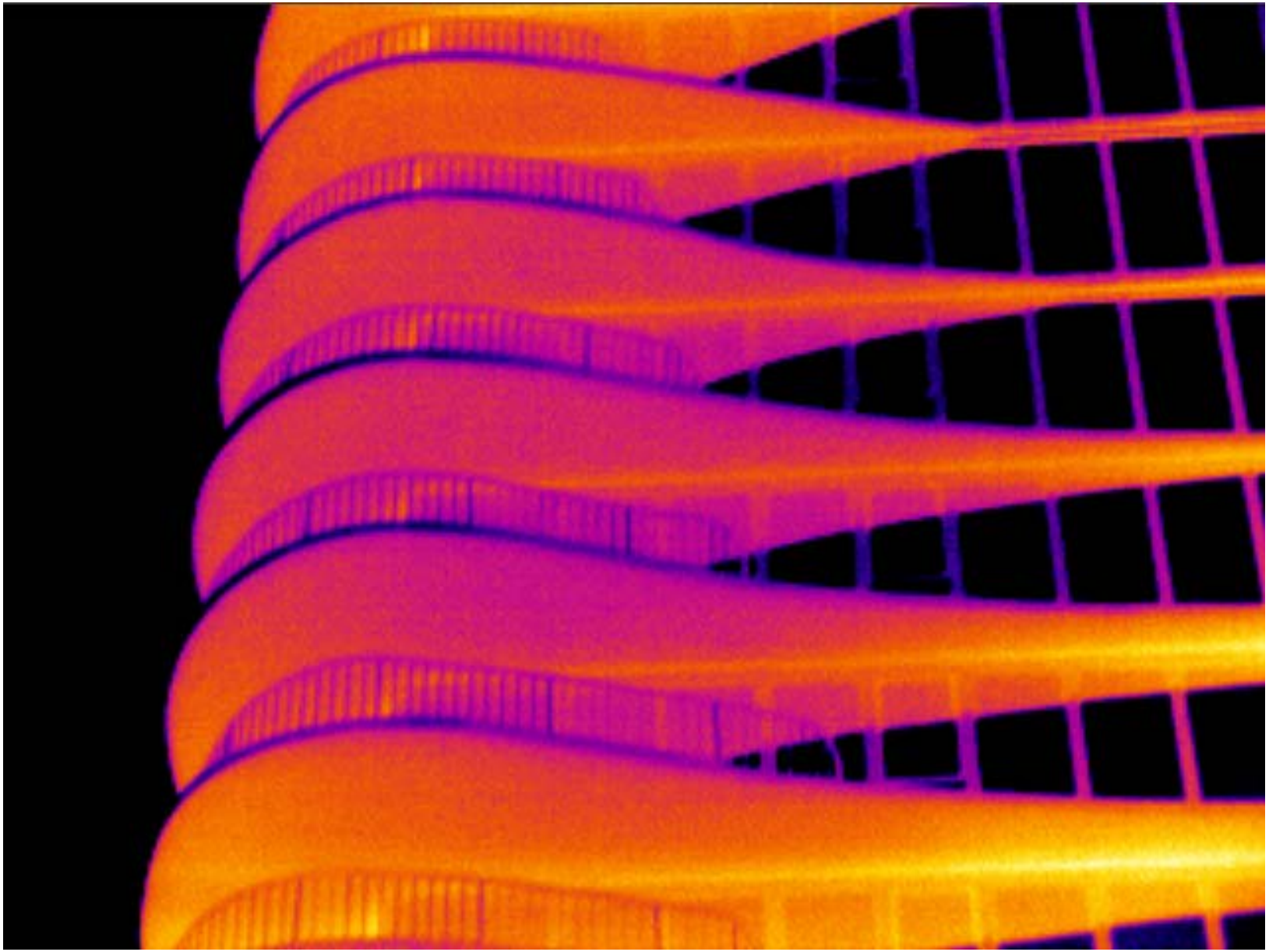
Don’t Do Stupid Things

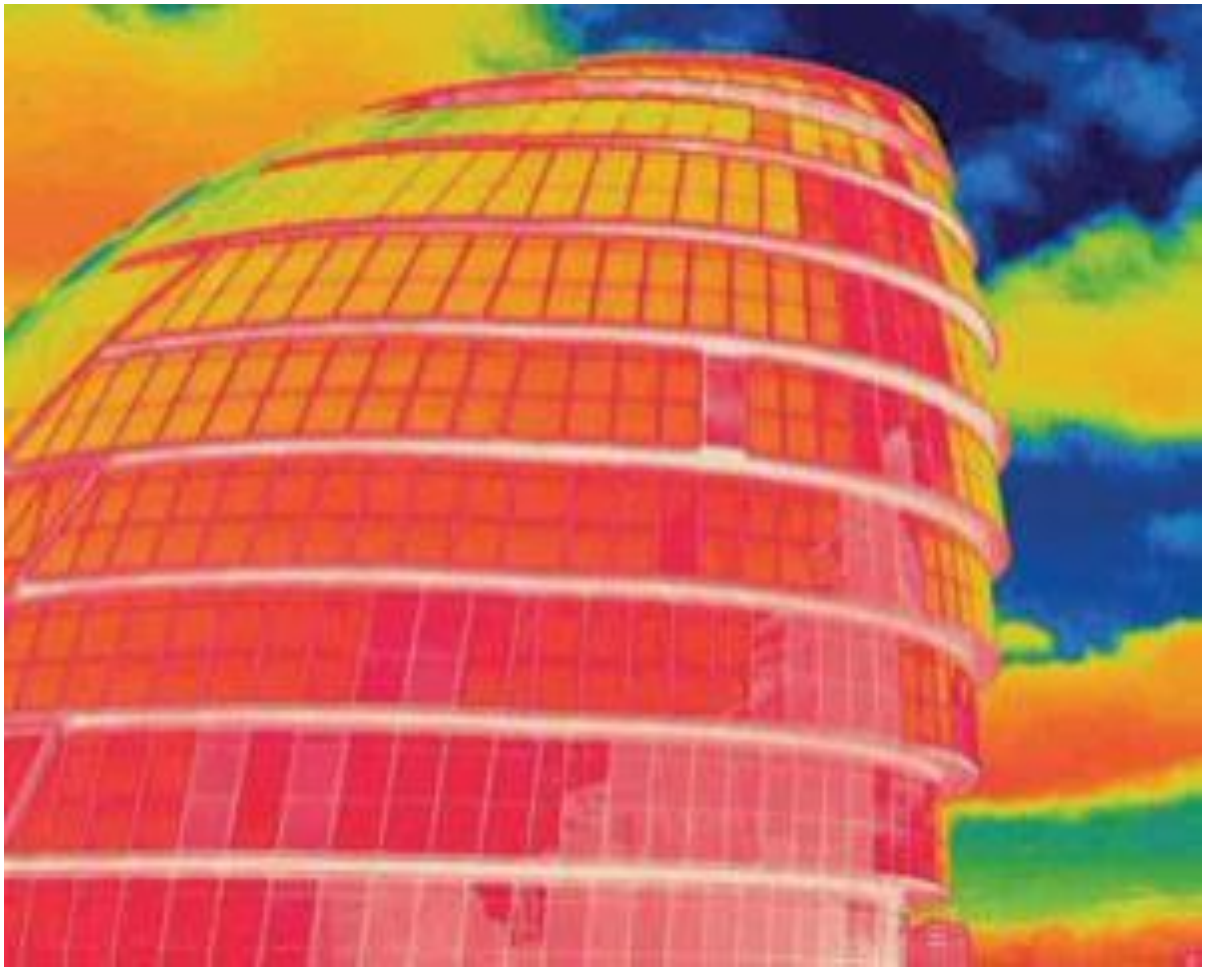


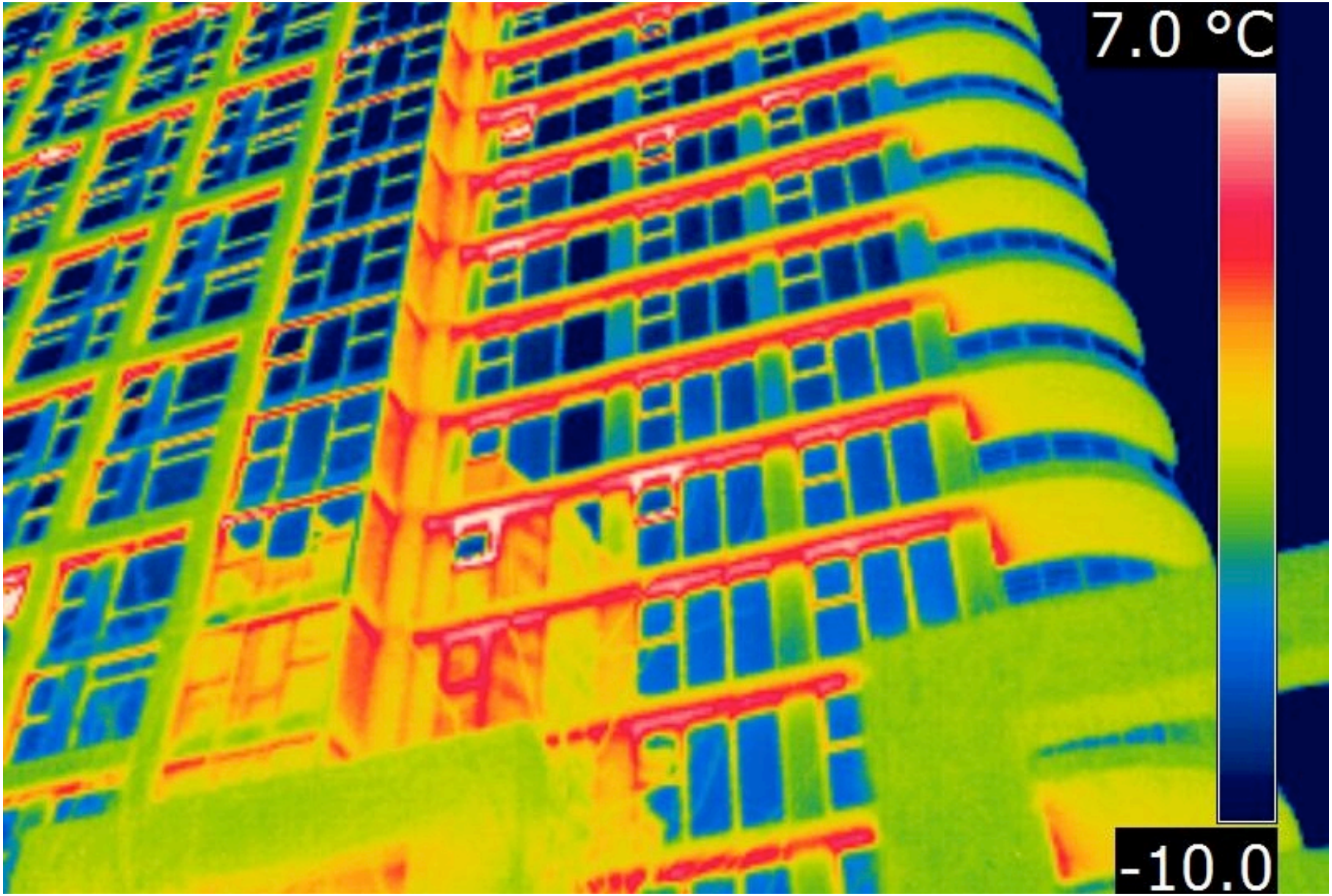


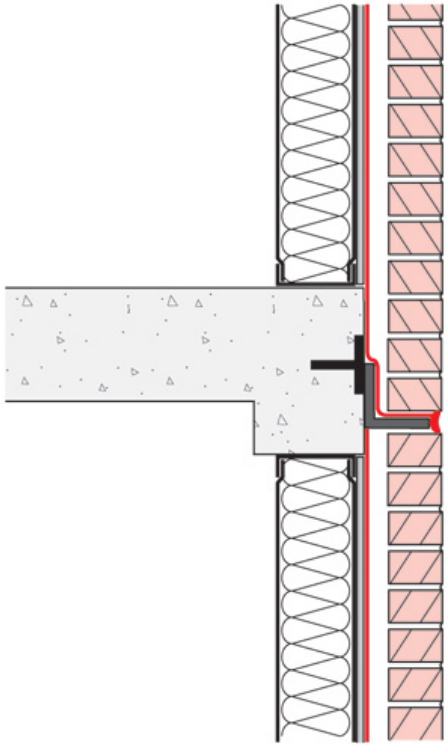




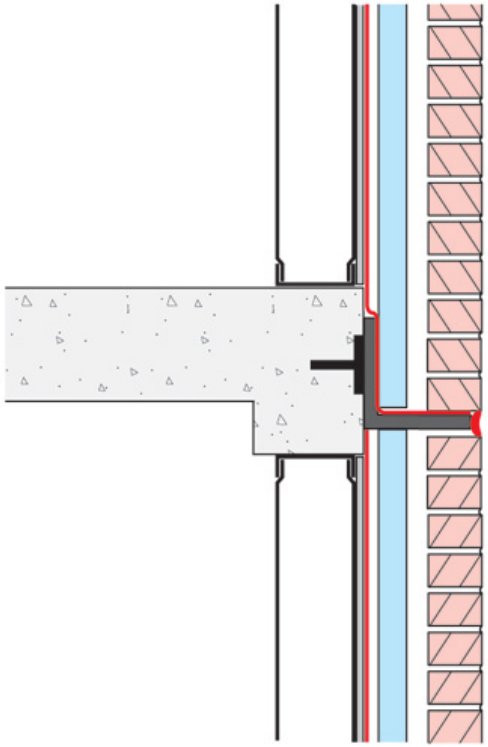




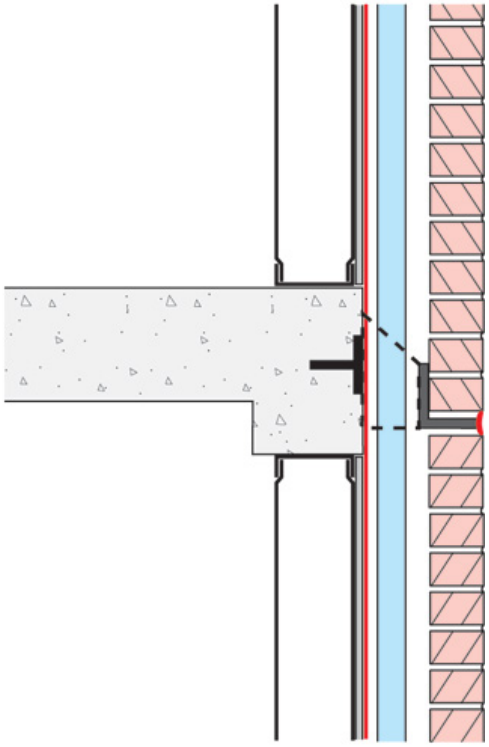

7.0 °C
-10.0



“The Ugly”



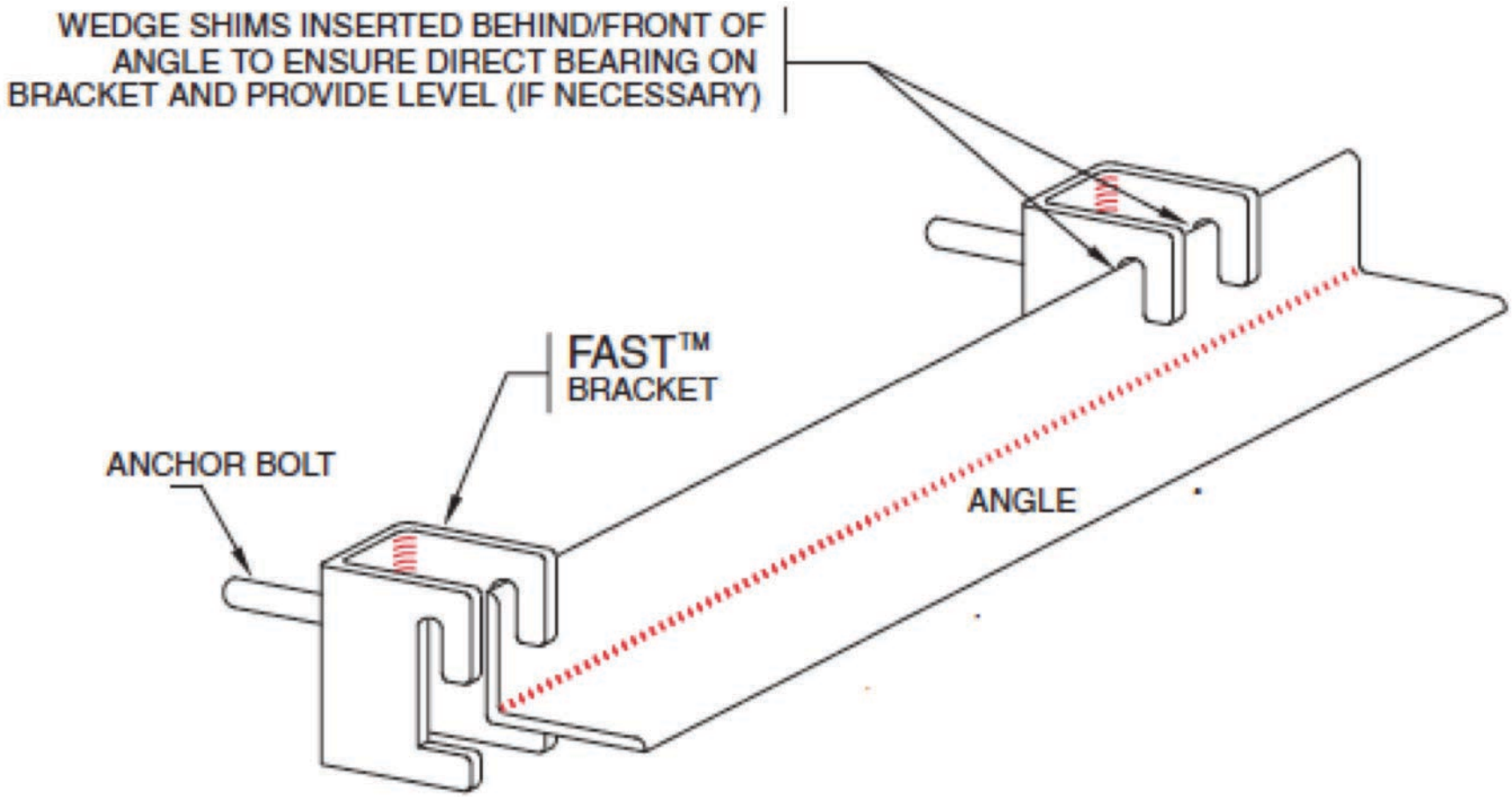
“The Bad”

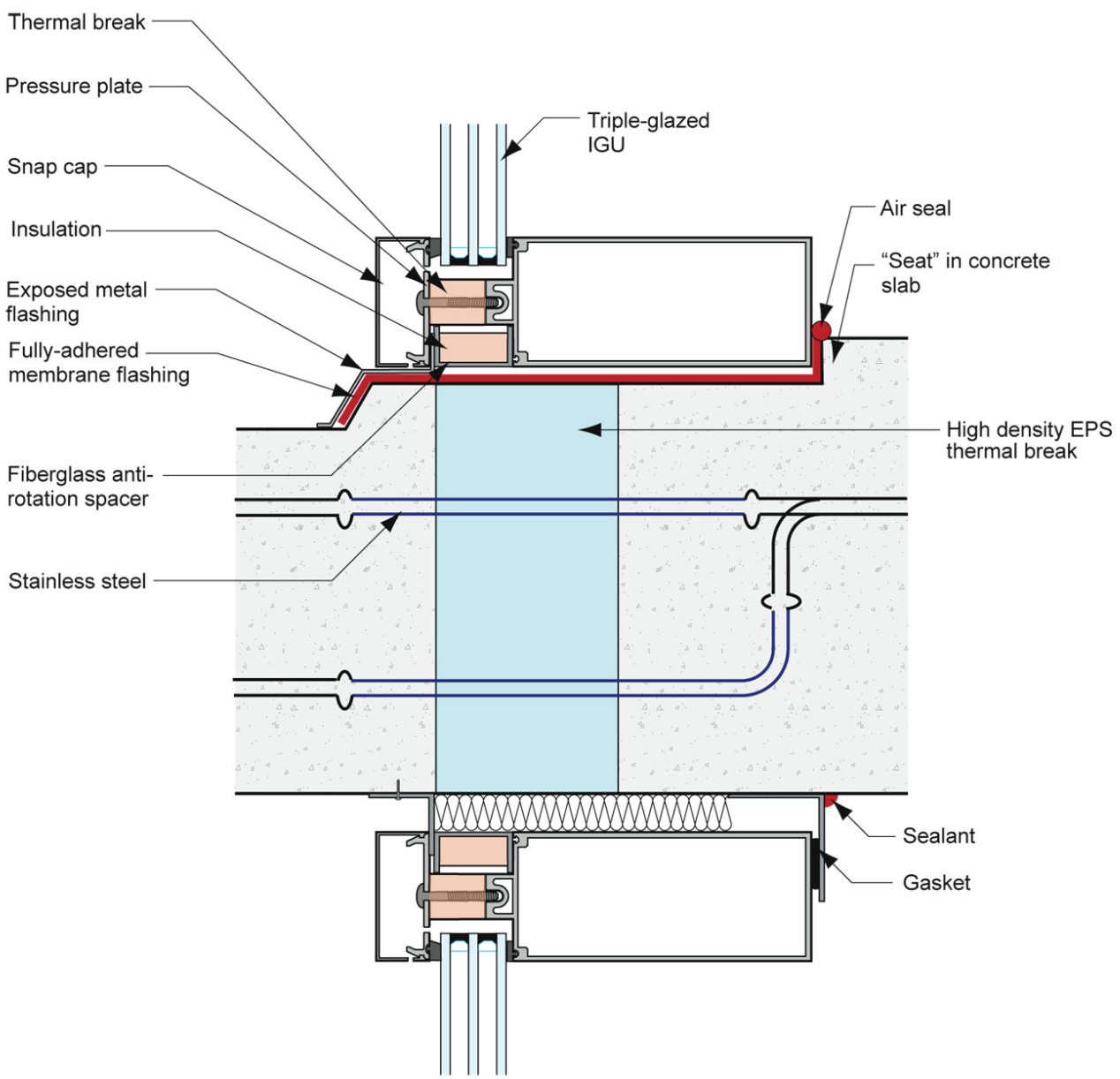


“The Good”

GP
DENSGLASS GOLD

Georgia-P
Bluesk


WEDGE SHIMS INSERTED BEHIND/FRONT OF ANGLE TO ENSURE DIRECT BEARING ON BRACKET AND PROVIDE LEVEL (IF NECESSARY)
FAST™ BRACKET
ANCHOR BOLT
ANGLE


Thermal break
Pressure plate
Snap cap
Insulation
Exposed metal flashing
Fully-adhered membrane flashing
Fiberglass anti-rotation spacer
Stainless steel
Triple-glazed IGU
Air seal
"Seat" in concrete slab
High density EPS thermal break
Sealant
Gasket