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

Building Science

Adventures In Building Science

www.buildingscience.com

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

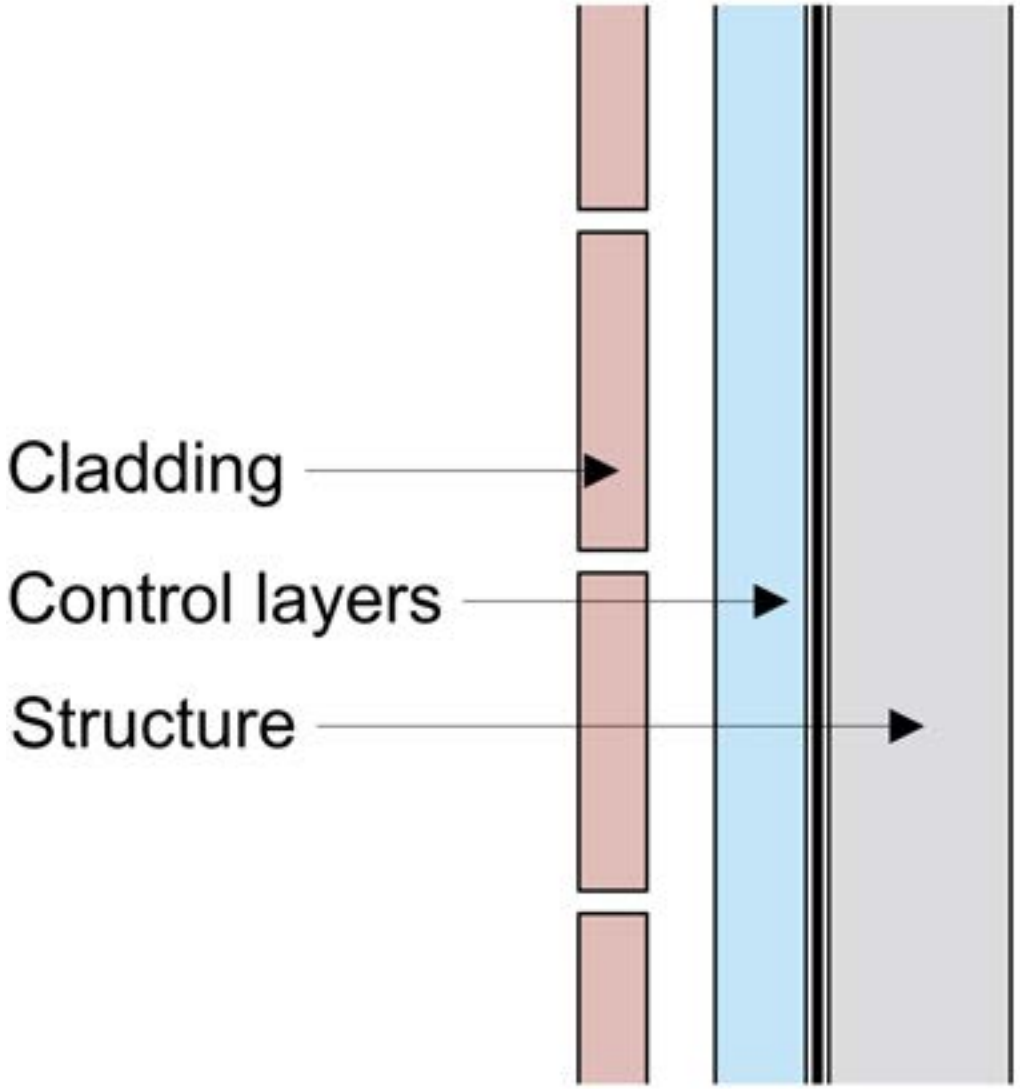
Moisture Flow Is From More To Less

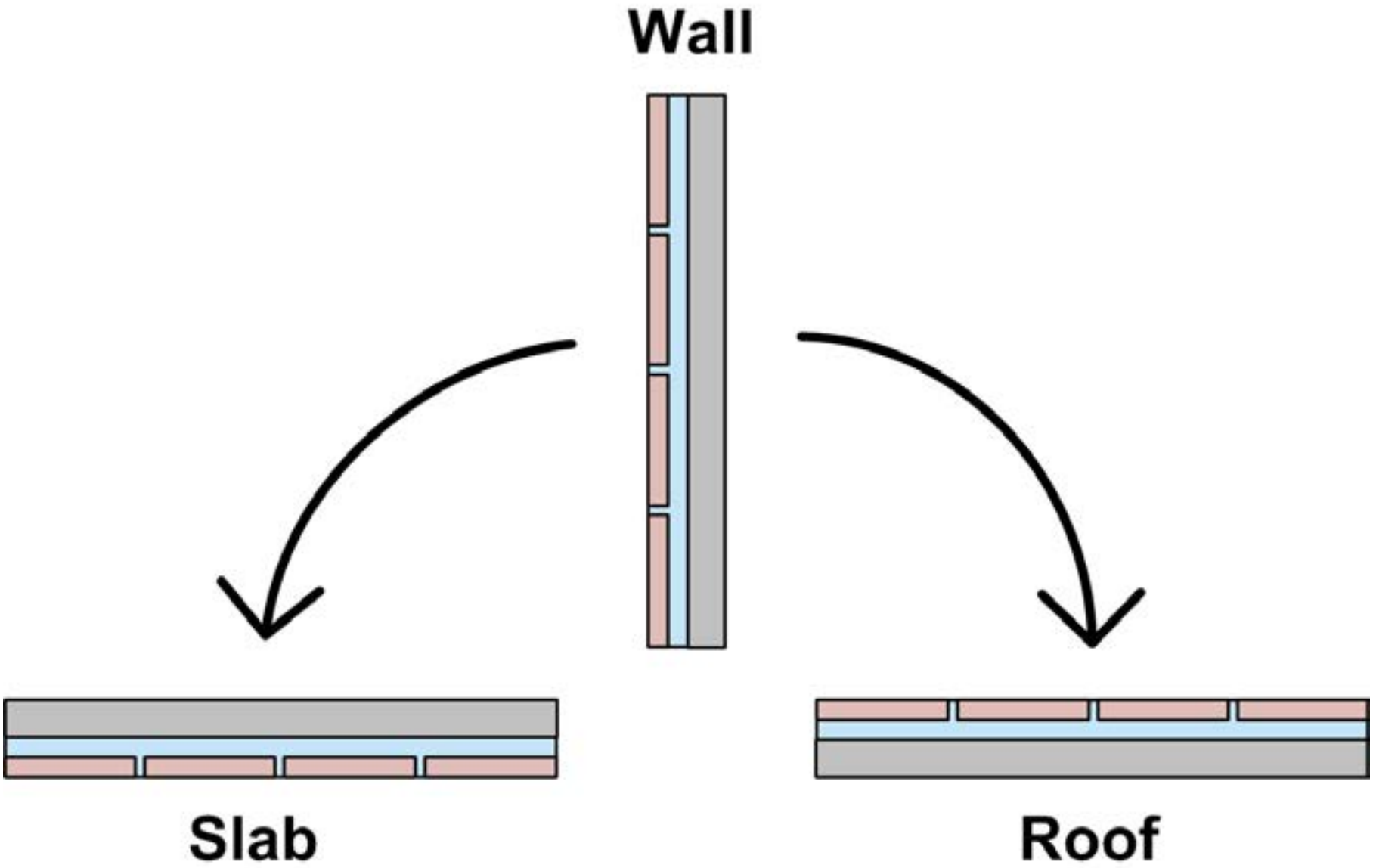
Water Control Layer

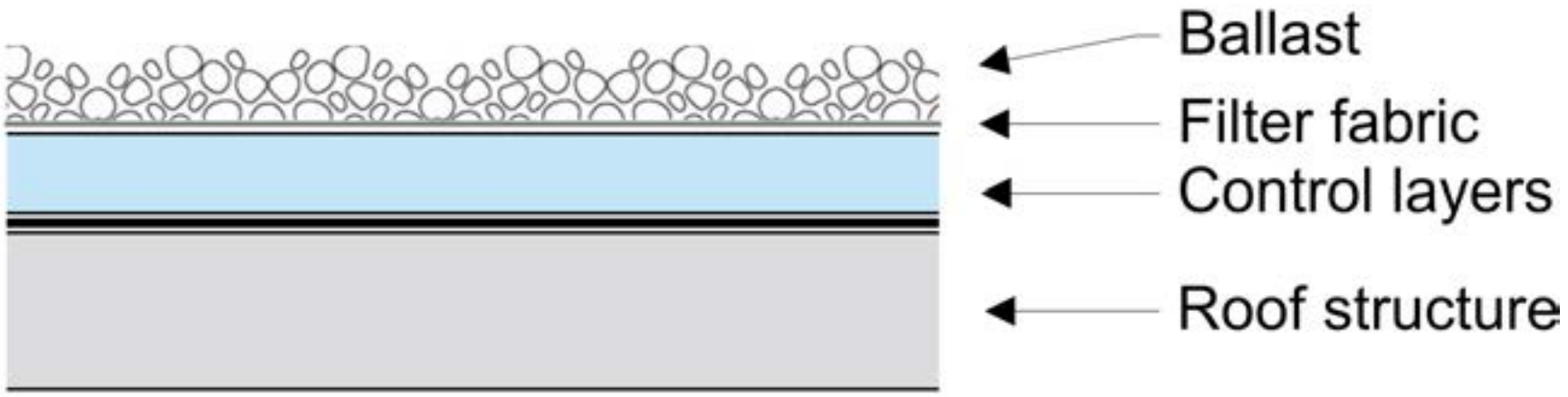
Air Control Layer

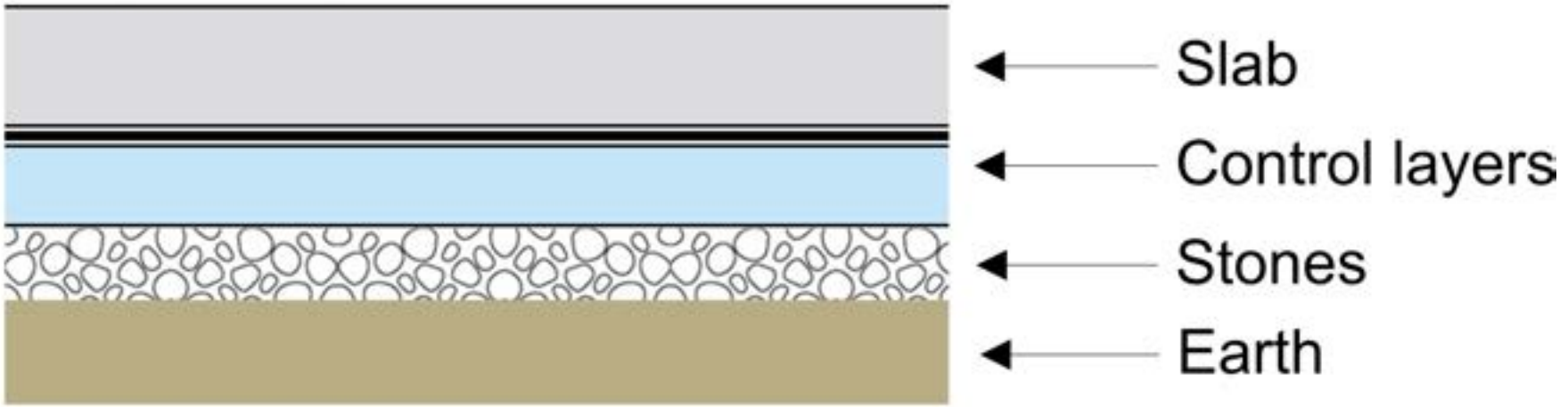
Vapor Control Layer

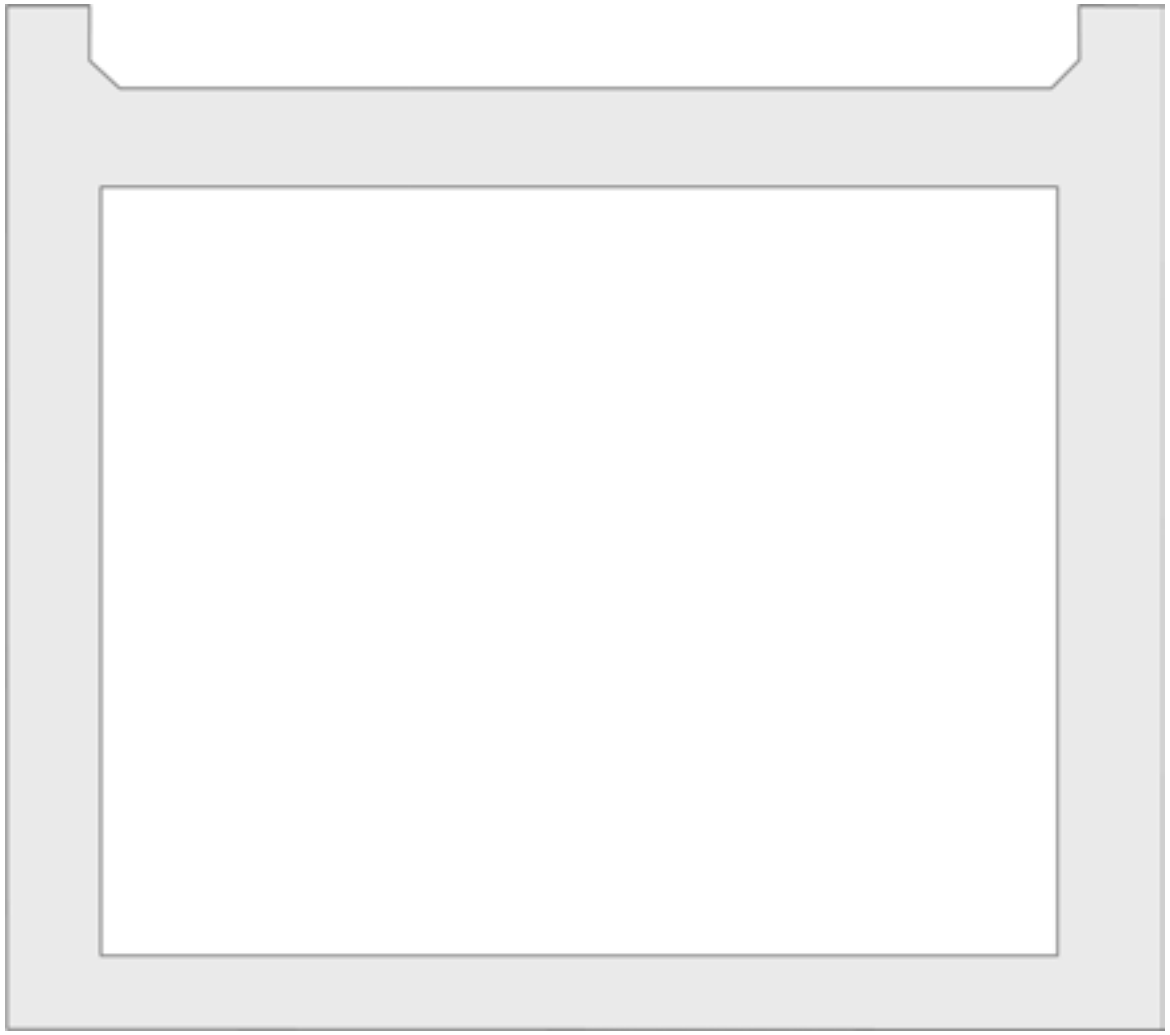
Thermal Control Layer


Cladding
Control layers
Structure

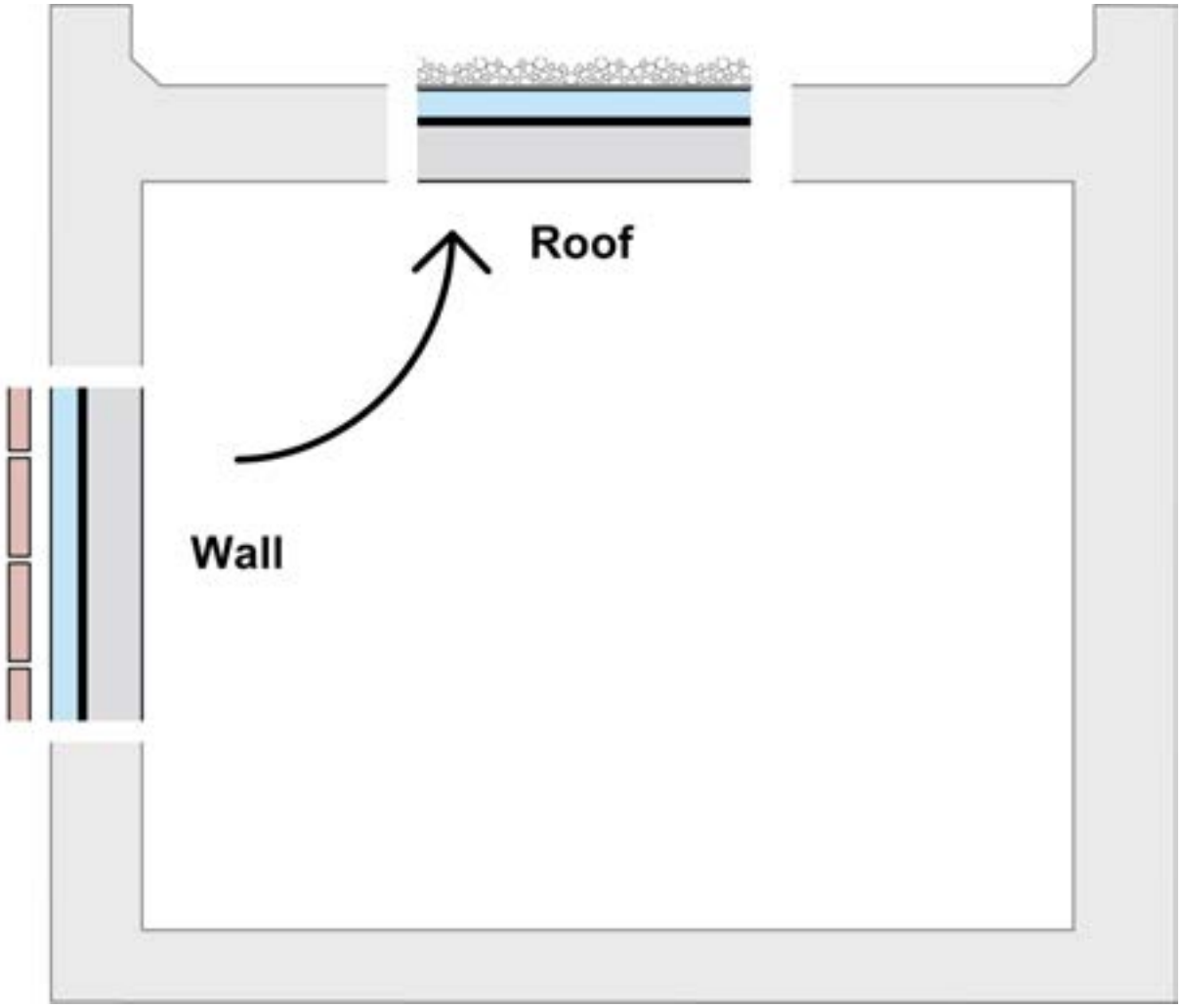

Wall
Slab
Roof

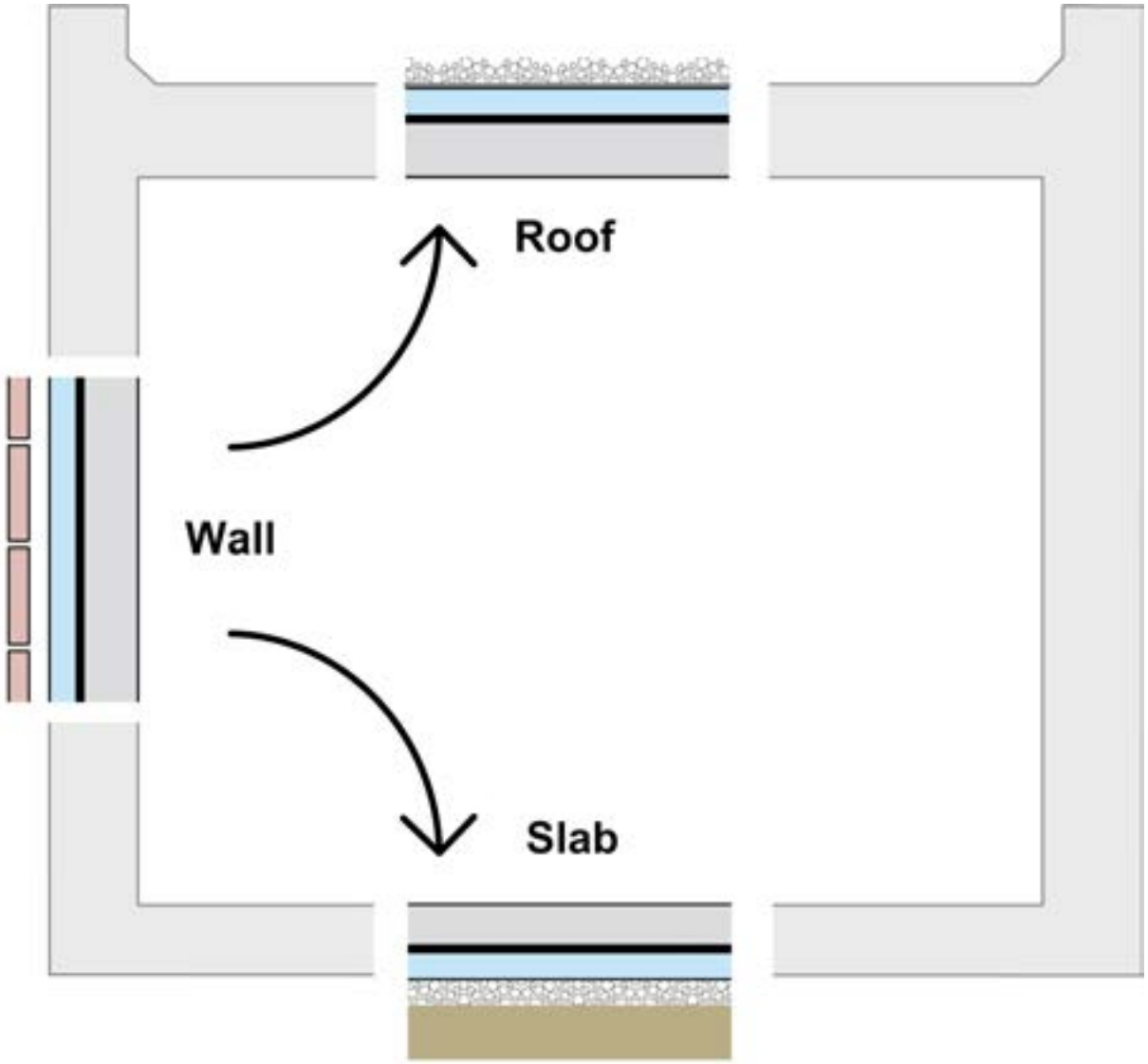

Ballast
Filter fabric
Control layers
Roof structure

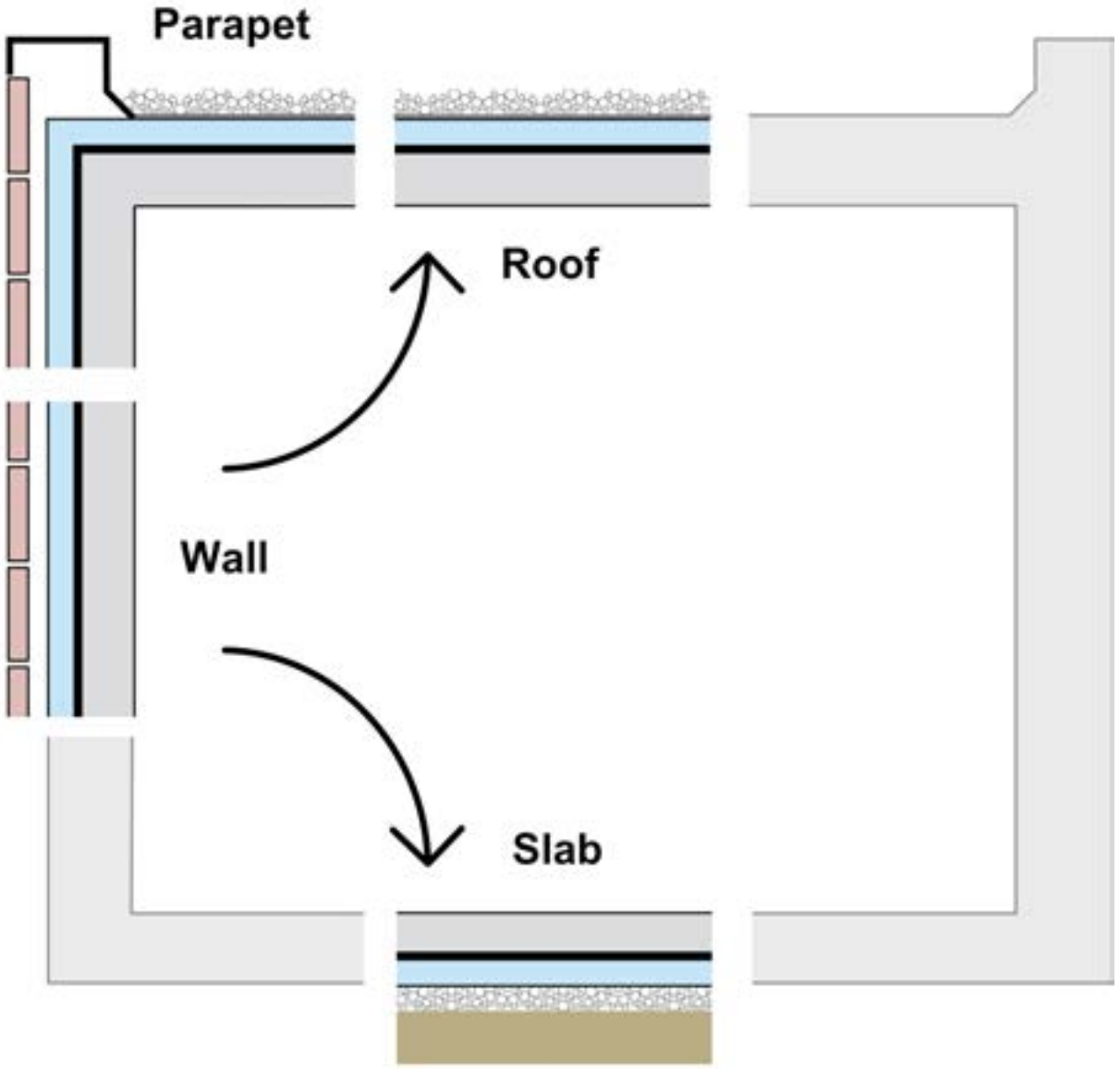

Slab
Control layers
Stones
Earth

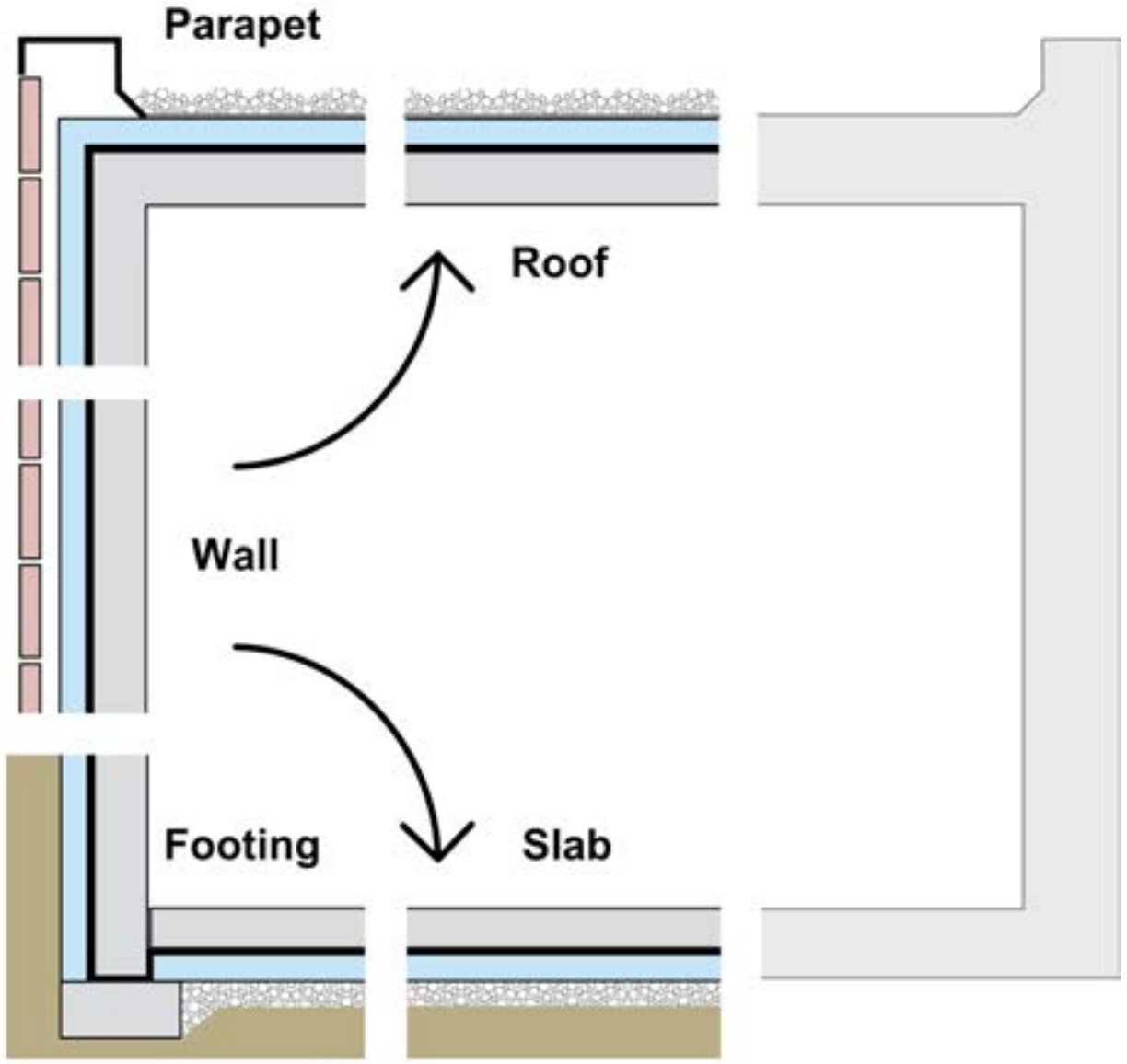


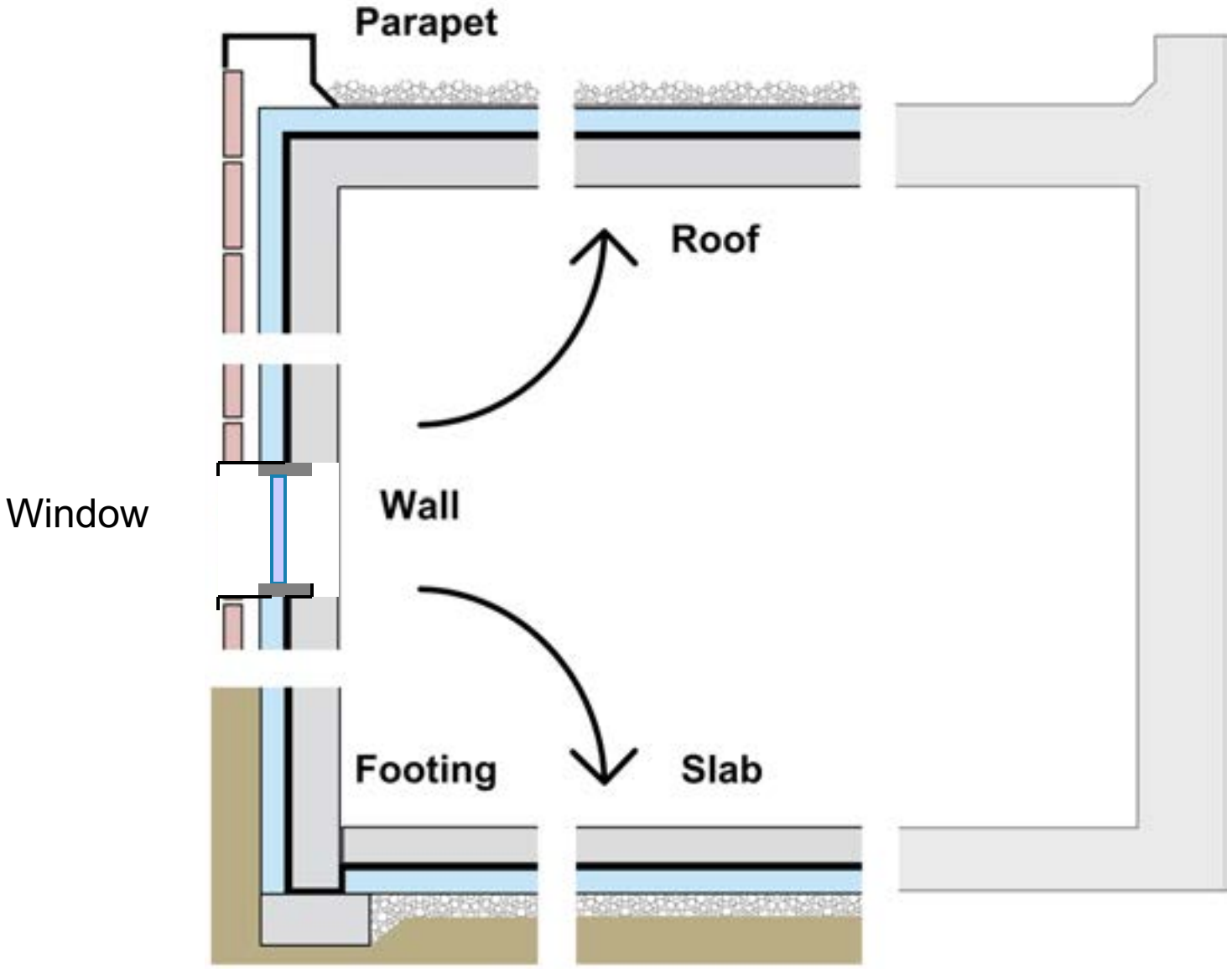
Wall

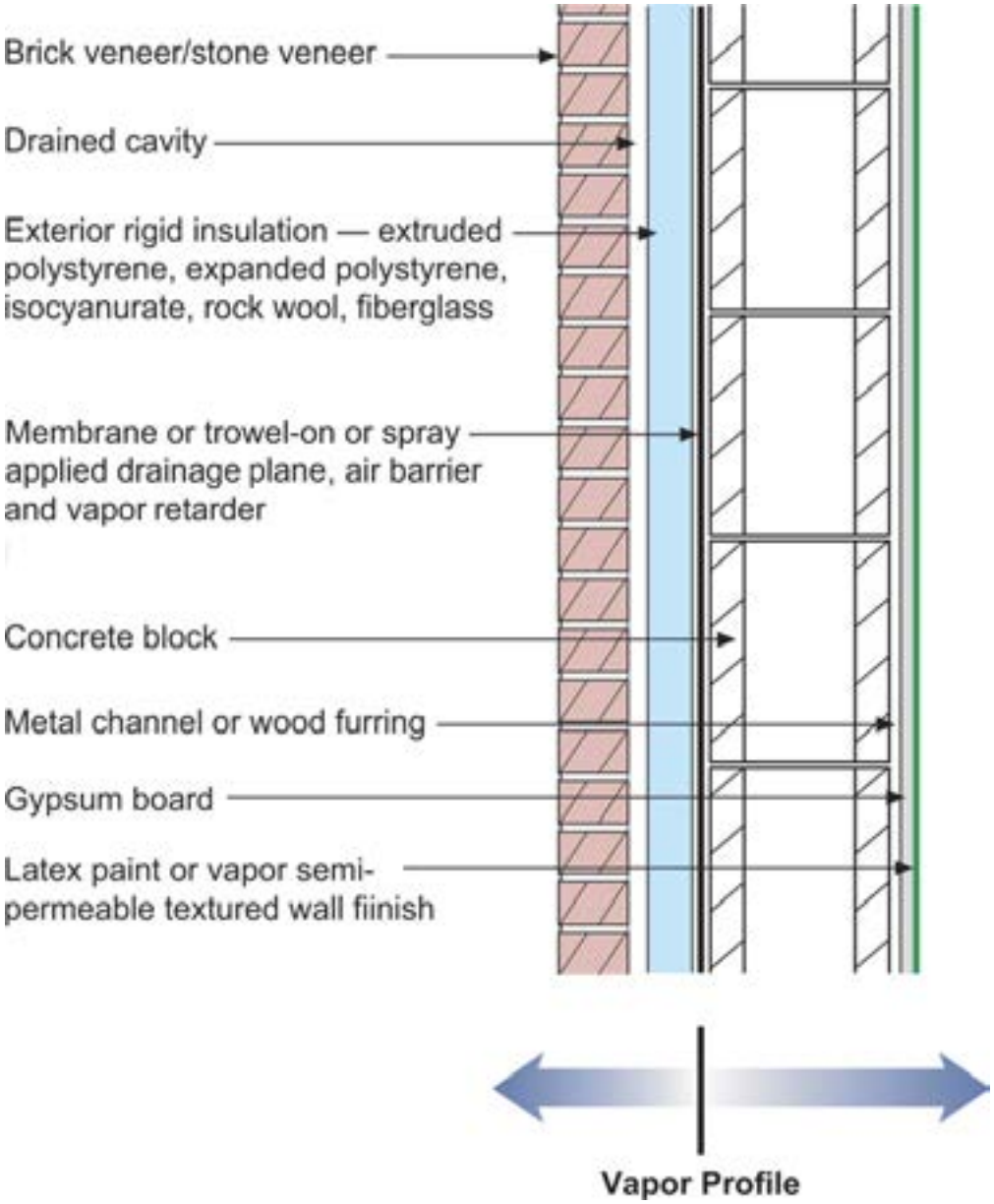

Roof
Wall

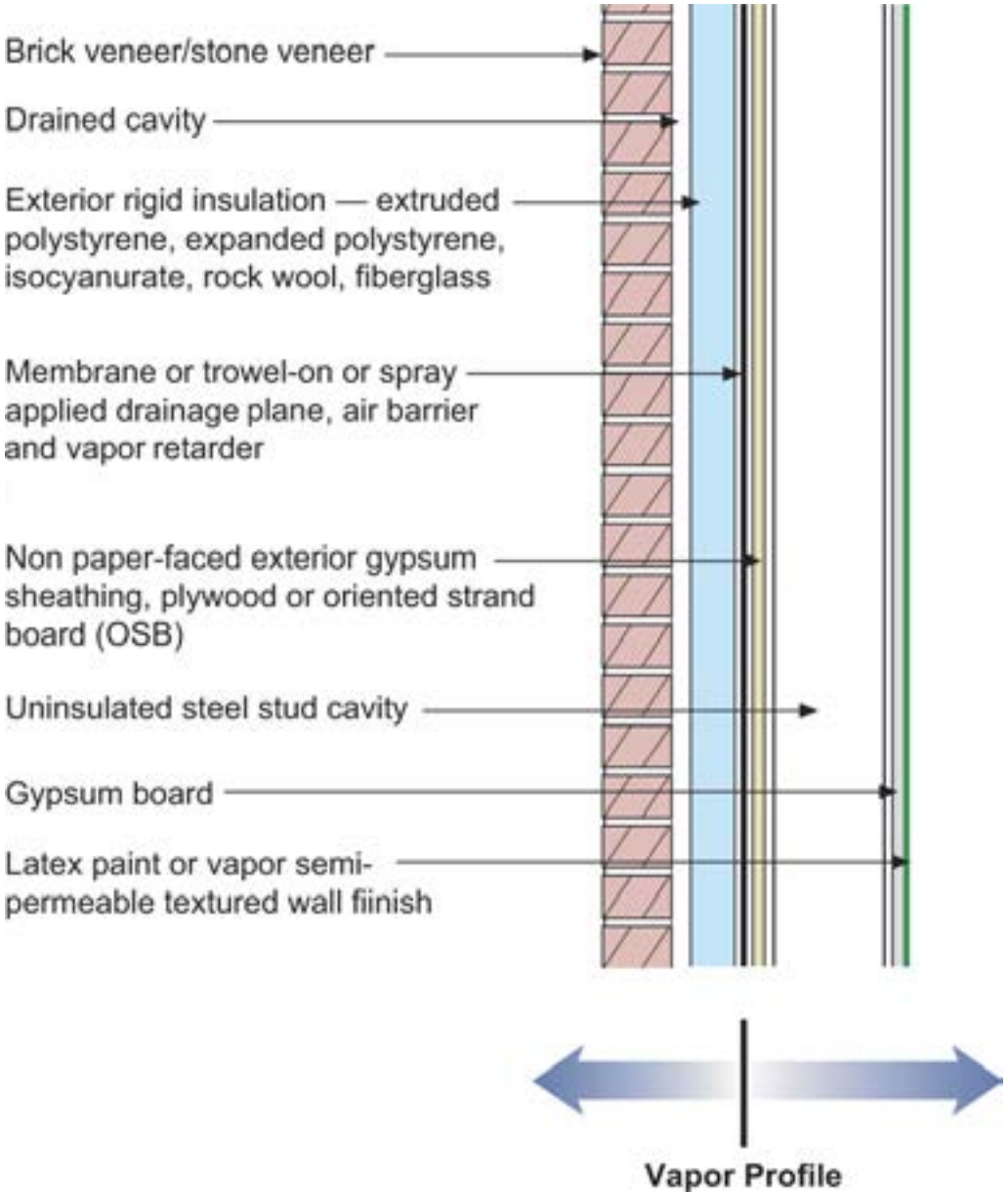

Roof
Wall
Slab

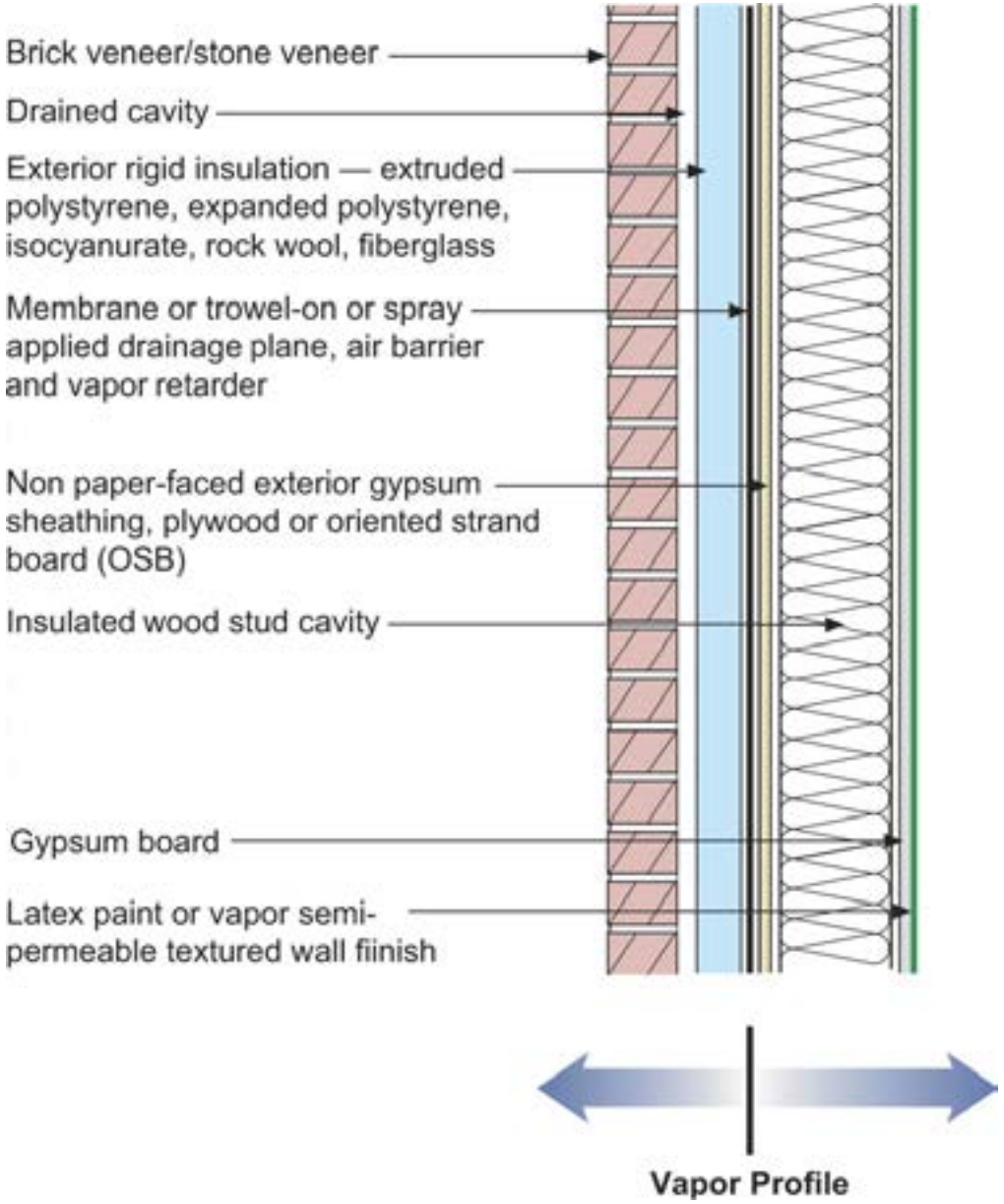

Parapet
Roof
Wall
Slab

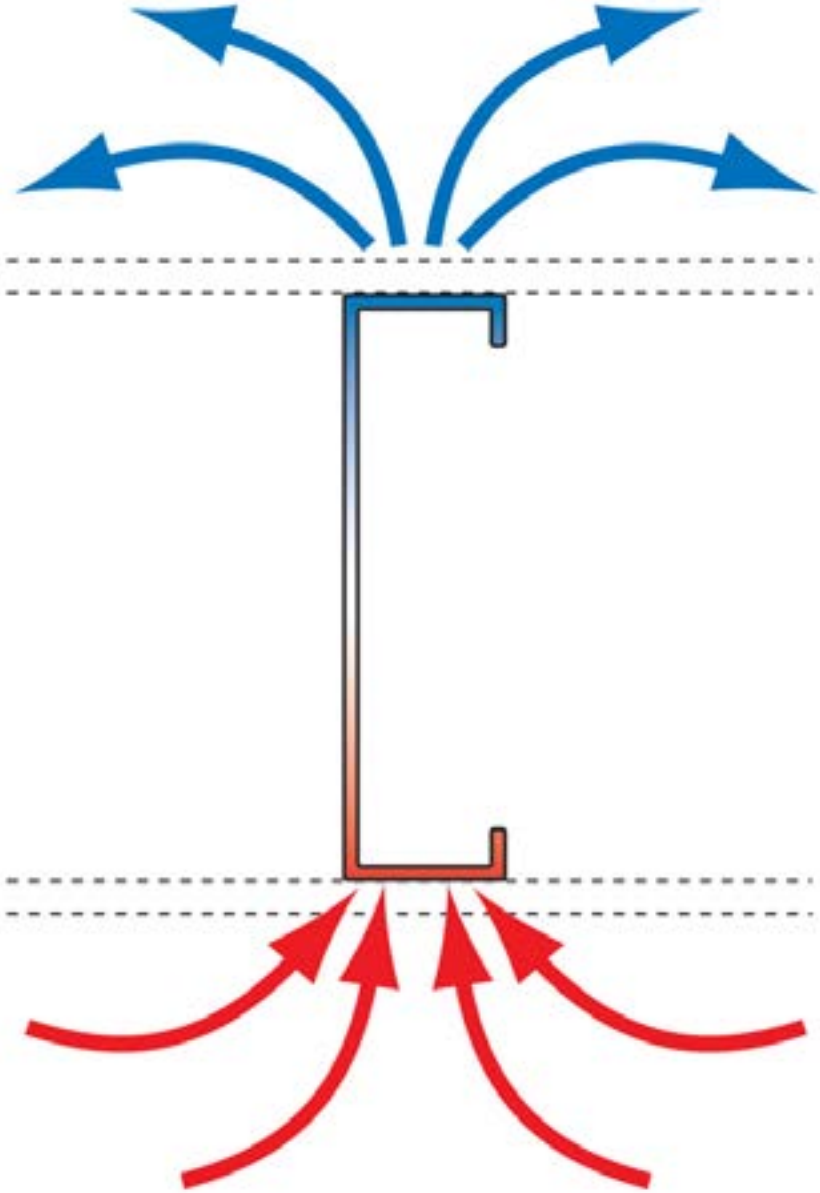

Parapet
Roof
Wall
Footing
Slab


Parapet
Roof
Window
Wall
Footing
Slab

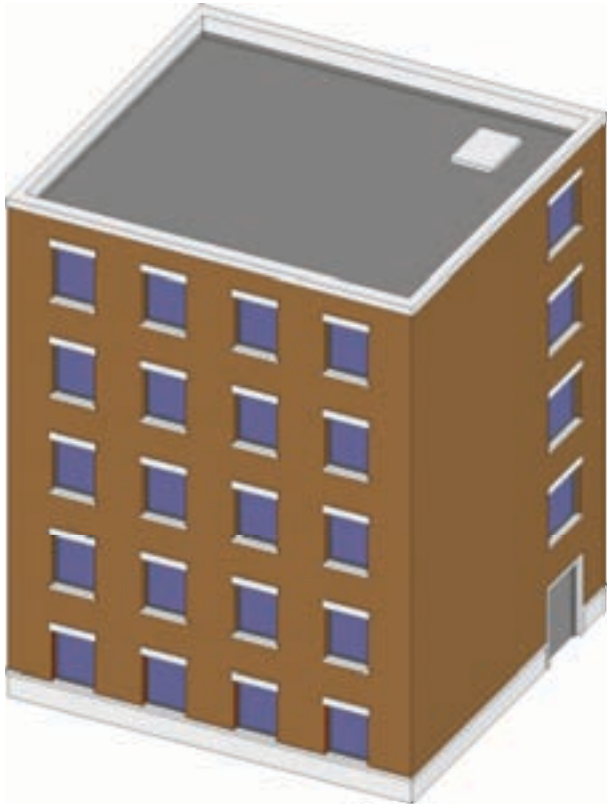

Brick veneer/stone veneer
Drained cavity
Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate, rock wool, fiberglass
Membrane or trowel-on or spray applied drainage plane, air barrier and vapor retarder
Concrete block
Metal channel or wood furring
Gypsum board
Latex paint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

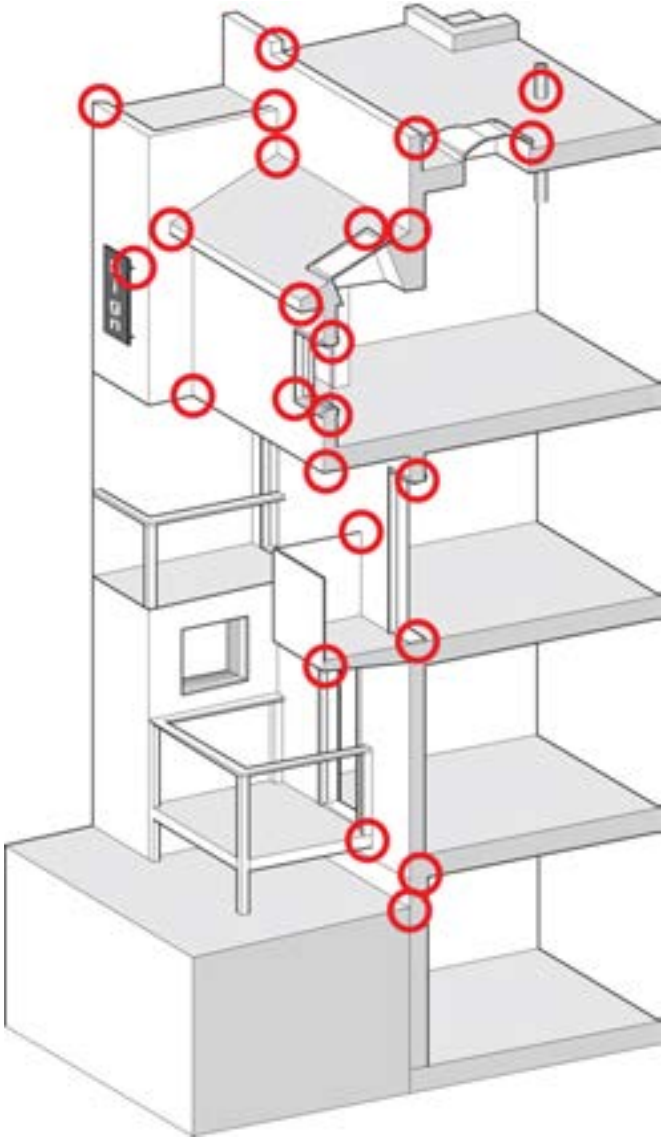

Brick veneer/stone veneer
Drained cavity
Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate, rock wool, fiberglass
Membrane or trowel-on or spray applied drainage plane, air barrier and vapor retarder
Non paper-faced exterior gypsum sheathing, plywood or oriented strand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



Commercial Enclosure: Simple Layers



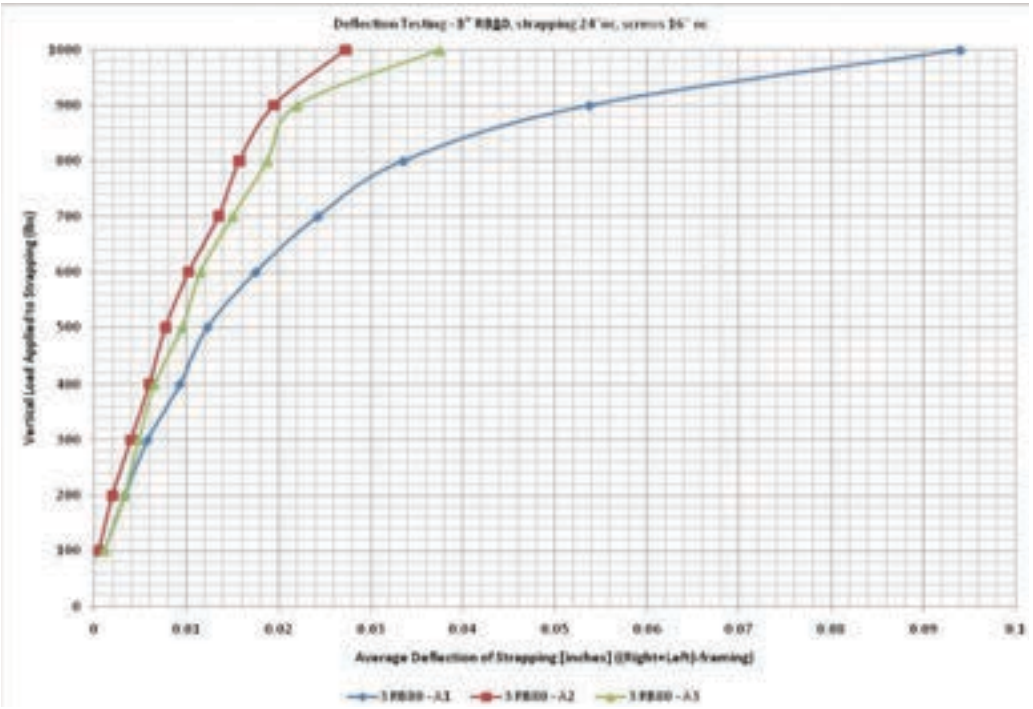
- Structure
- Rain/Air/Vapor
- Insulation
- Finish

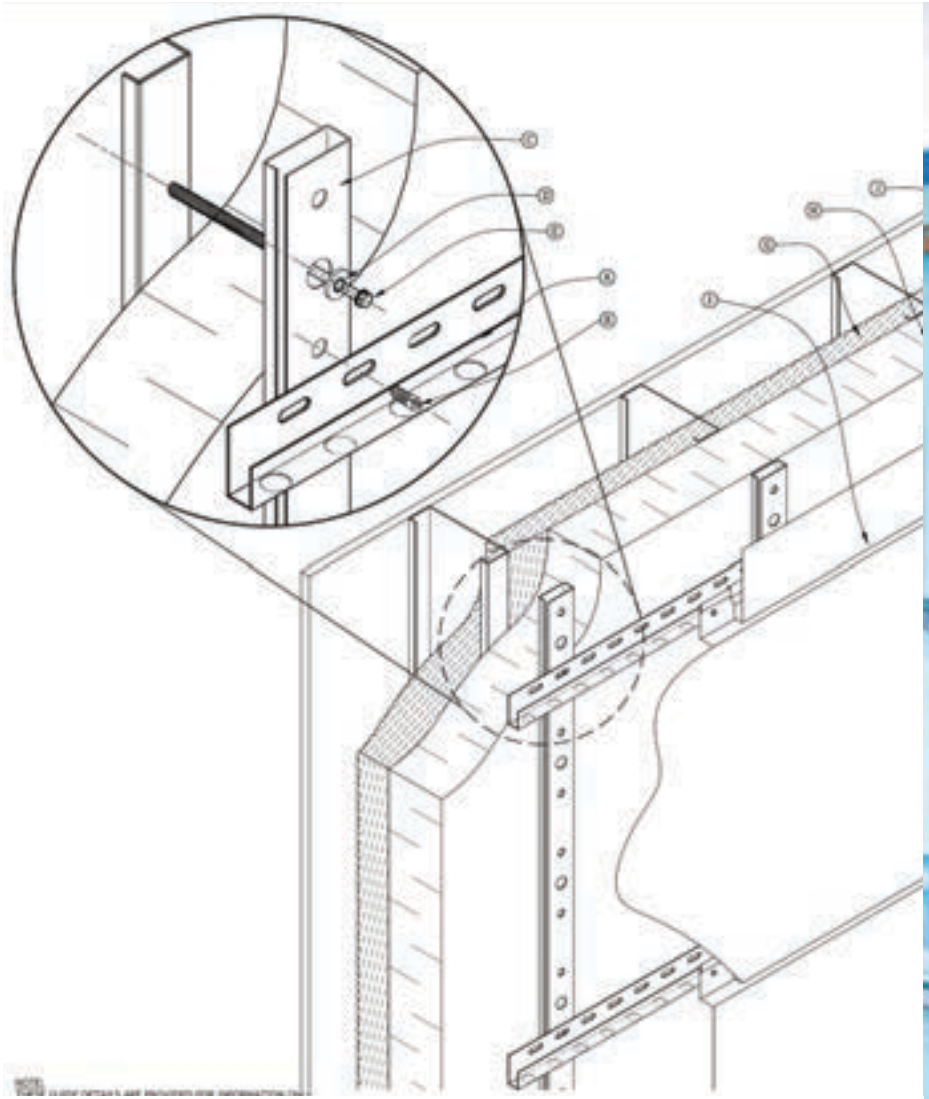


PlastiSpan HD
R8
PlastiSpan HD
R8
PlastiSpan HD
PlastiSpan HD

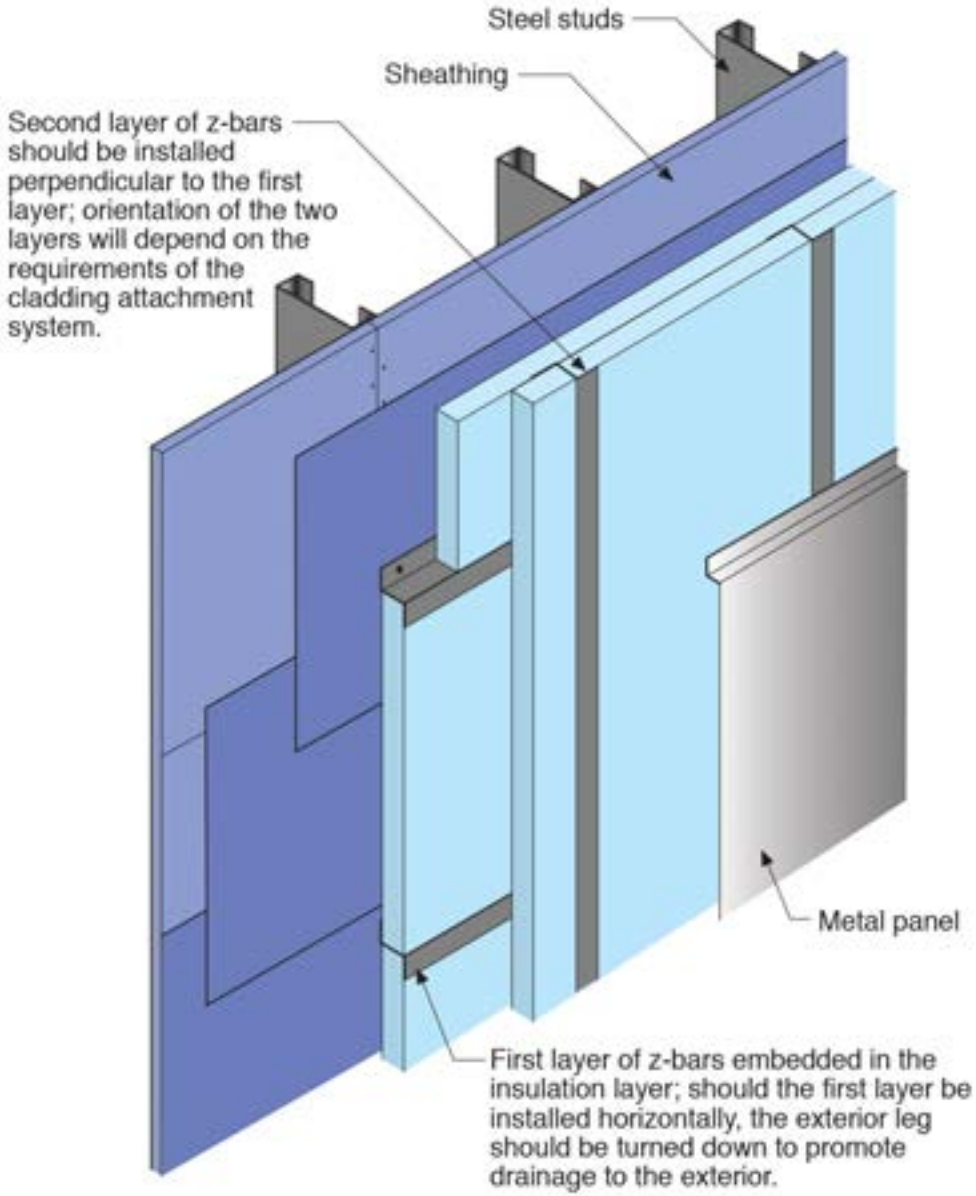
Rockwool

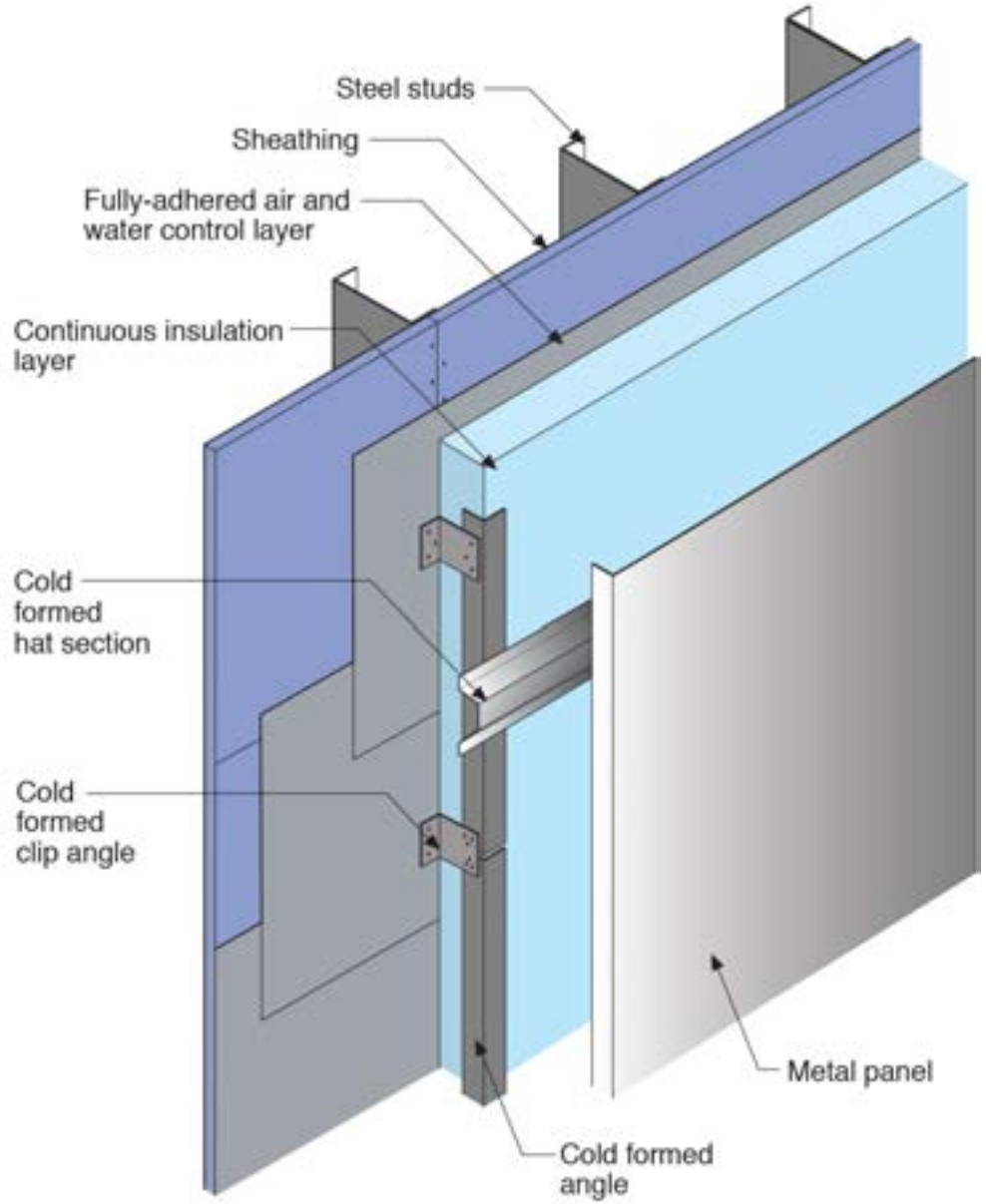
1x3 furring @ 24” o.c.
#10 screws @ 16” o.c. vertically
Result: 20 psf cladding weight
with < 2/100” deflection

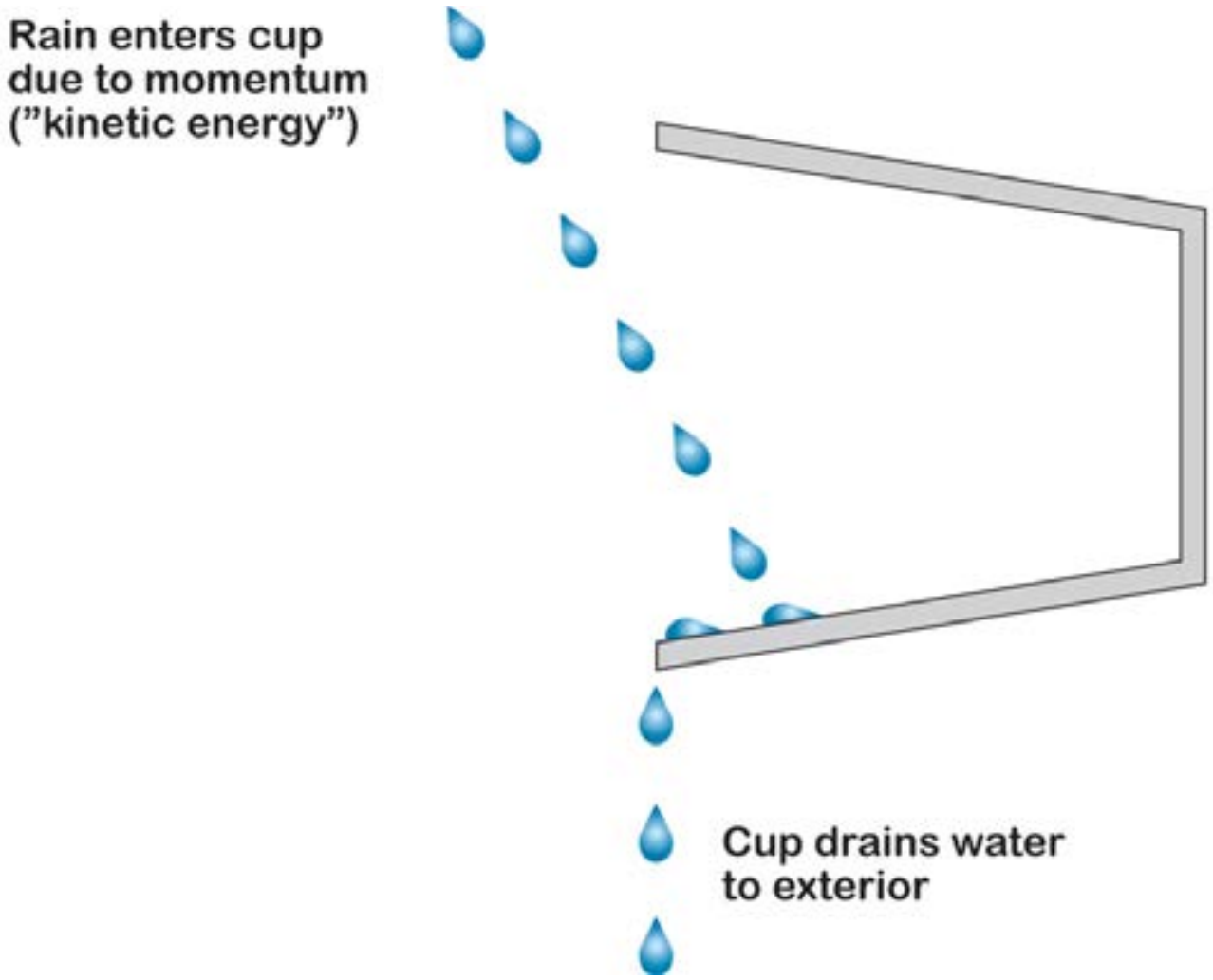


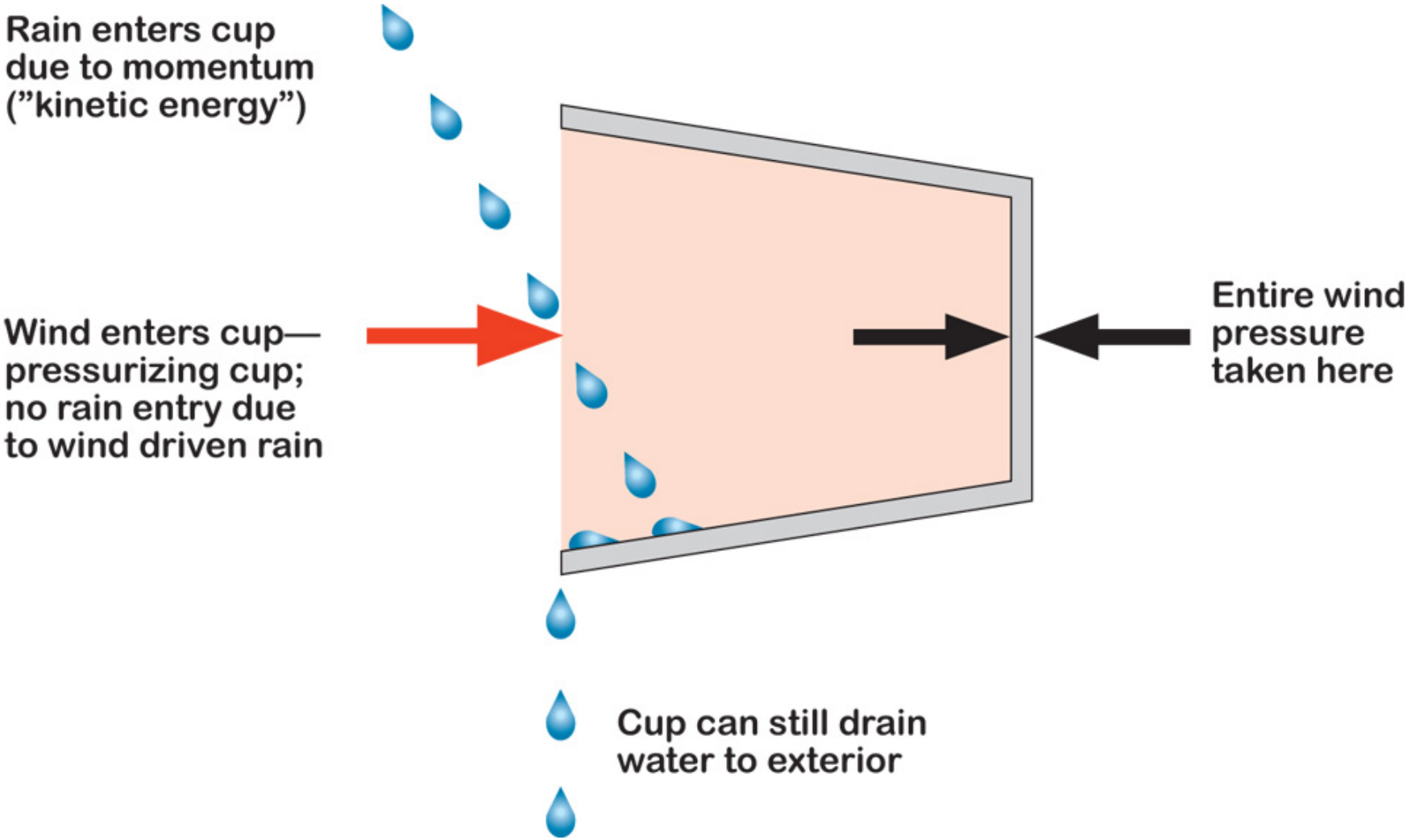


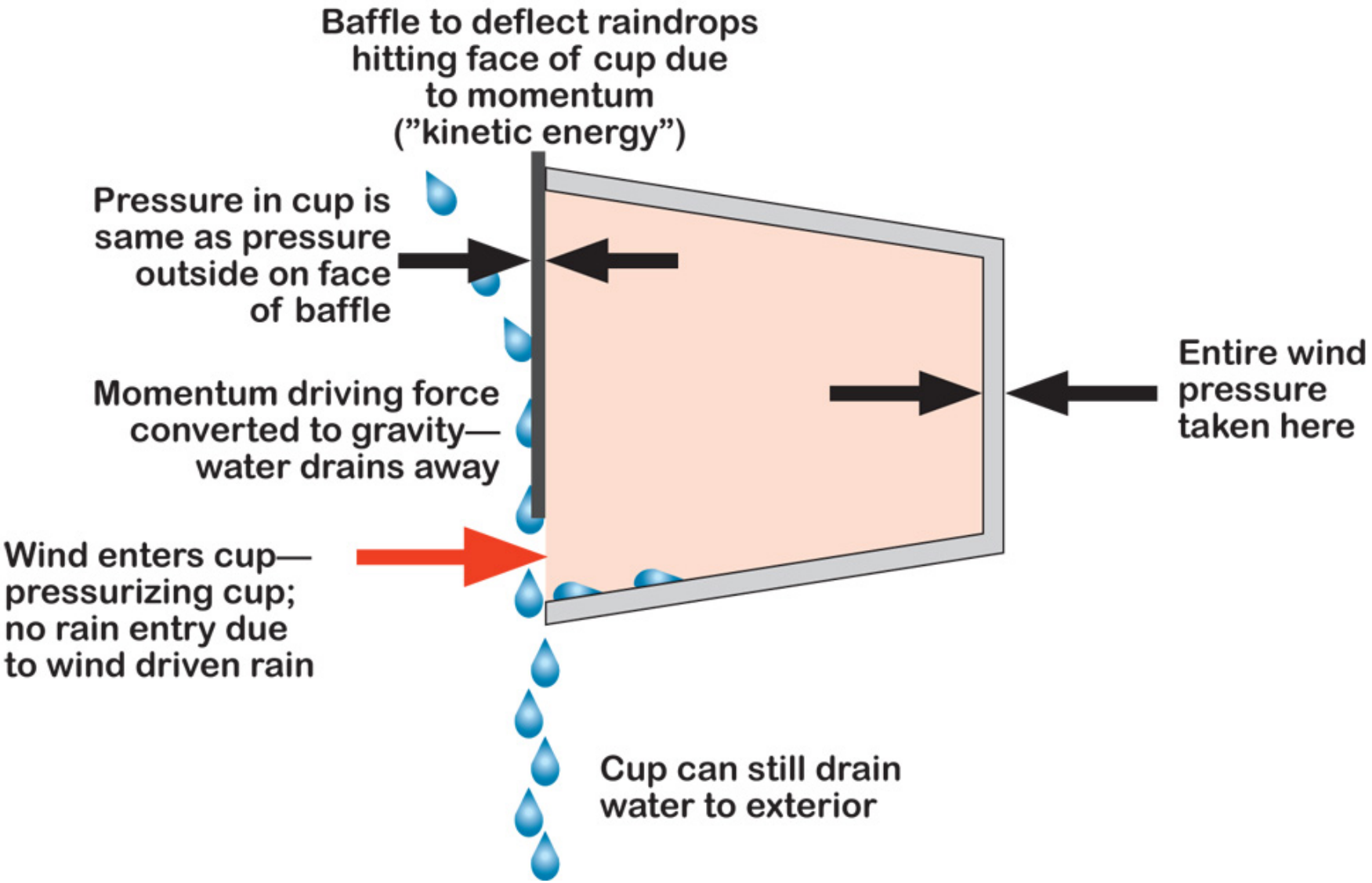
DOW
Thermax ci
Exterior Insulation

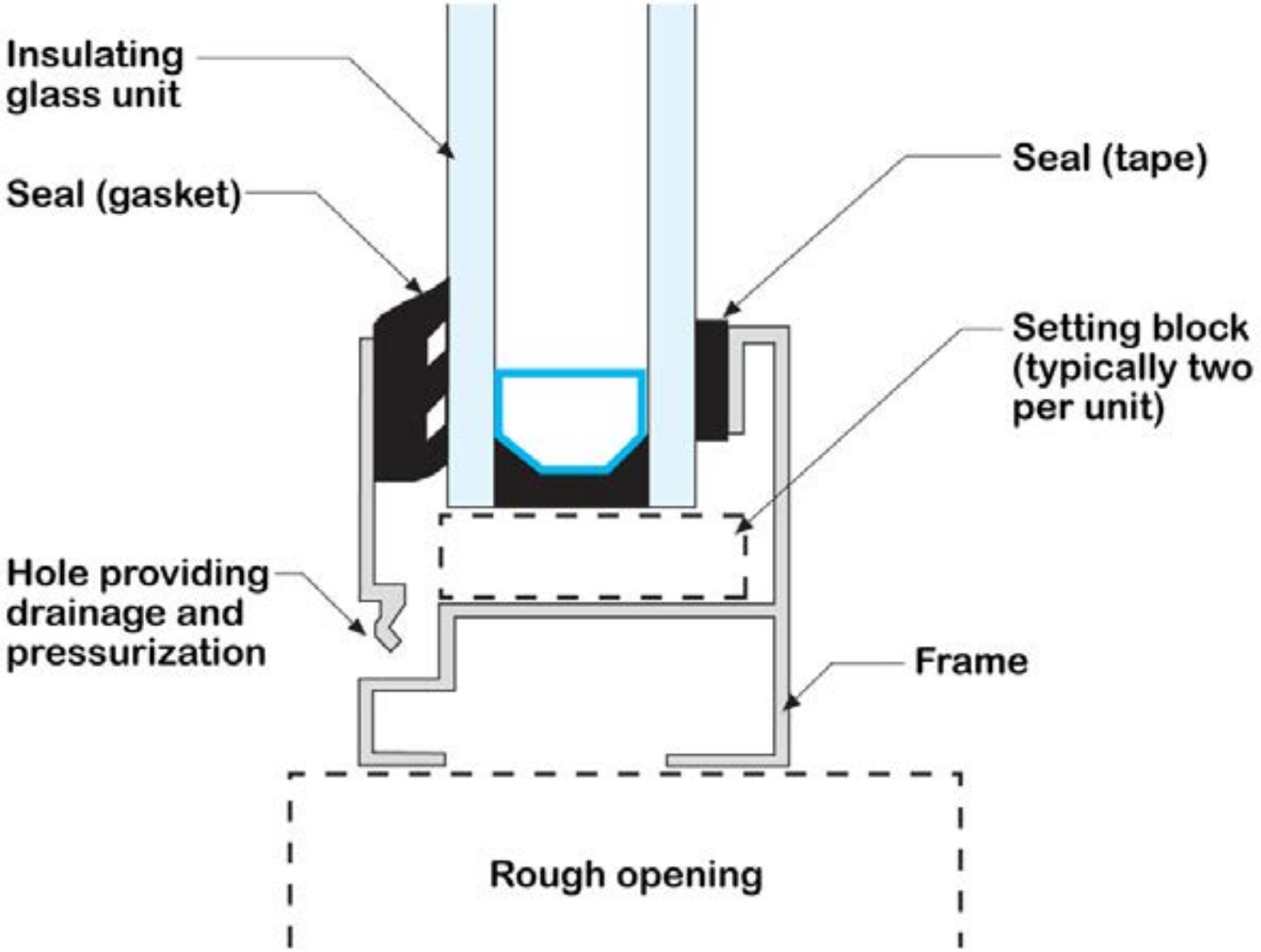

Steel studs
Sheathing
Second layer of z-bars should be installed perpendicular to the first layer; orientation of the two layers will depend on the requirements of the cladding attachment system.
Metal panel
First layer of z-bars embedded in the insulation layer; should the first layer be installed horizontally, the exterior leg should be turned down to promote drainage to the exterior.

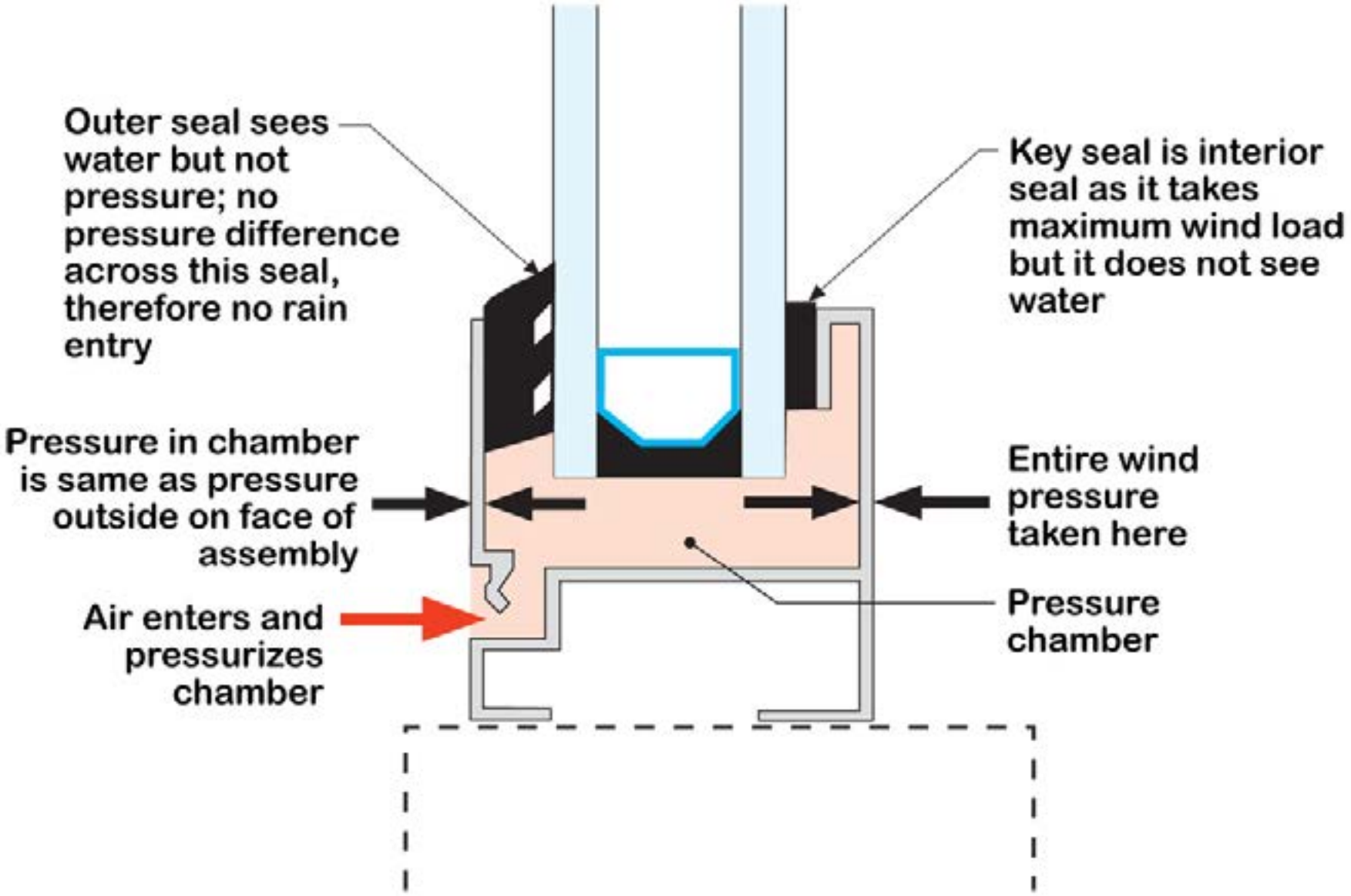

Steel studs
Sheathing
Fully-adhered air and water control layer
Continuous insulation layer
Cold formed hat section
Cold formed clip angle
Metal panel
Cold formed angle

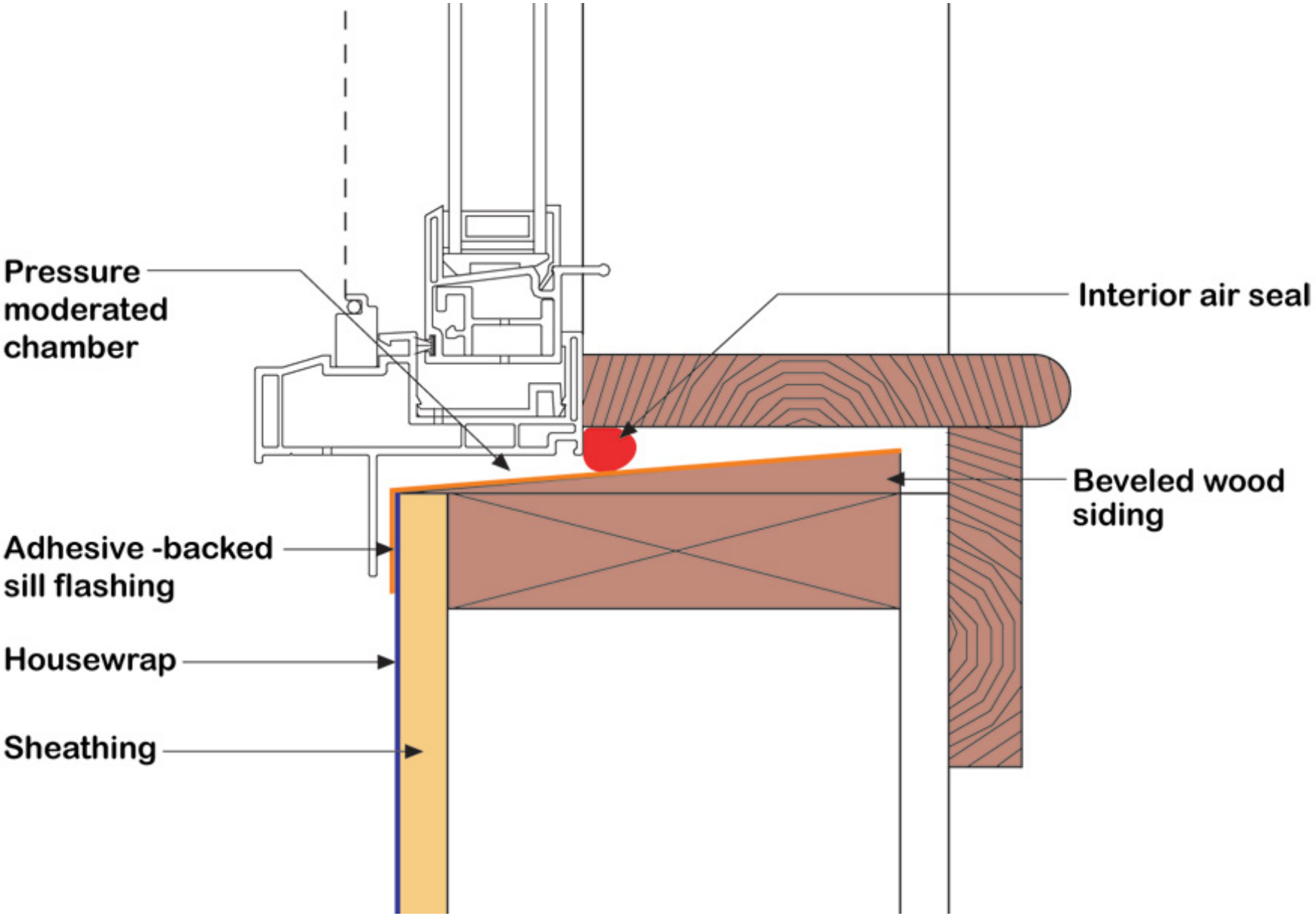

Rain enters cup
due to momentum
("kinetic energy")
Cup drains water
to exterior

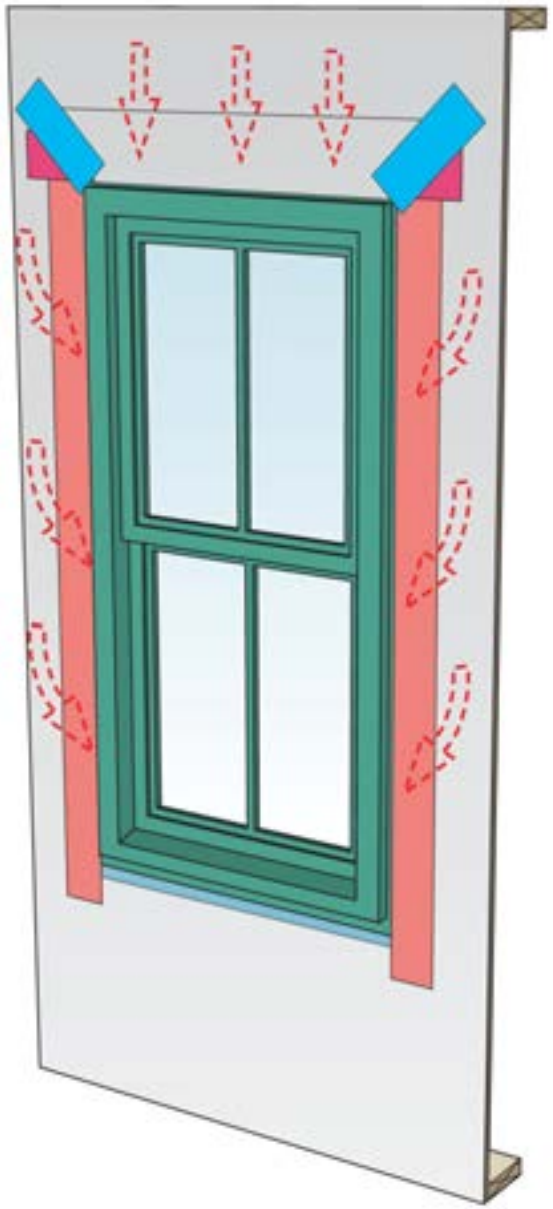

Rain enters cup due to momentum ("kinetic energy")
Wind enters cup— pressurizing cup; no rain entry due to wind driven rain
Entire wind pressure taken here
Cup can still drain water to exterior

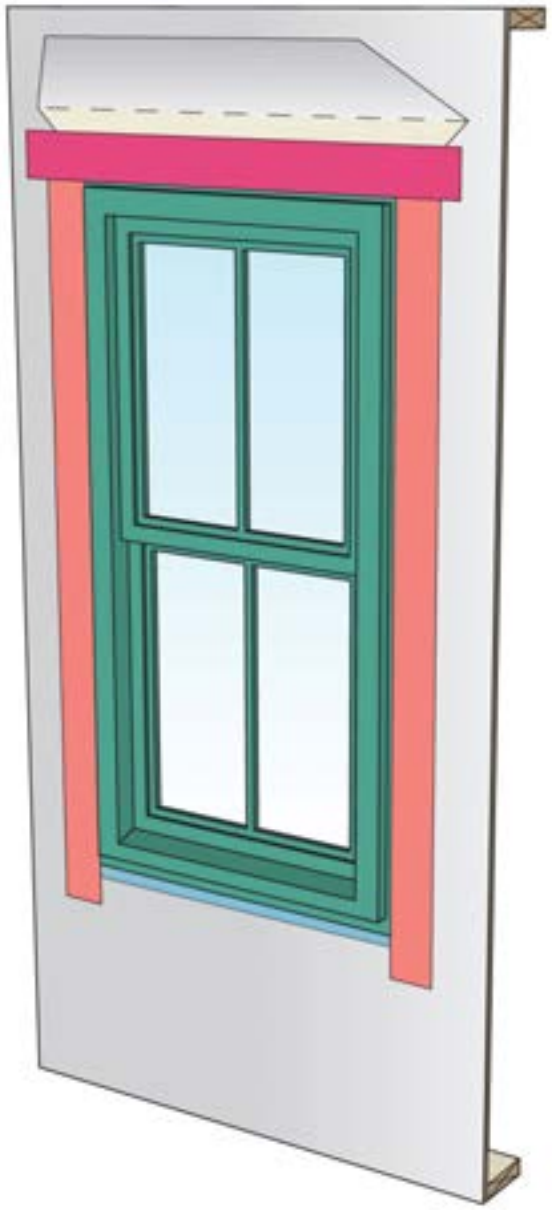

Baffle to deflect raindrops hitting face of cup due to momentum ("kinetic energy")
Pressure in cup is same as pressure outside on face of baffle
Momentum driving force converted to gravity— water drains away
Wind enters cup— pressurizing cup; no rain entry due to wind driven rain
Entire wind pressure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

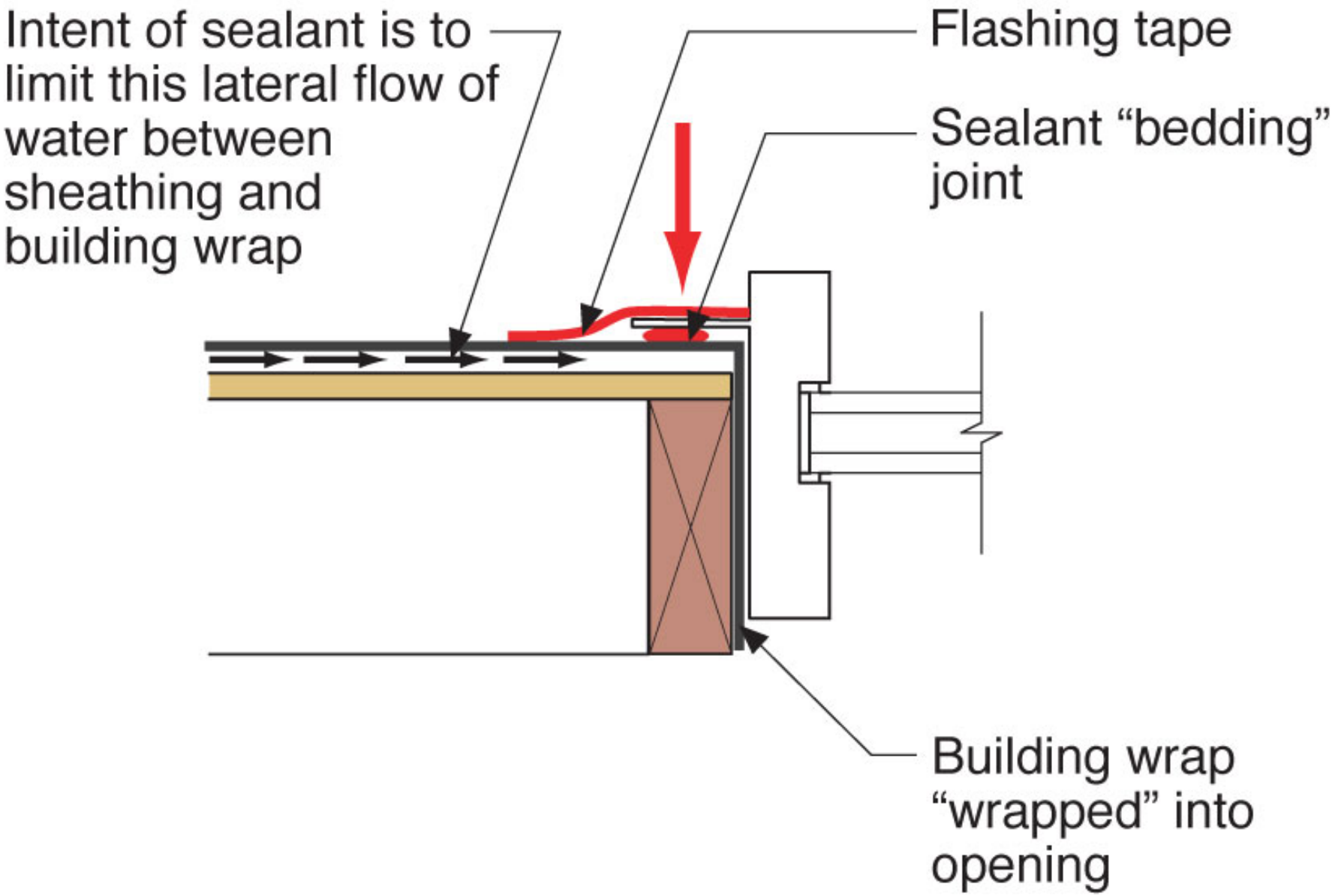

Insulating glass unit
Seal (gasket)
Seal (tape)
Setting block (typically two per unit)
Hole providing drainage and pressurization
Frame
Rough opening

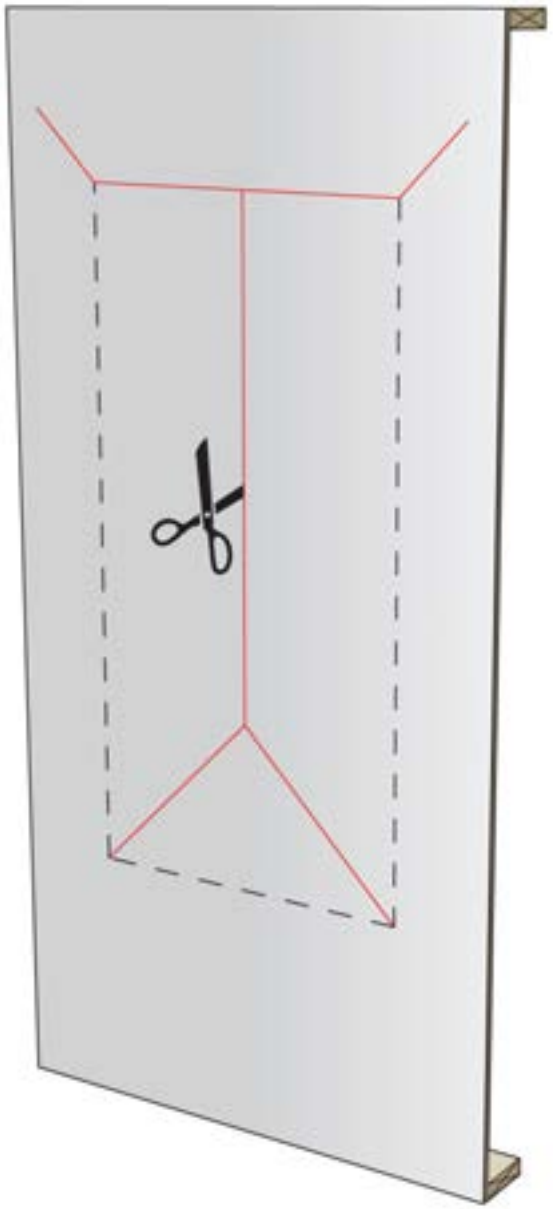

Outer seal sees water but not pressure; no pressure difference across this seal, therefore no rain entry
Key seal is interior seal as it takes maximum wind load but it does not see water
Pressure in chamber is same as pressure outside on face of assembly
Entire wind pressure taken here
Air enters and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

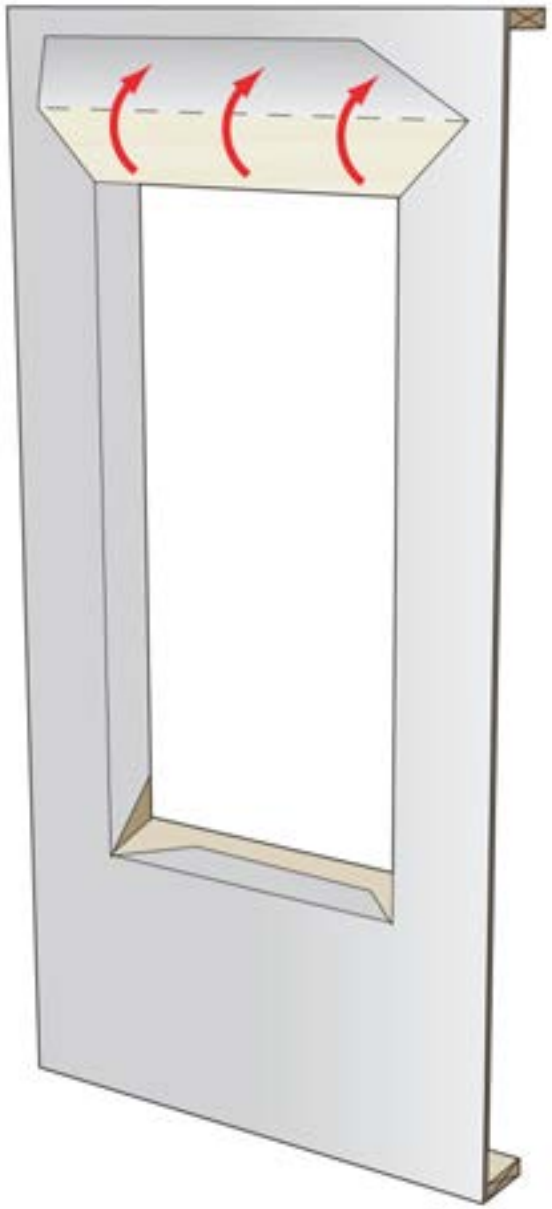

Pressure moderated chamber
Interior air seal
Beveled wood siding
Adhesive -backed sill flashing
Housewrap
Sheathing

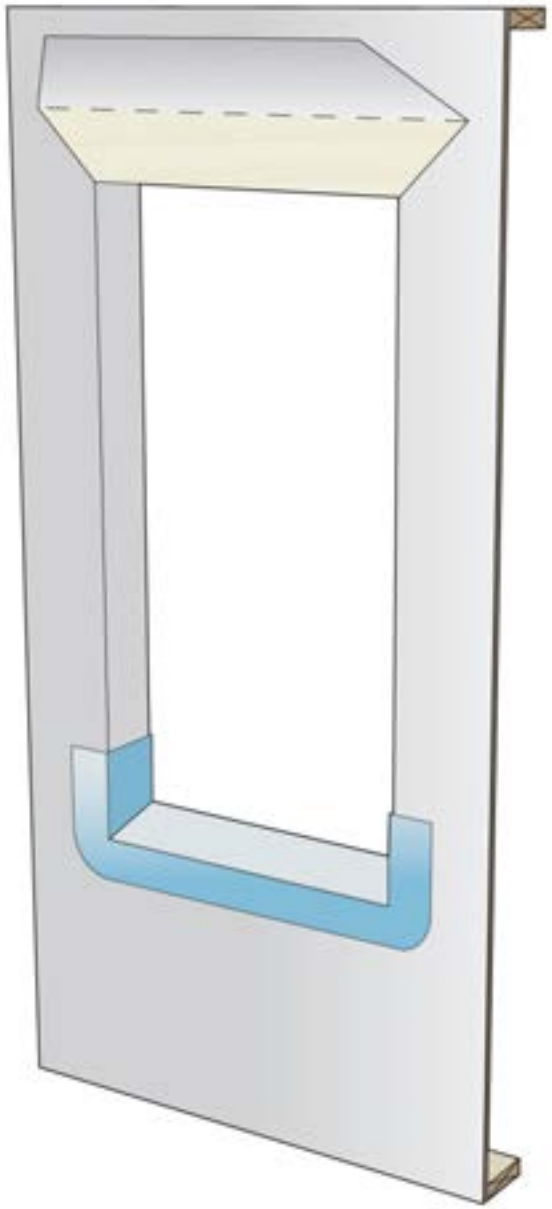


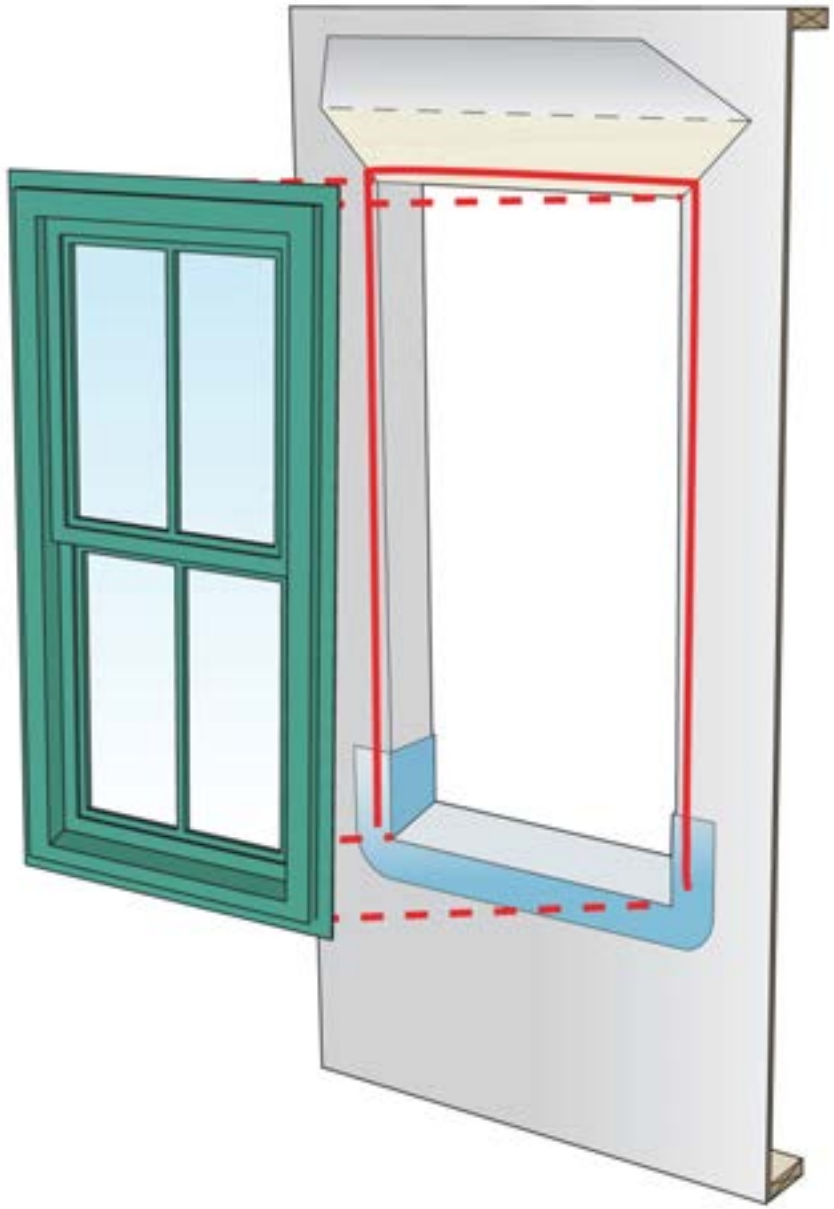


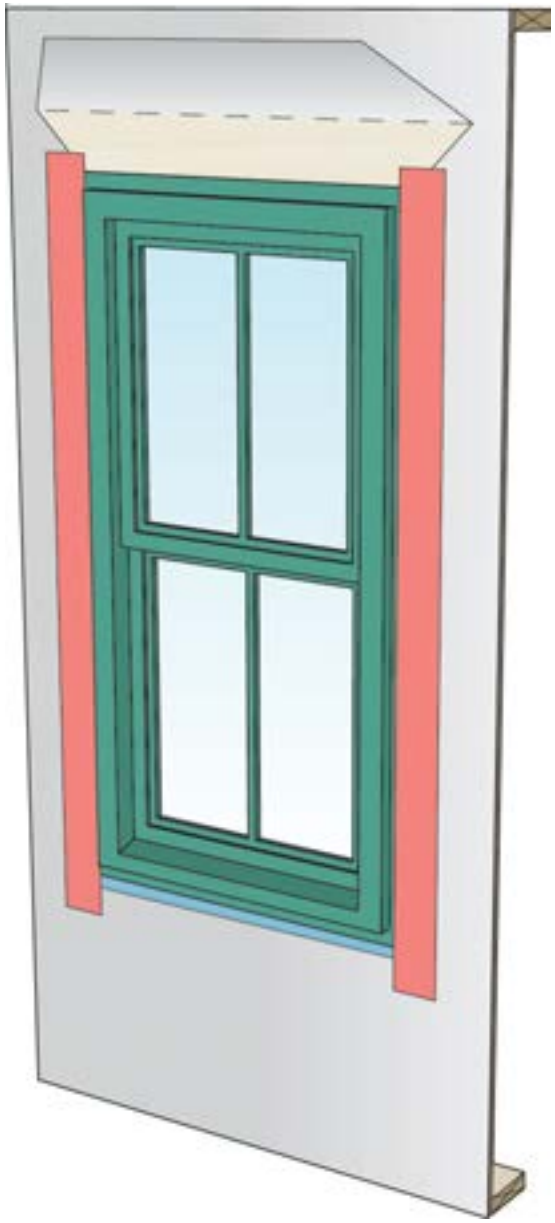

Intent of sealant is to limit this lateral flow of water between sheathing and building wrap
Flashing tape
Sealant “bedding” joint
Building wrap “wrapped” into opening

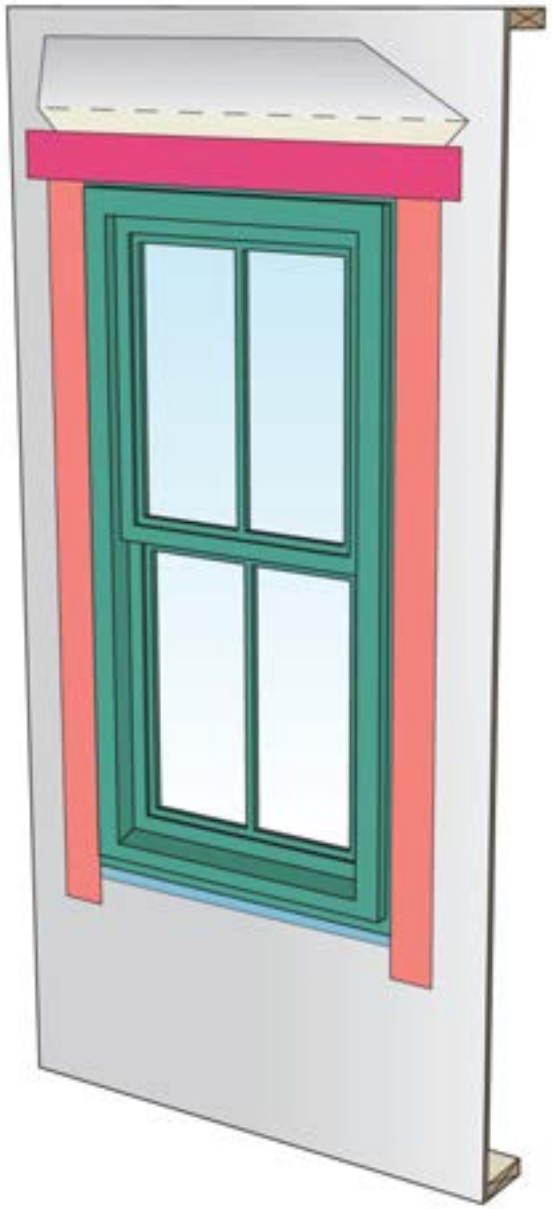


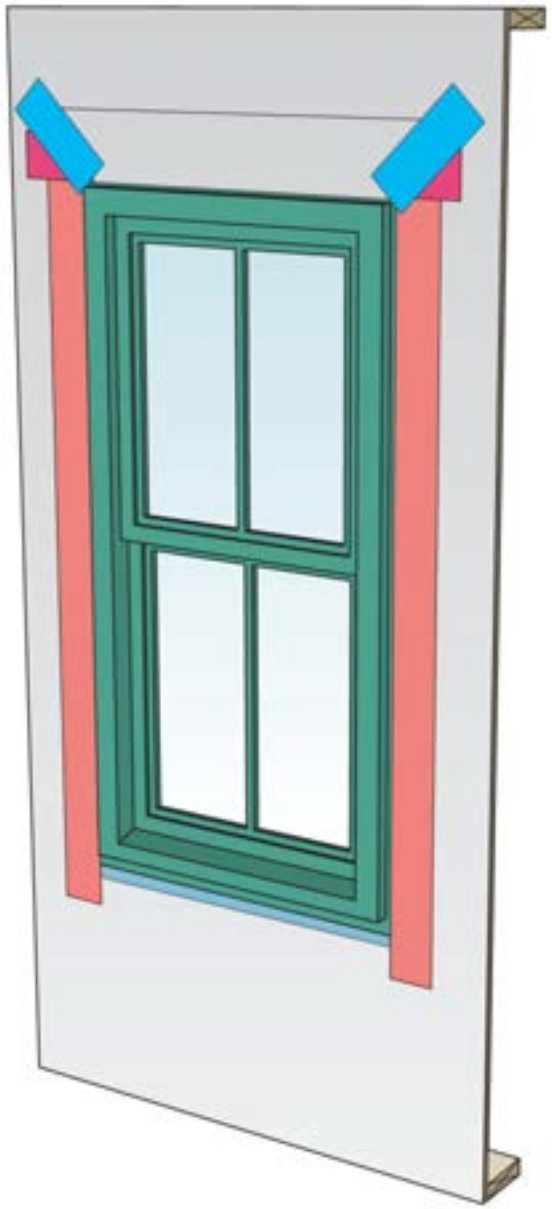


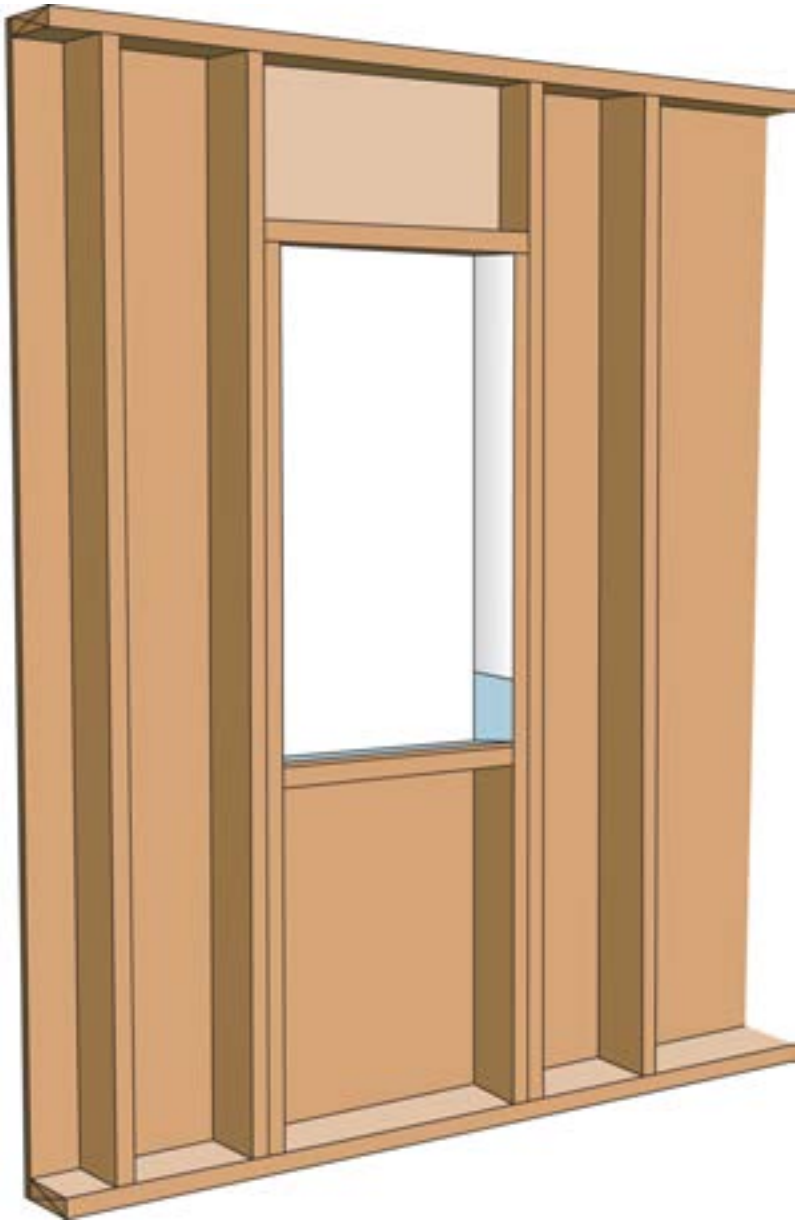


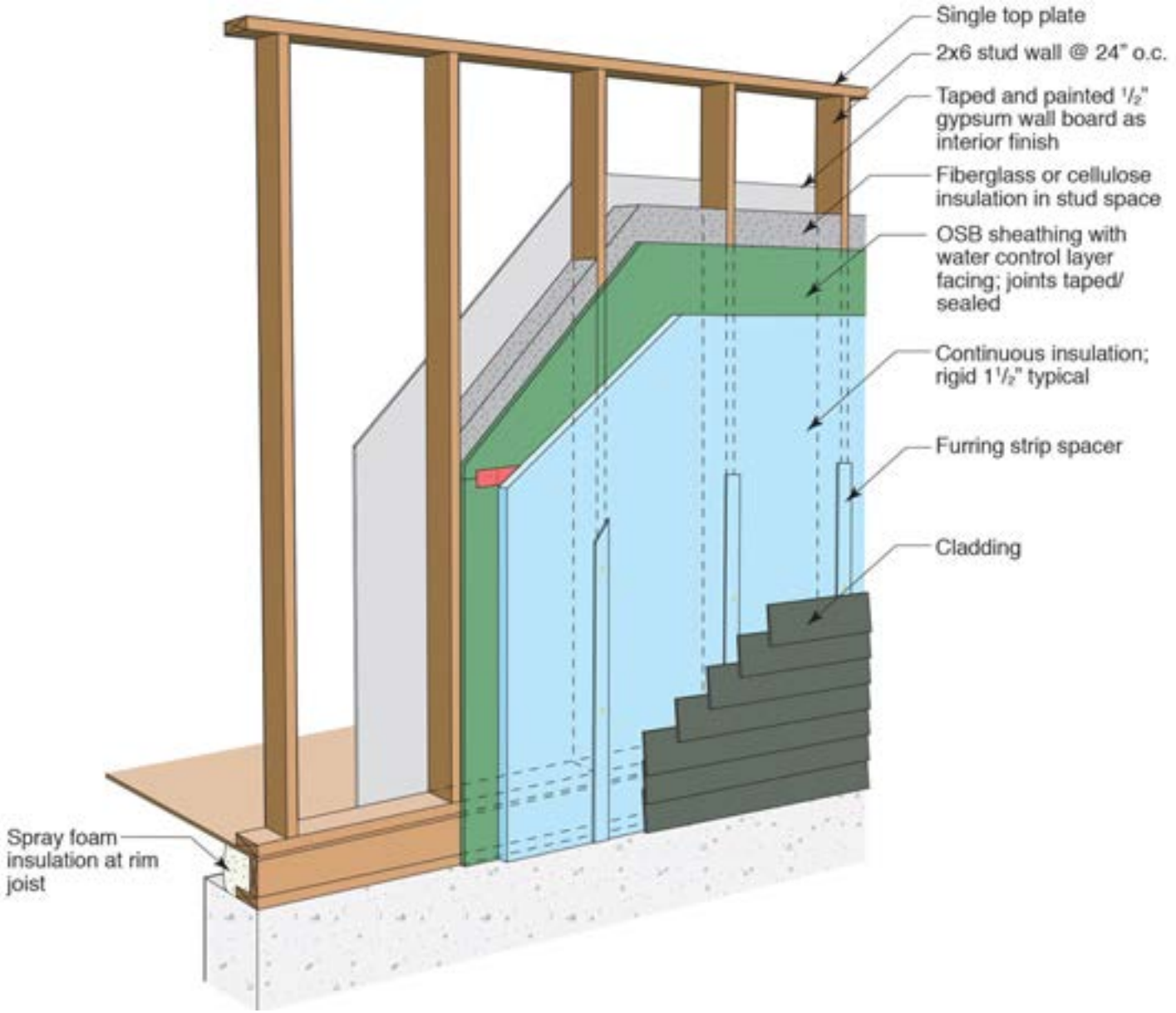


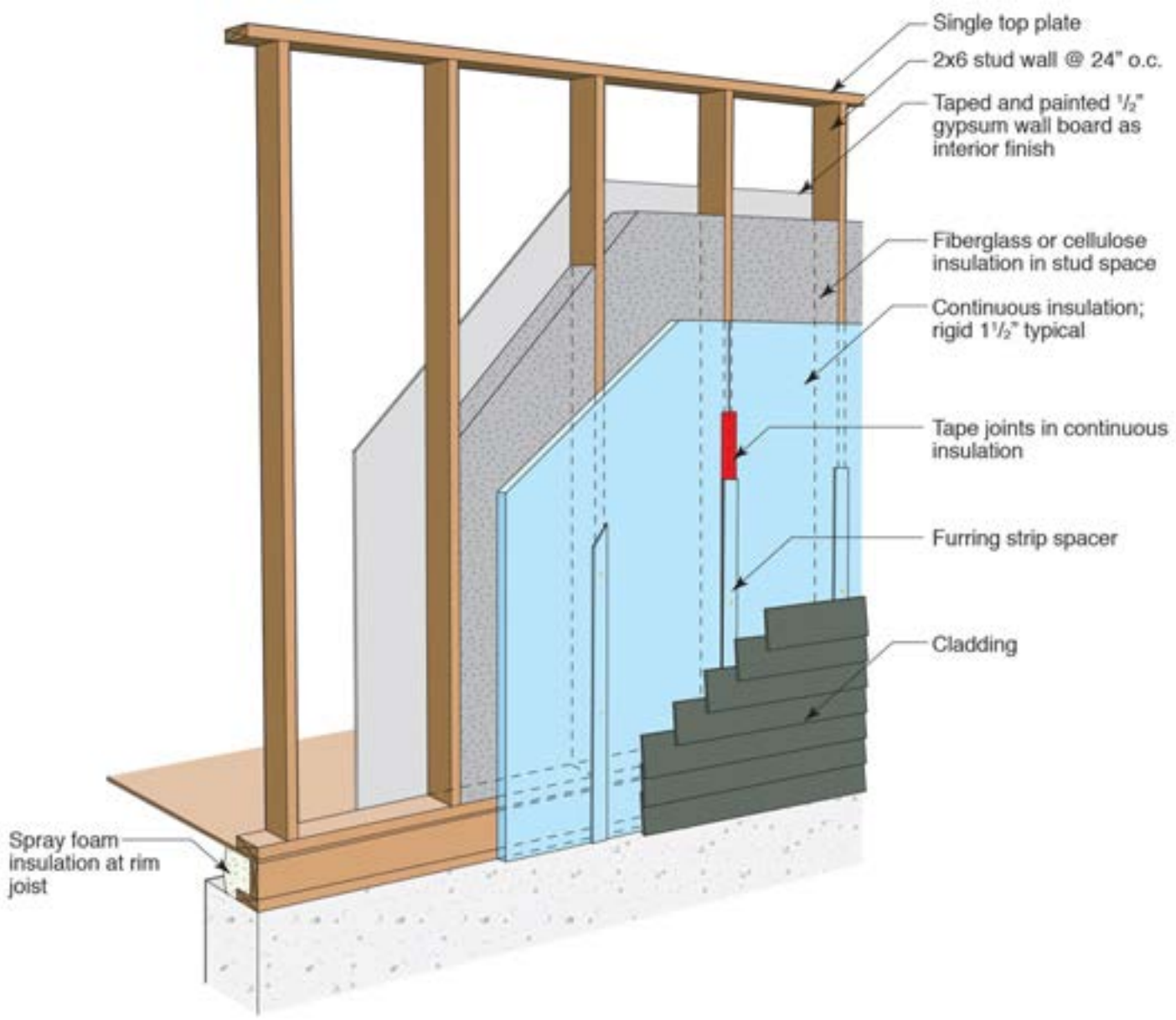









Single top plate
2x6 stud wall @ 24" o.c.
Taped and painted ½" gypsum wall board as interior finish
Fiberglass or cellulose insulation in stud space
OSB sheathing with water control layer facing; joints taped/ sealed
Continuous insulation; rigid 1½" typical
Furring strip spacer
Cladding
Spray foam insulation at rim joist


Single top plate
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Taped and painted ½" gypsum wall board as interior finish
Fiberglass or cellulose insulation in stud space
Continuous insulation; rigid 1½" typical
Tape joints in continuous insulation
Furring strip spacer
Cladding
Spray foam insulation at rim joist

Where Is The Water Control Layer?

Where Is The Water Control Layer?

Behind The Continuous Insulation?

Or The Face of The Continuous Insulation?

Where Is The Water Control Layer?

Behind The Continuous Insulation?

Or The Face of The Continuous Insulation?

Where Is The Window?

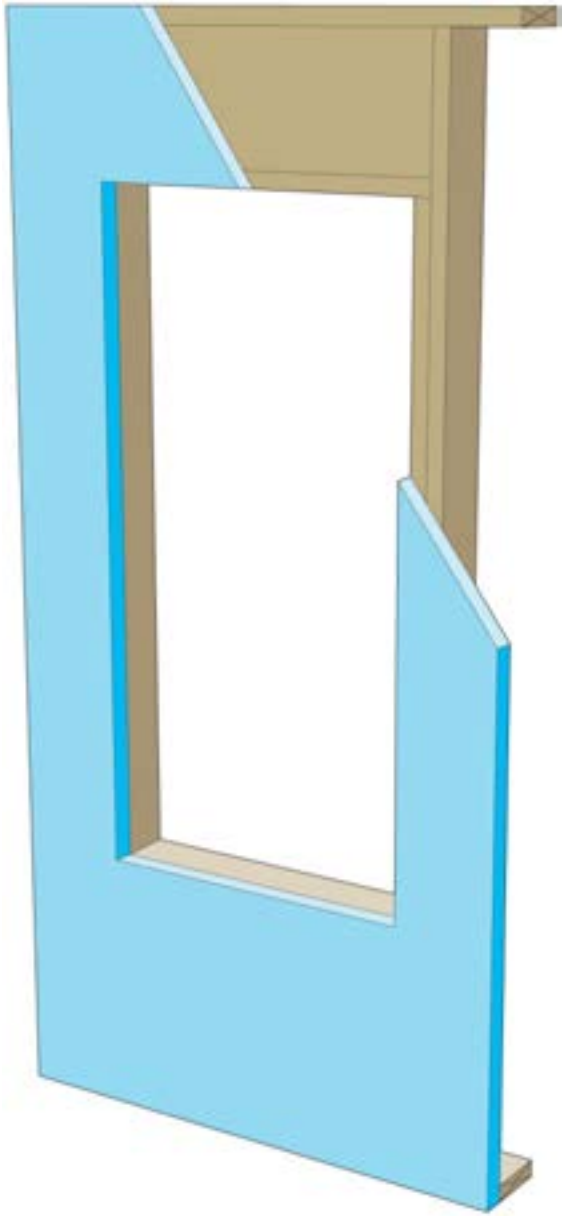
Where Is The Water Control Layer?

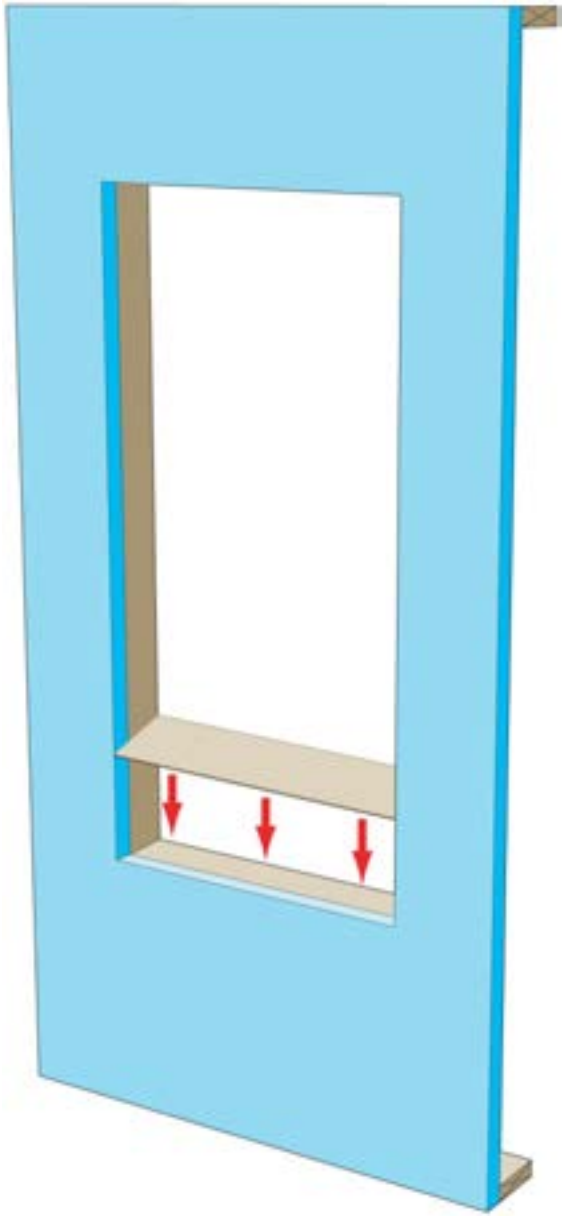
Behind The Continuous Insulation?

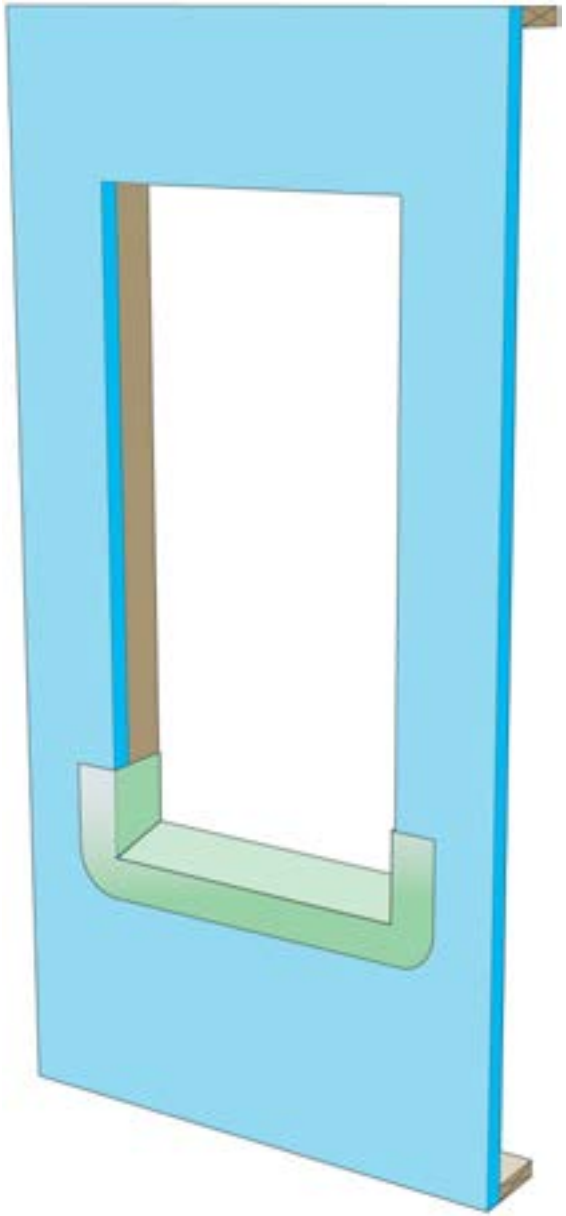
Or The Face of The Continuous Insulation?

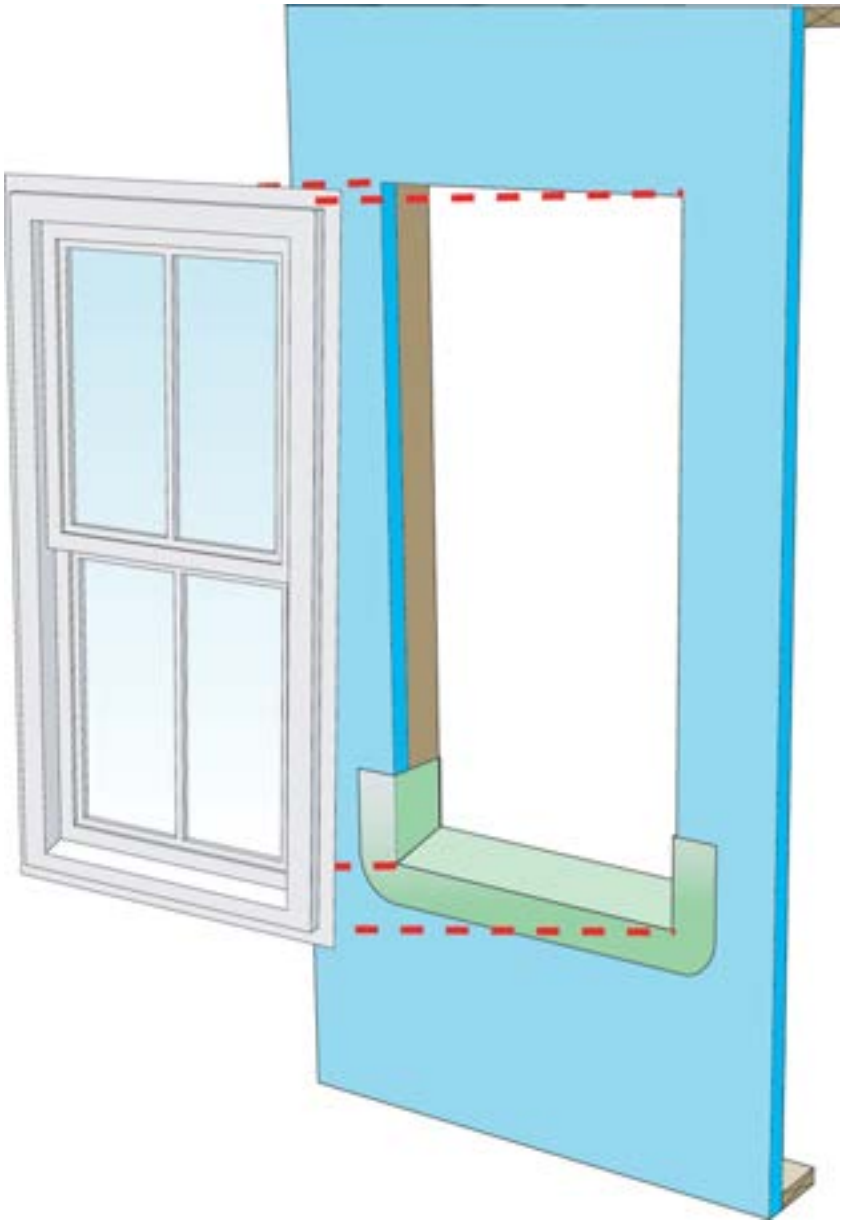
Where Is The Window?

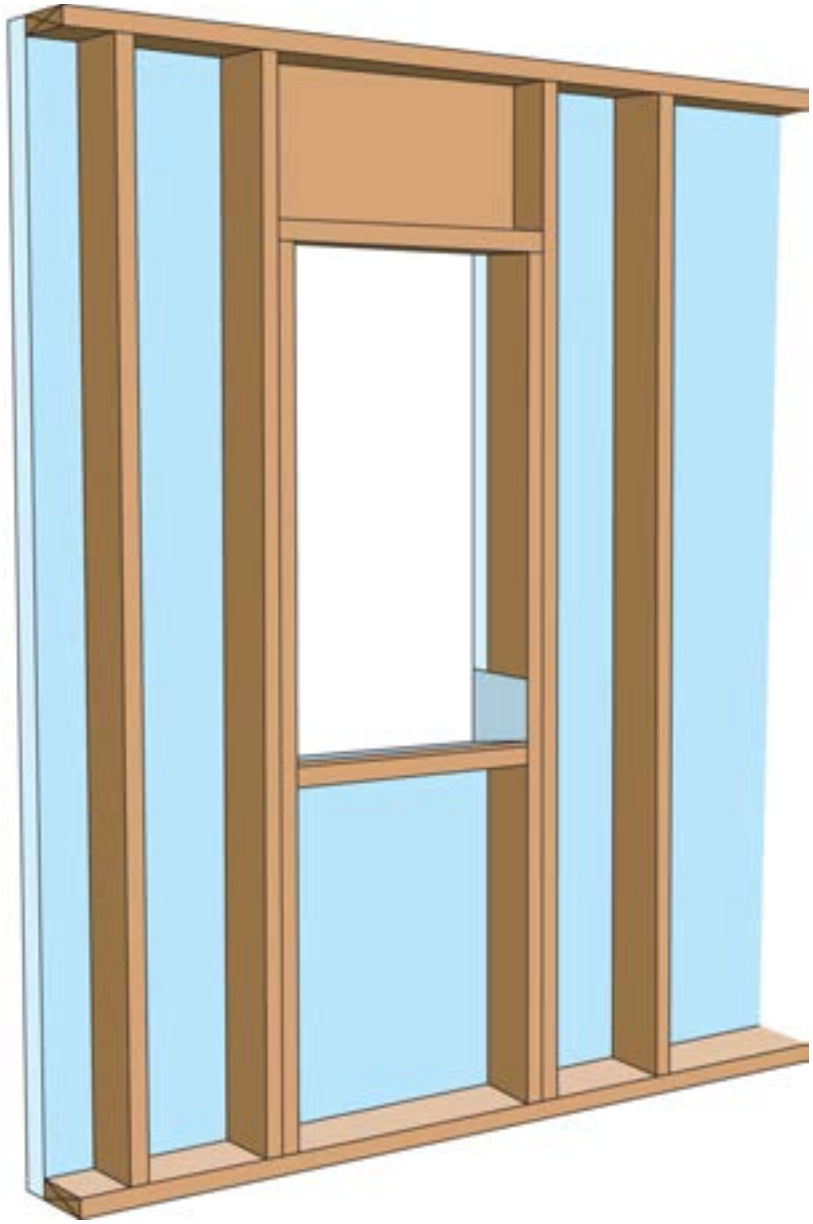
Is It An Innie Or Outie Or Tweeny?

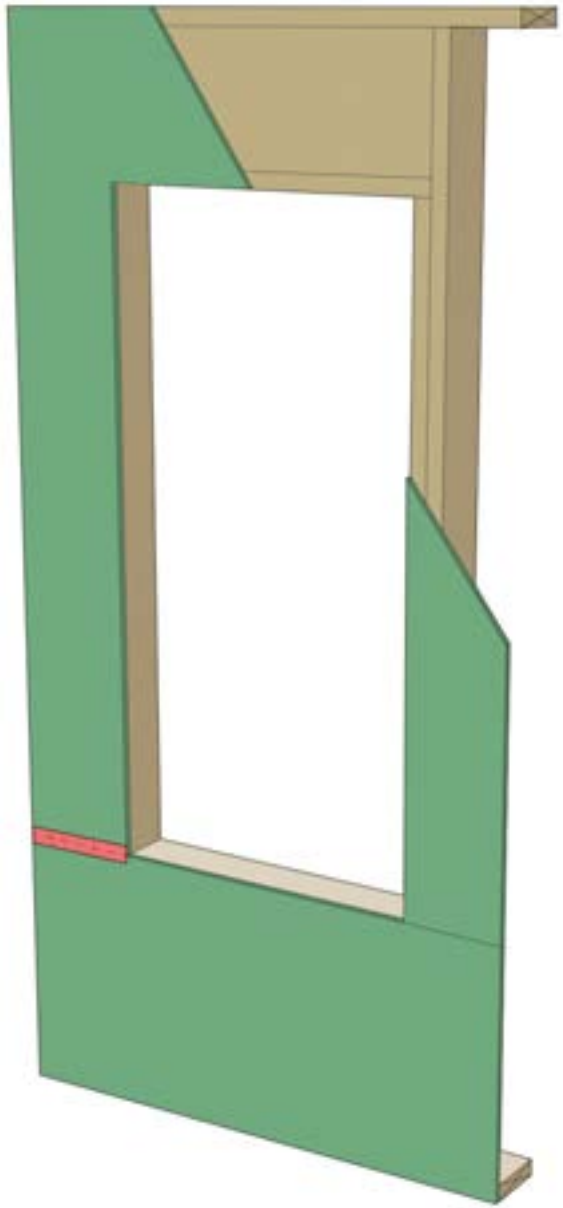


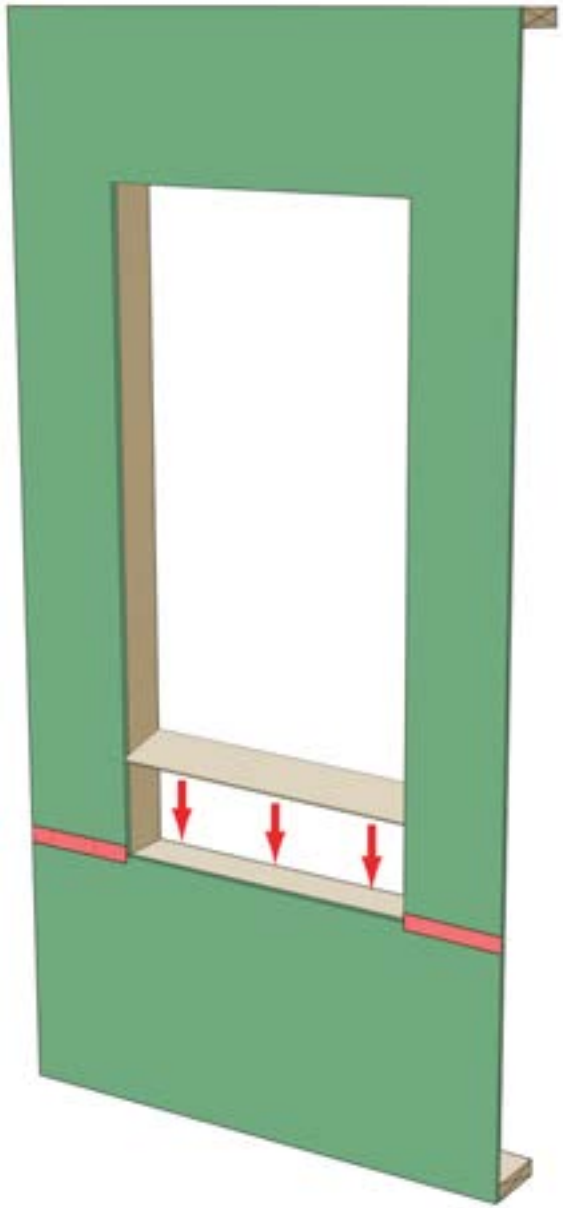


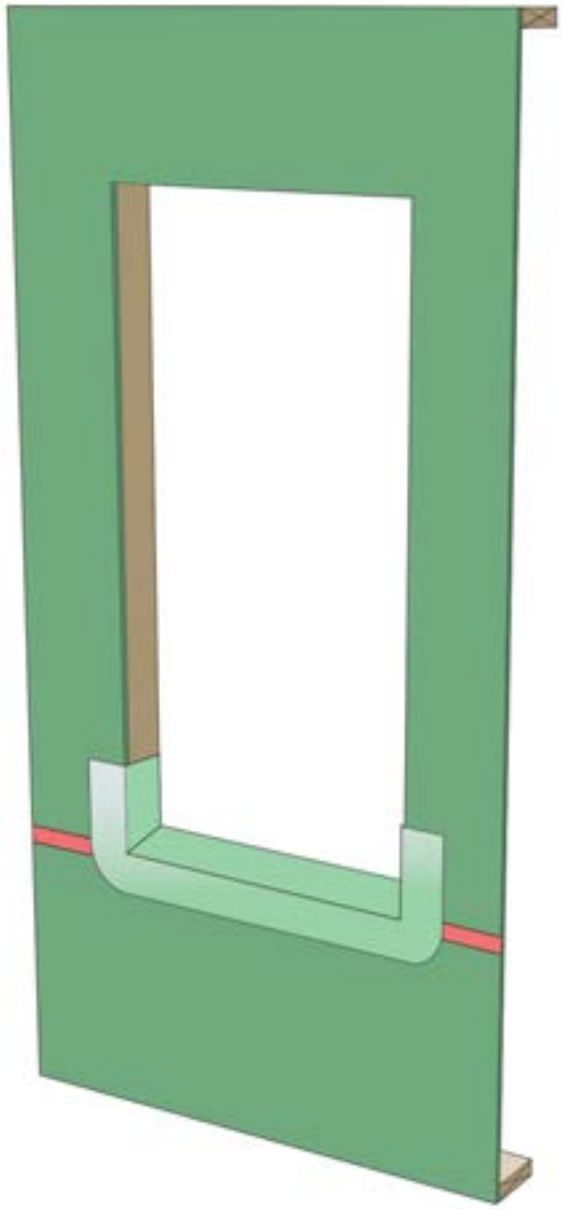


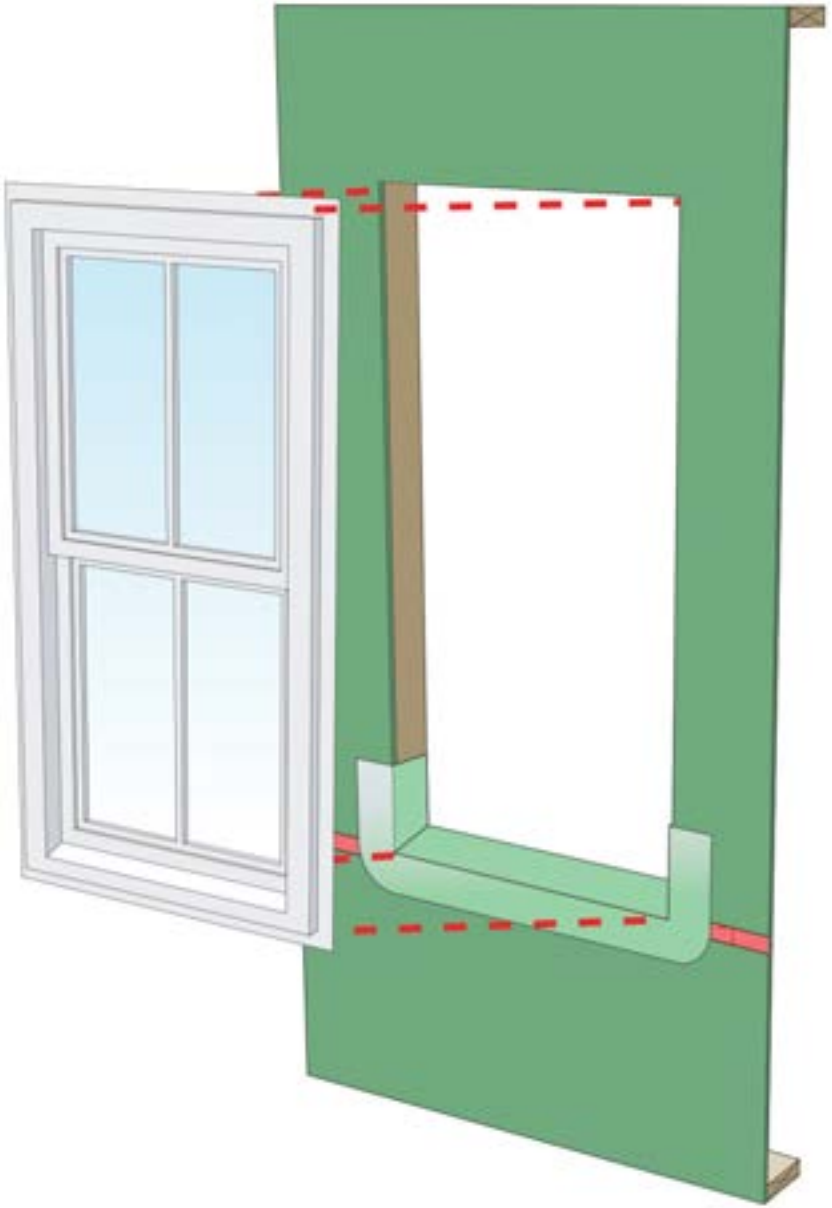


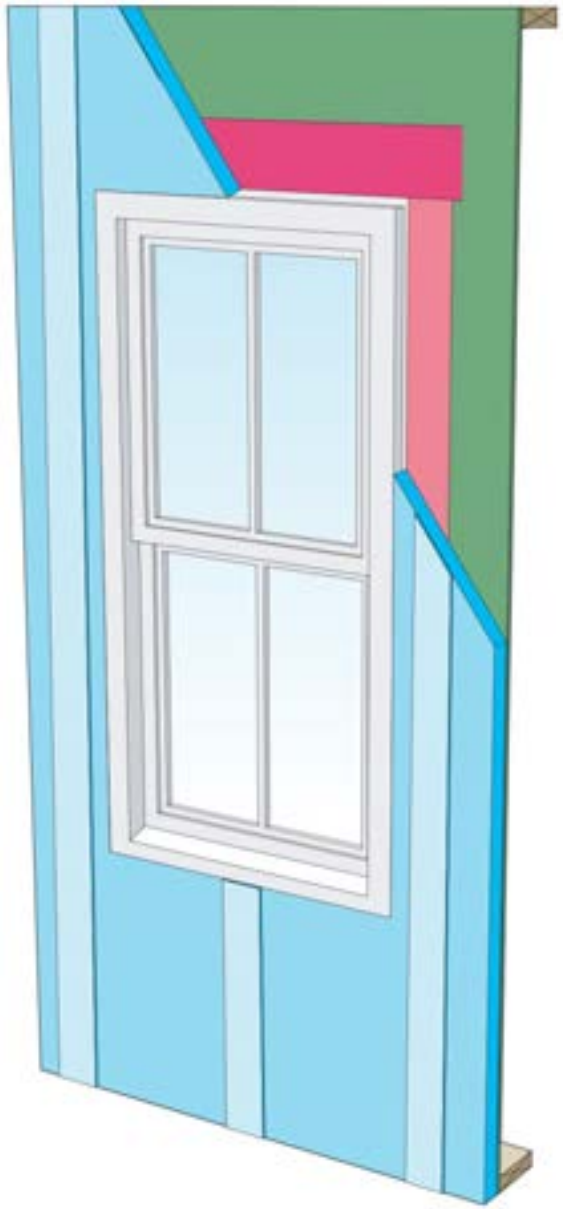


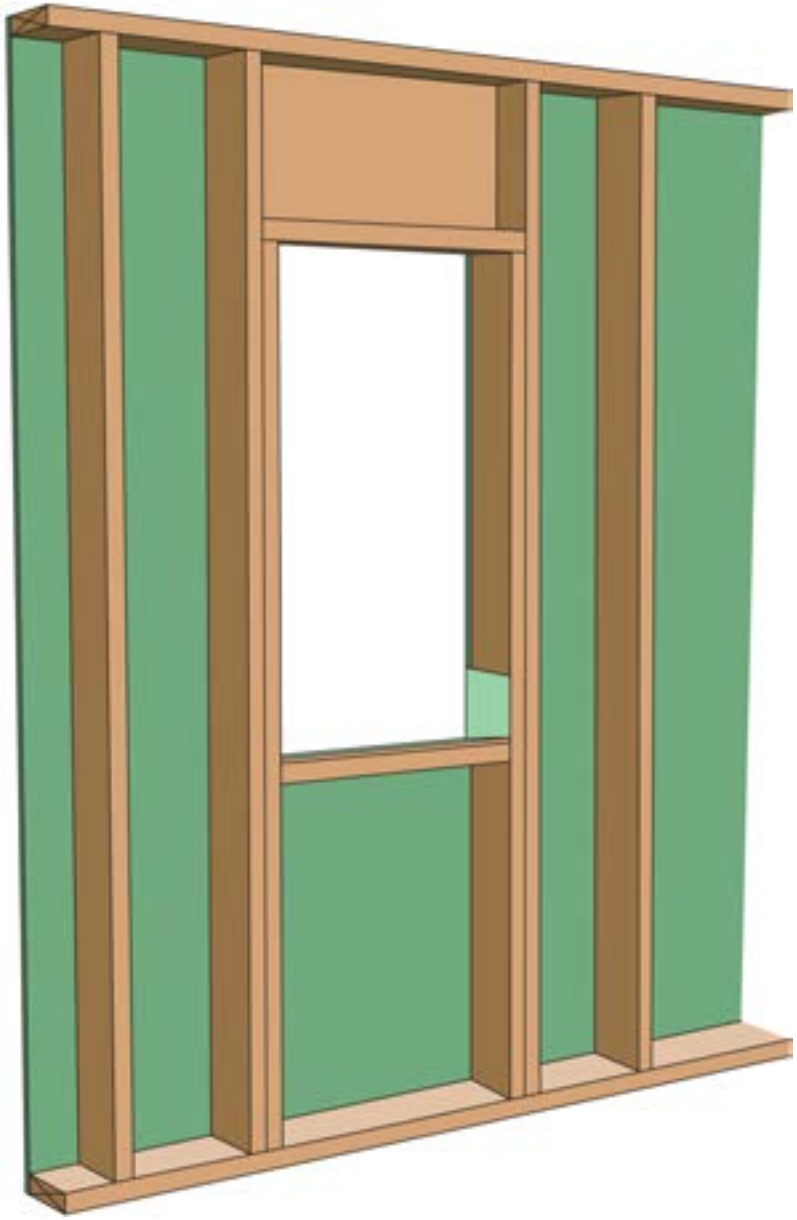


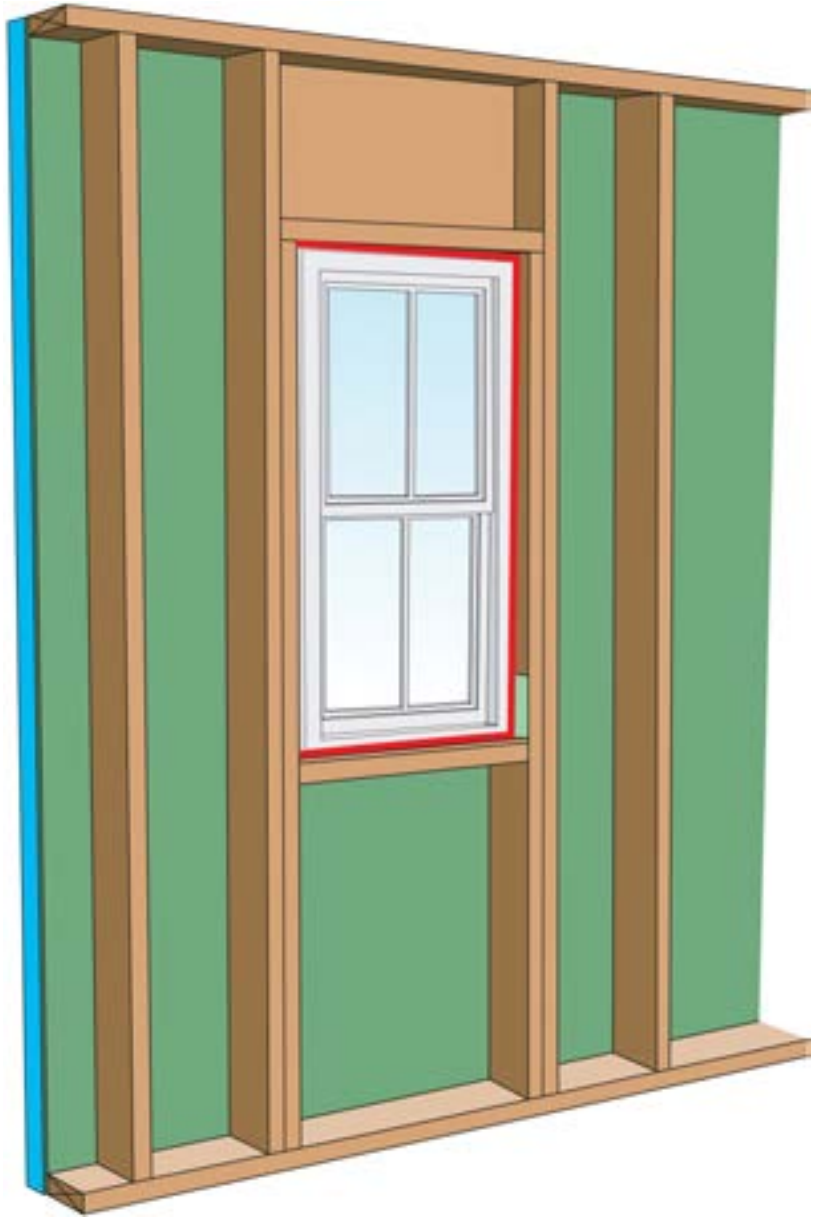


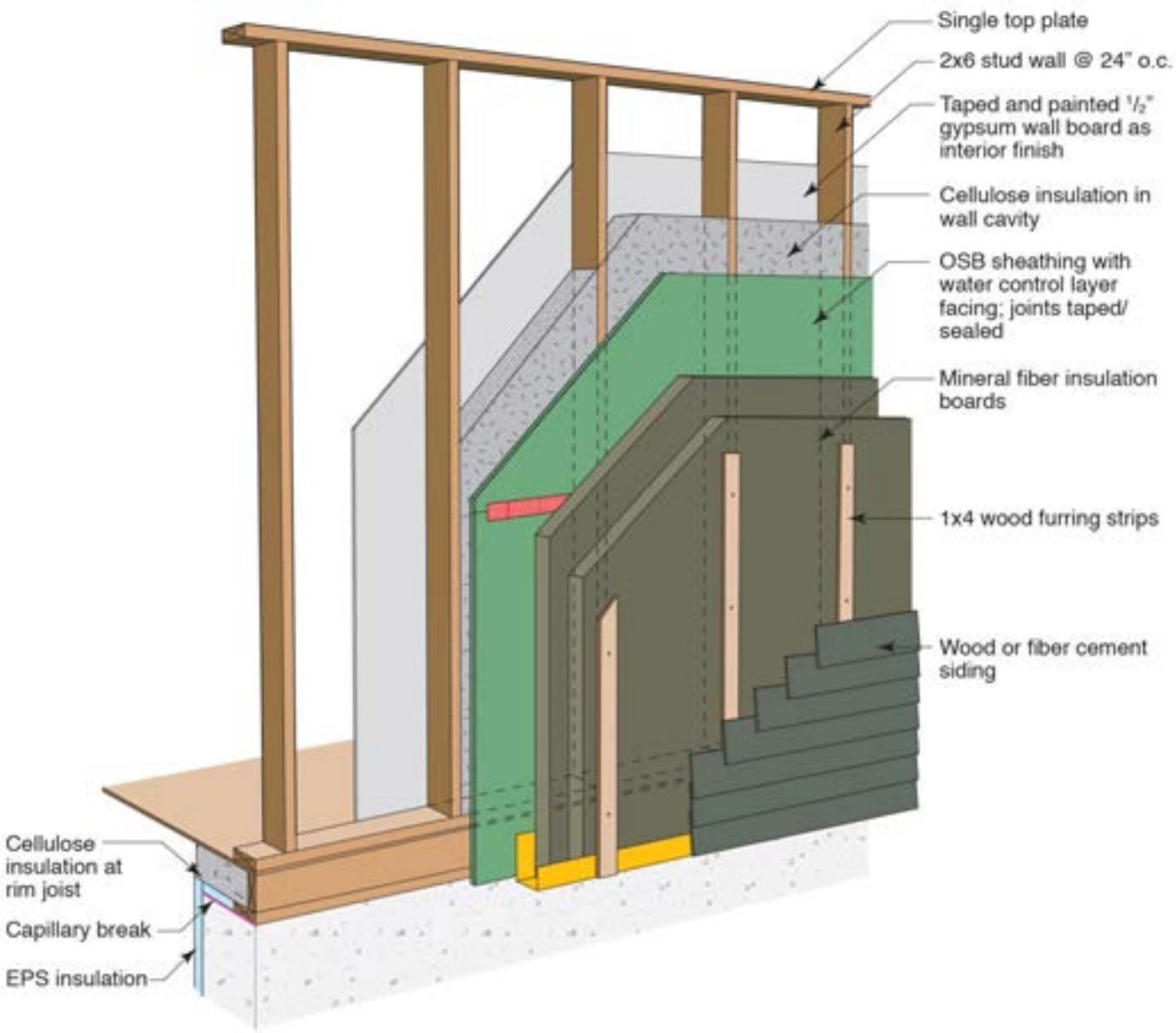


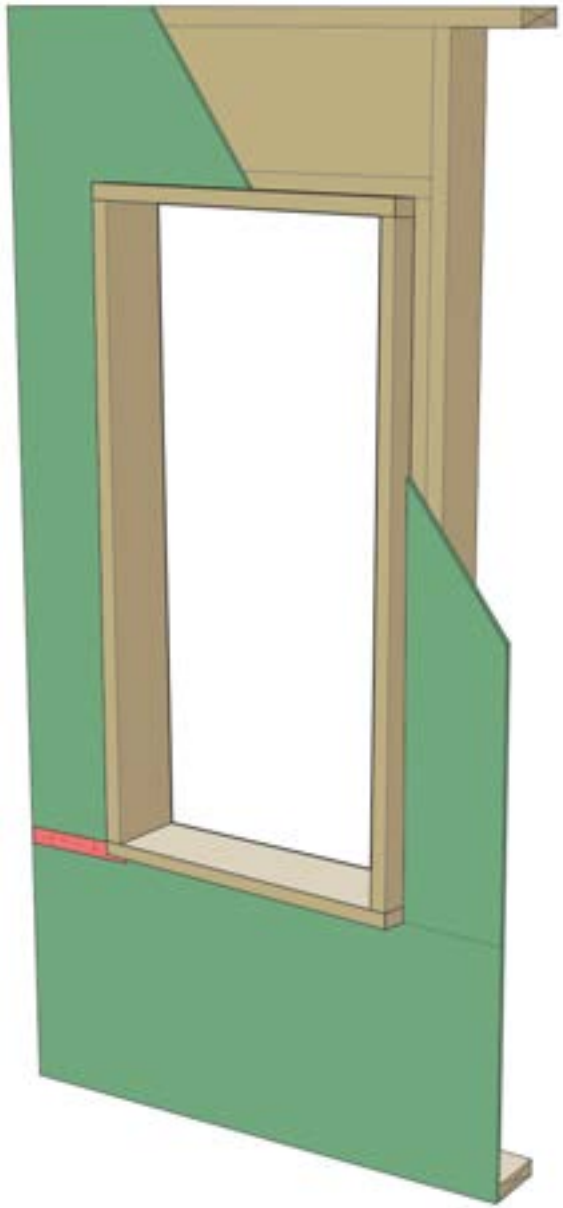


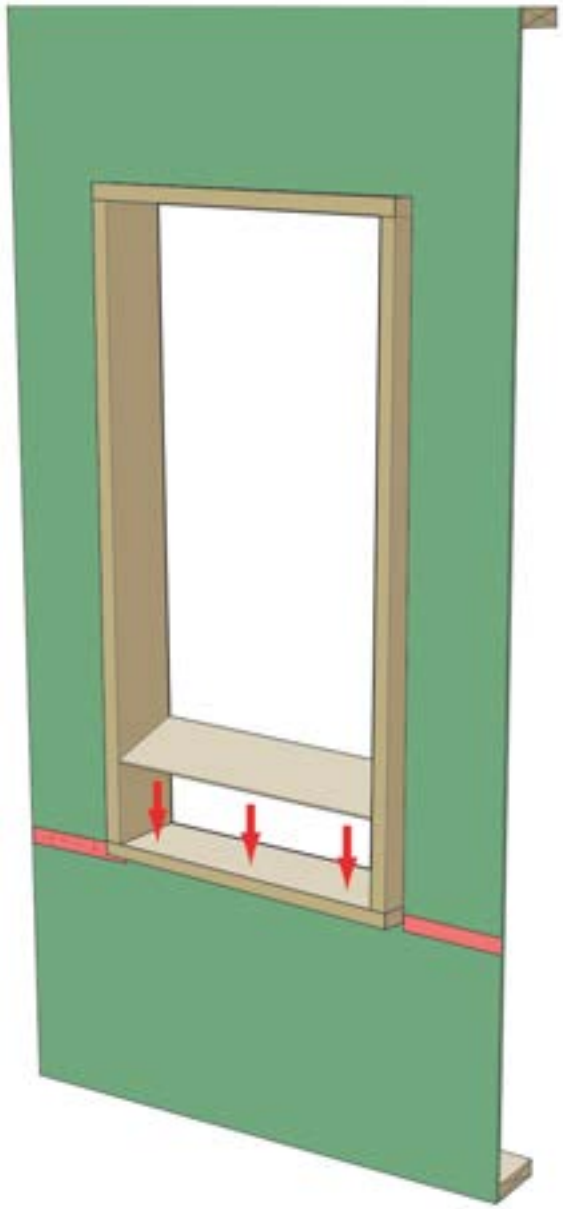


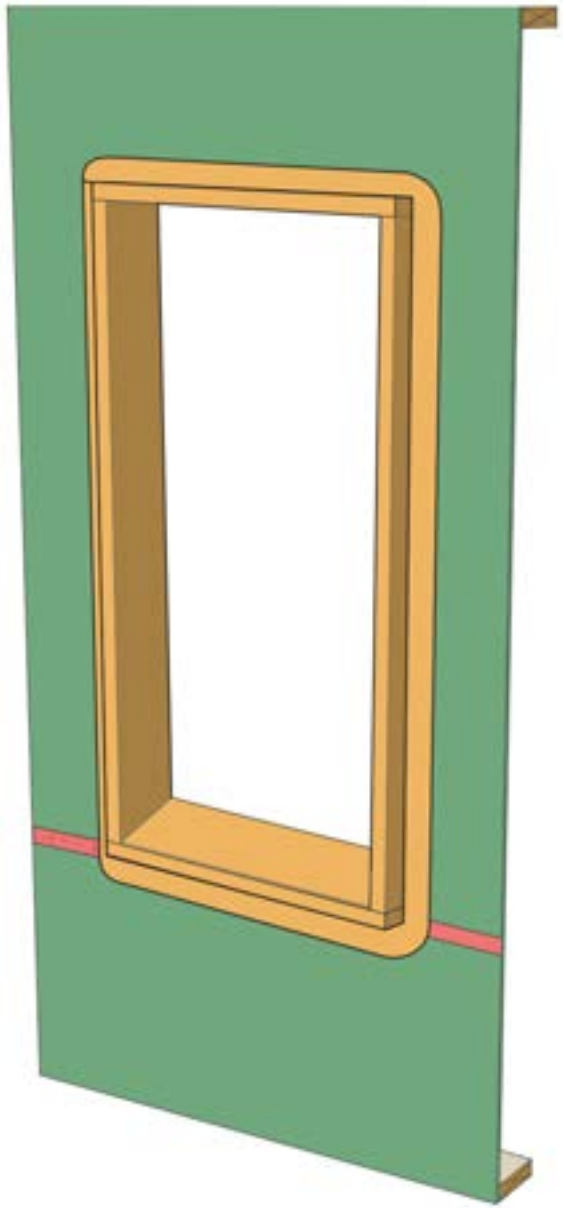


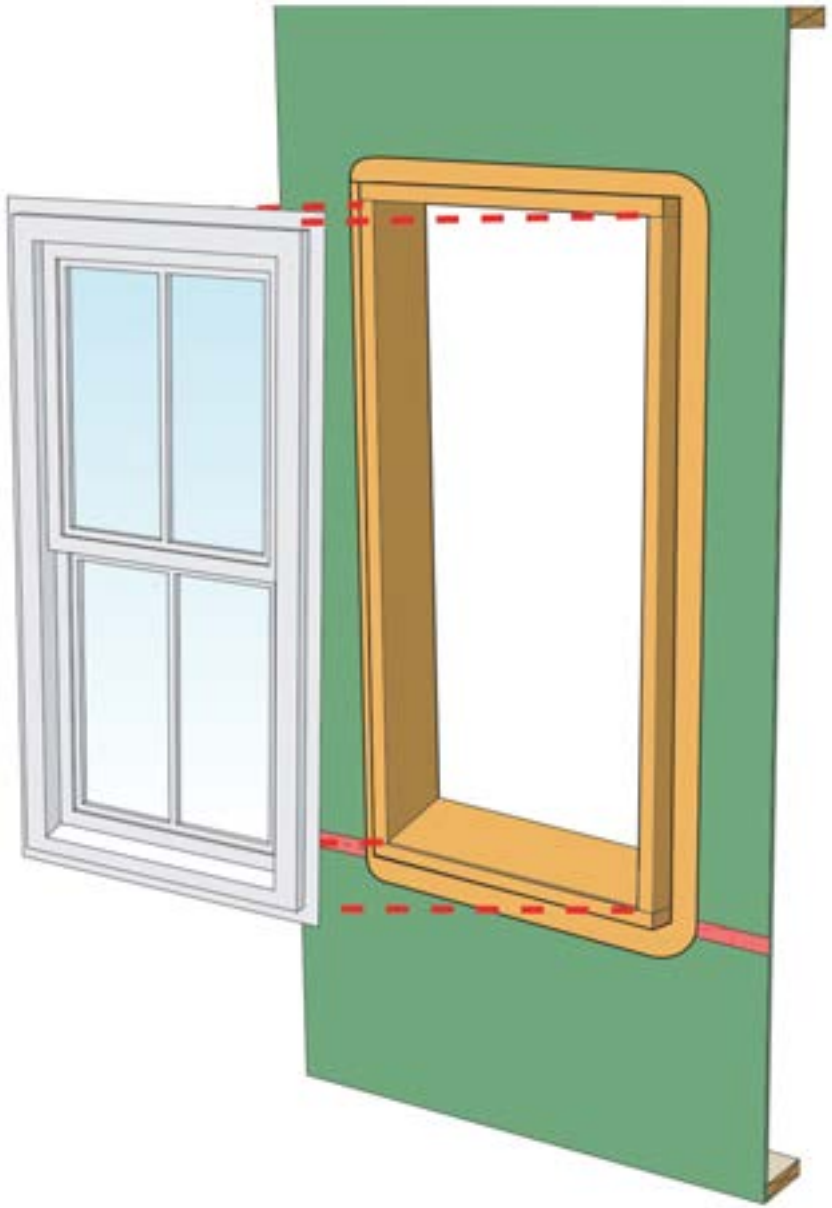


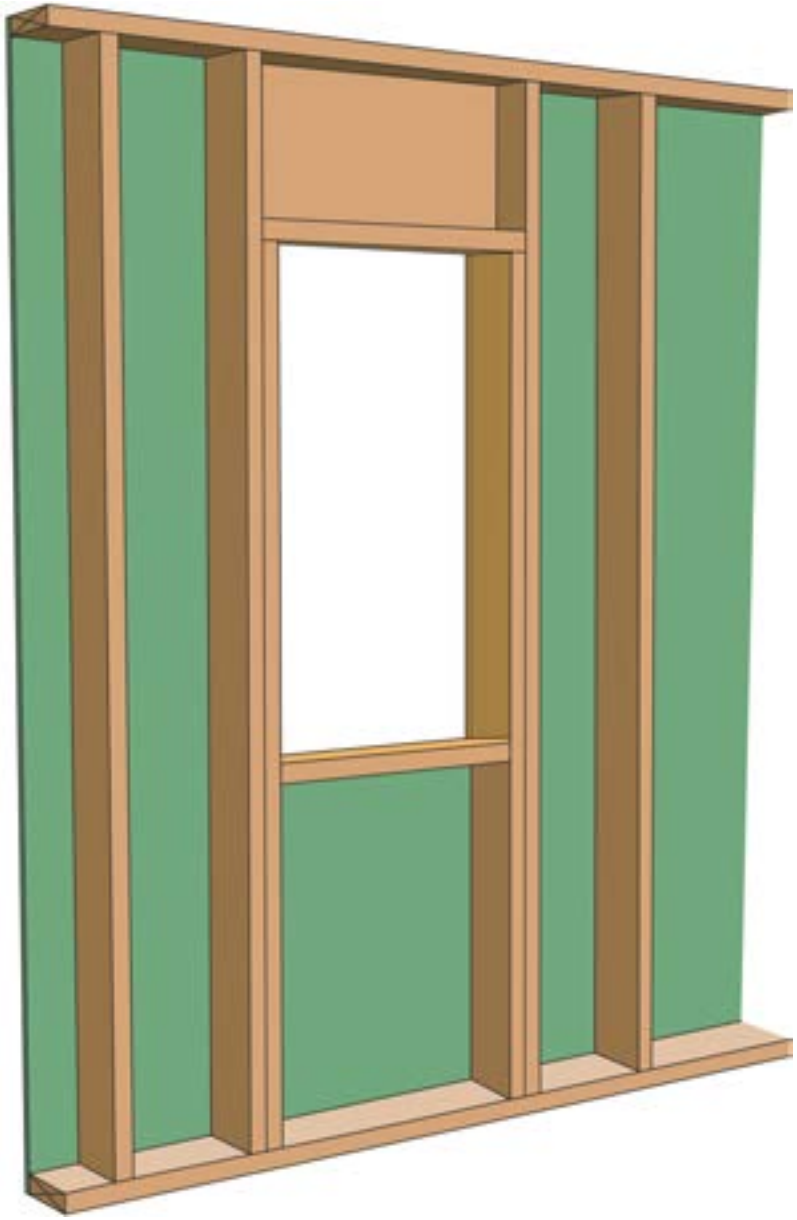

Single top plate
2x6 stud wall @ 24" o.c.
Taped and painted ½" gypsum wall board as interior finish
Cellulose insulation in wall cavity
OSB sheathing with water control layer facing; joints taped/ sealed
Mineral fiber insulation boards
1x4 wood furring strips
Wood or fiber cement siding
Cellulose insulation at rim joist
Capillary break
EPS insulation

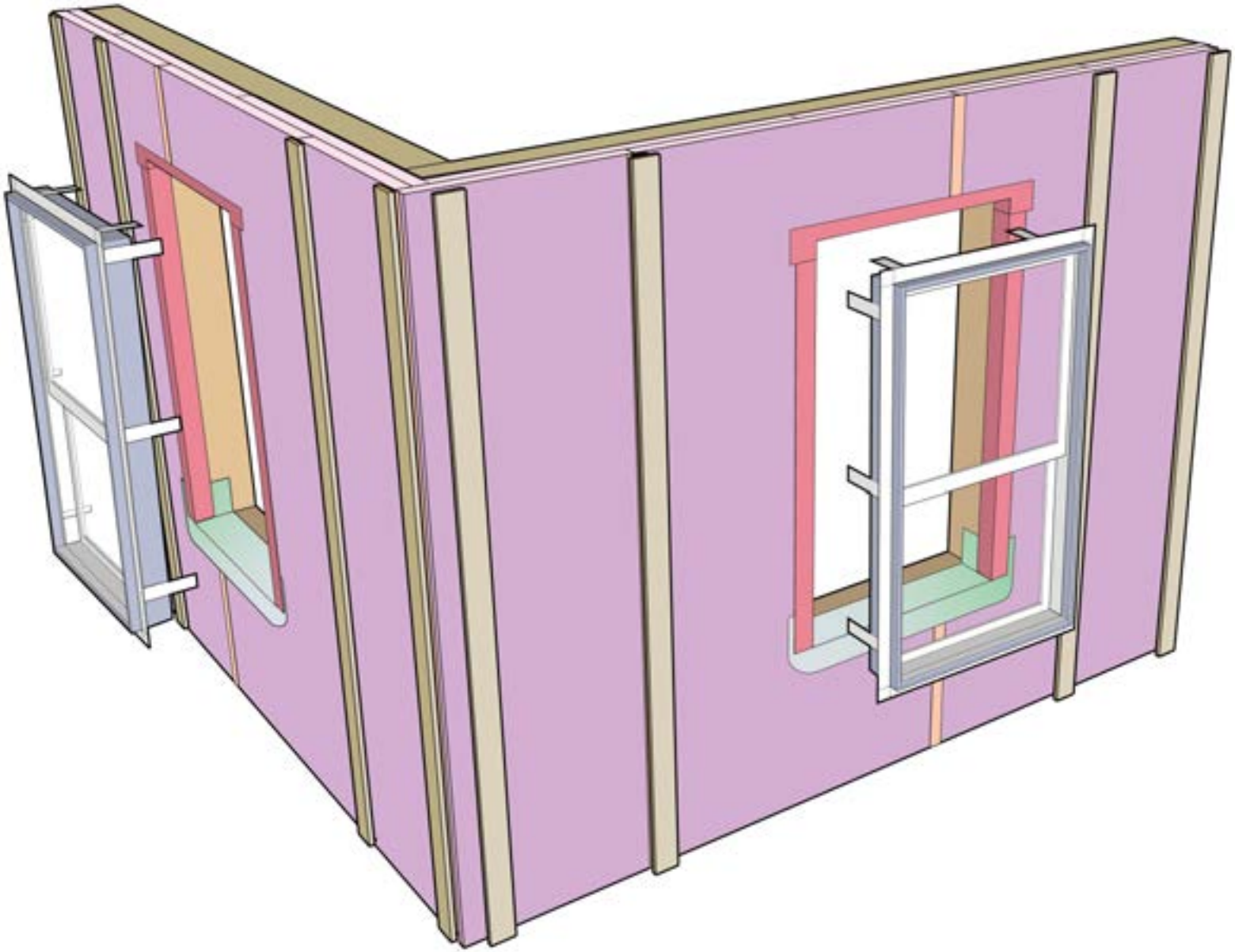


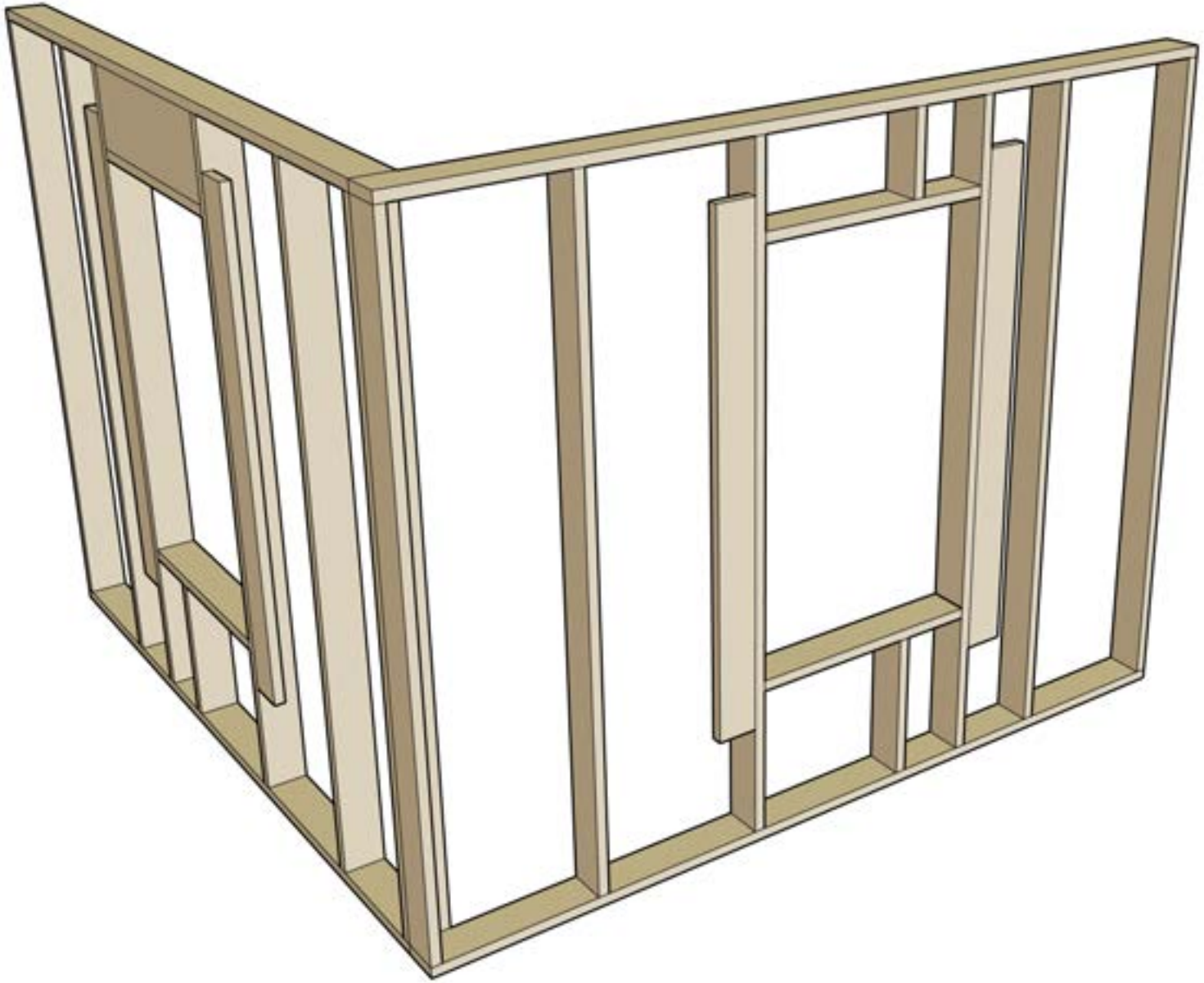


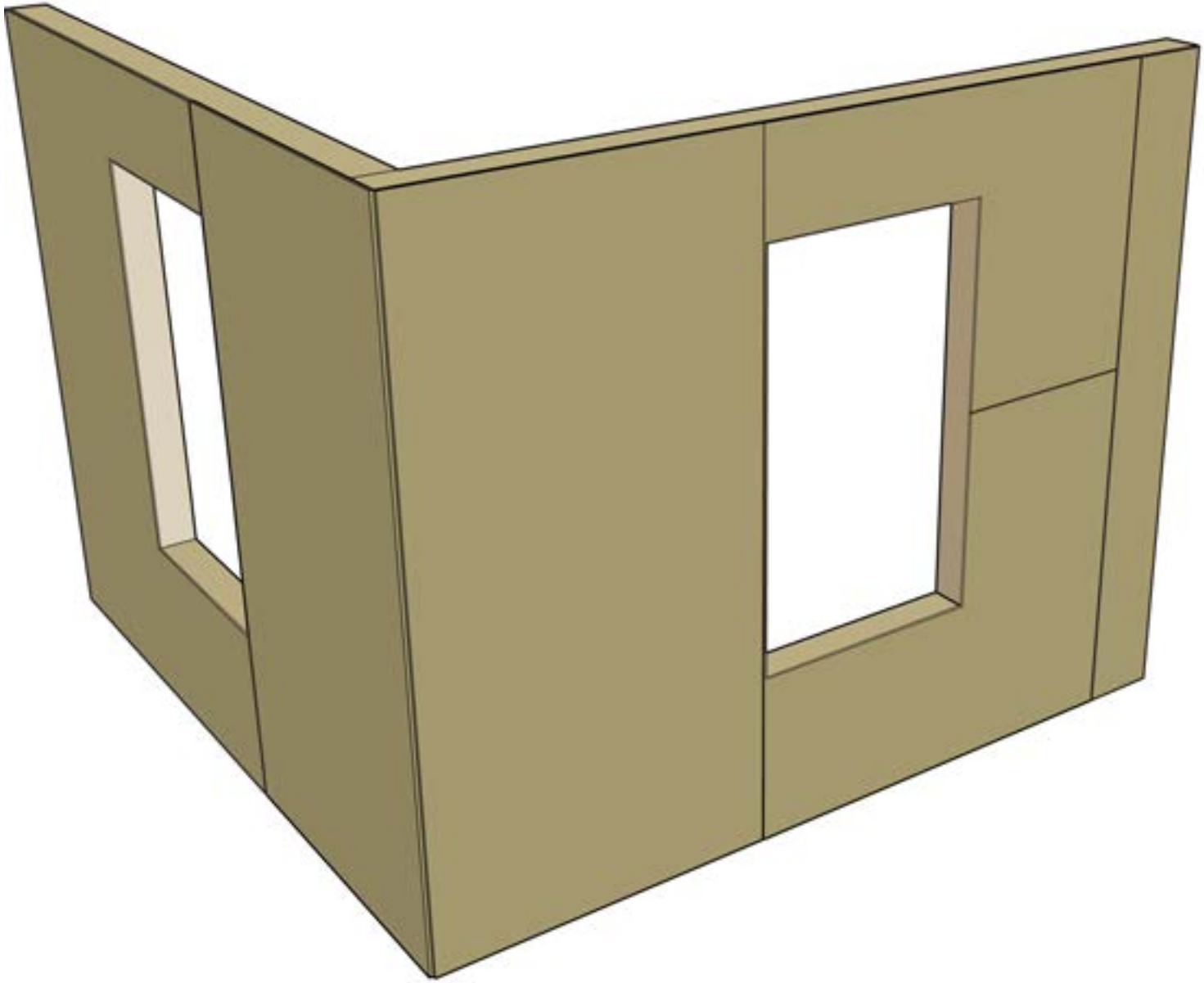


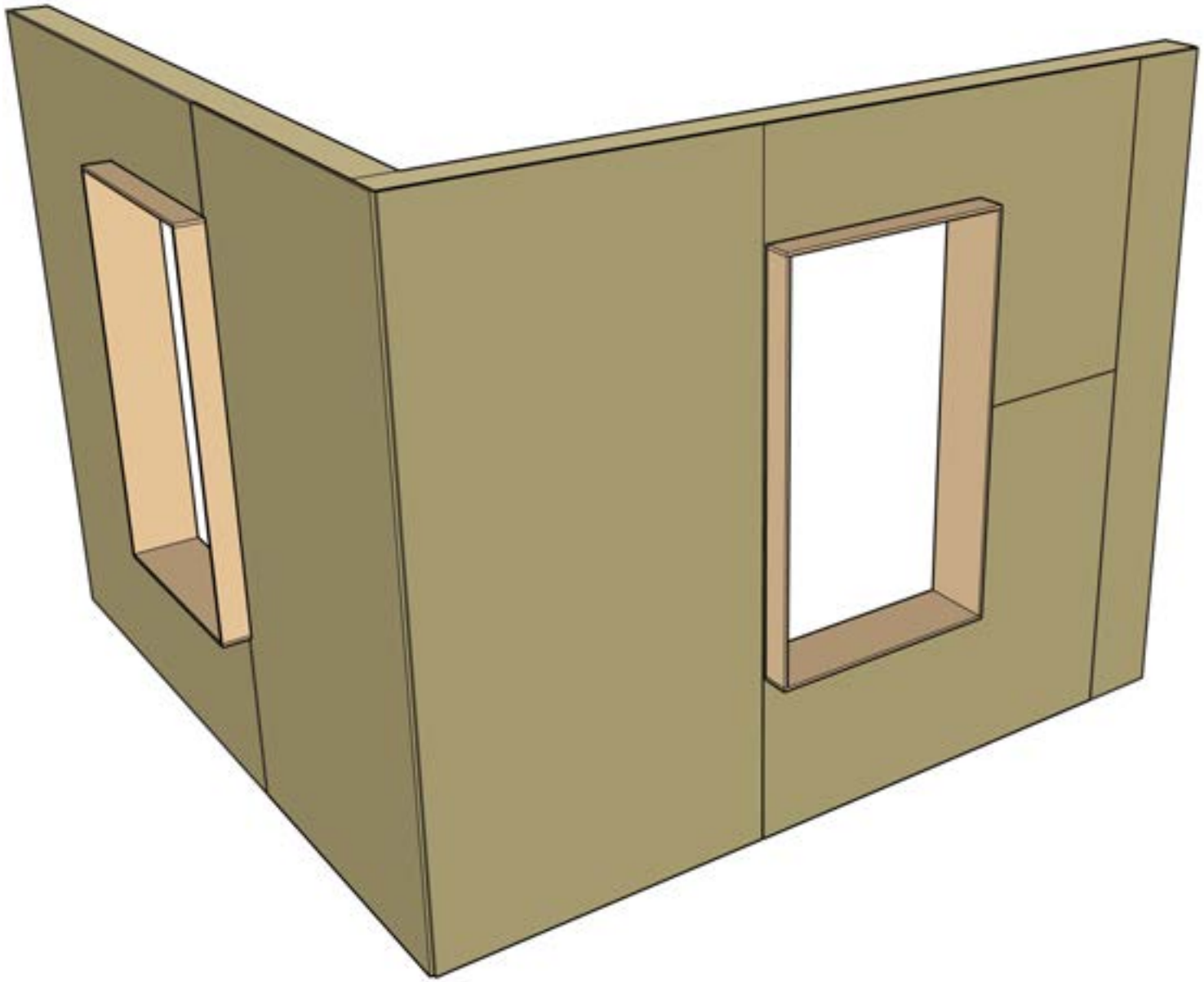


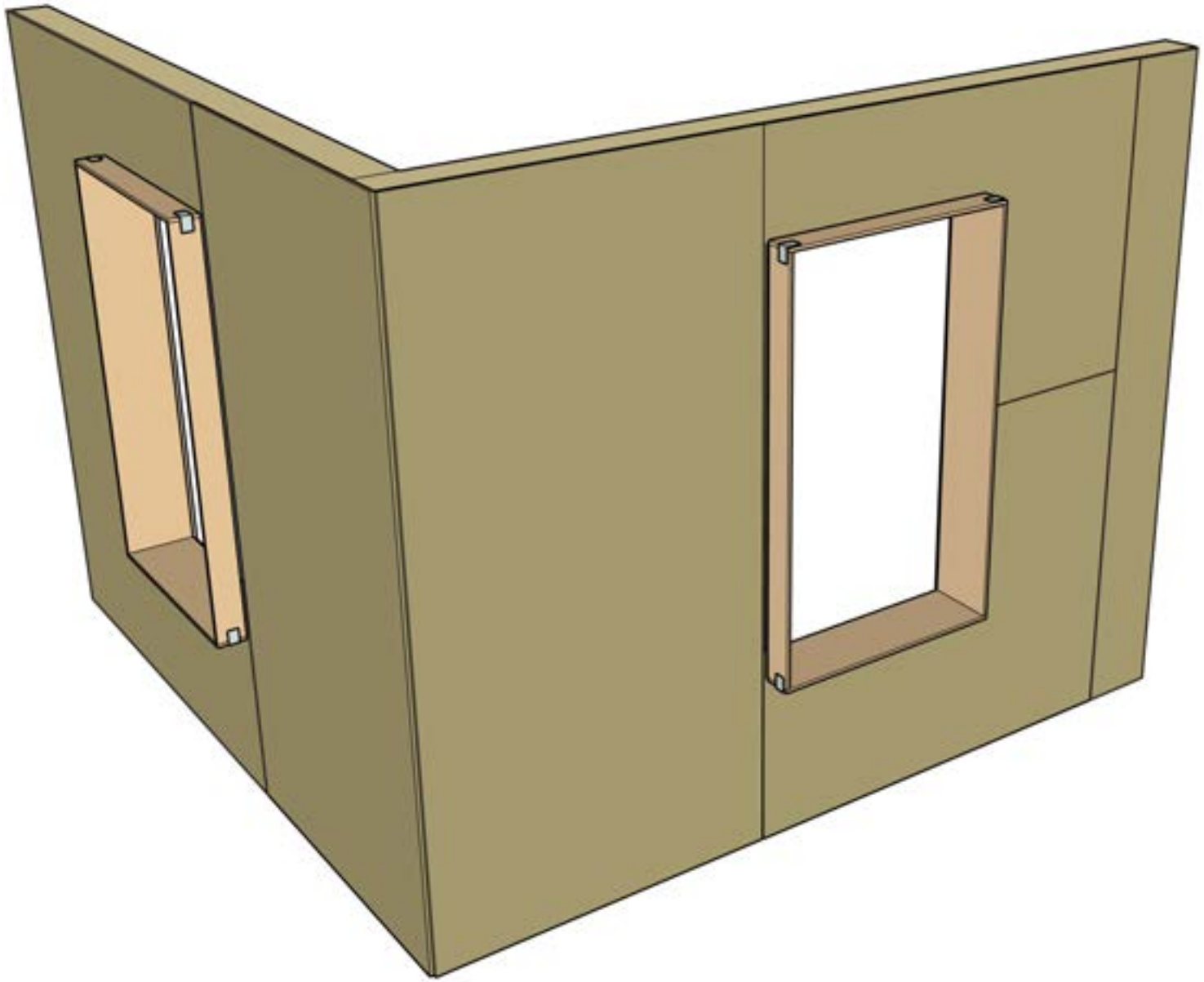


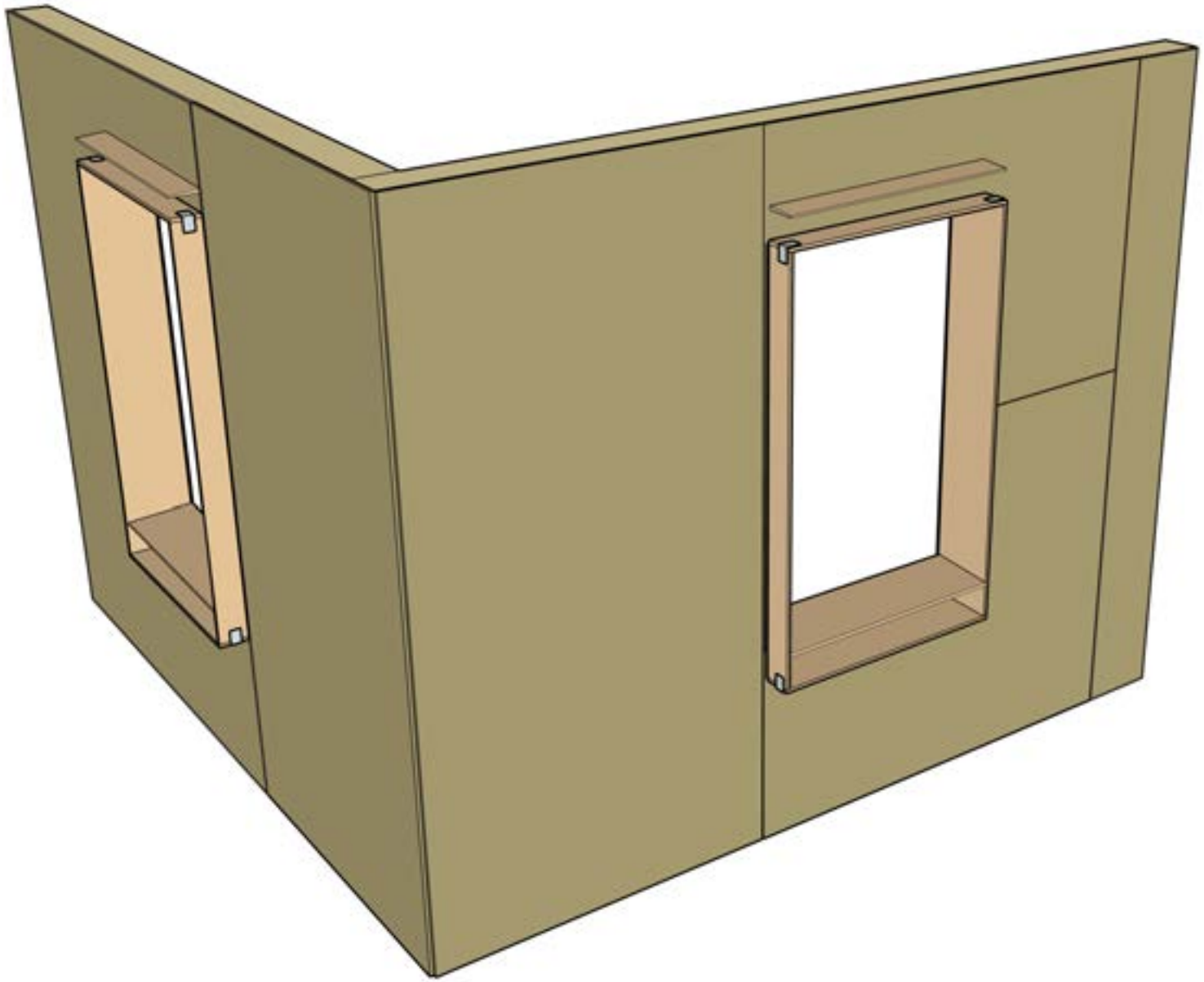


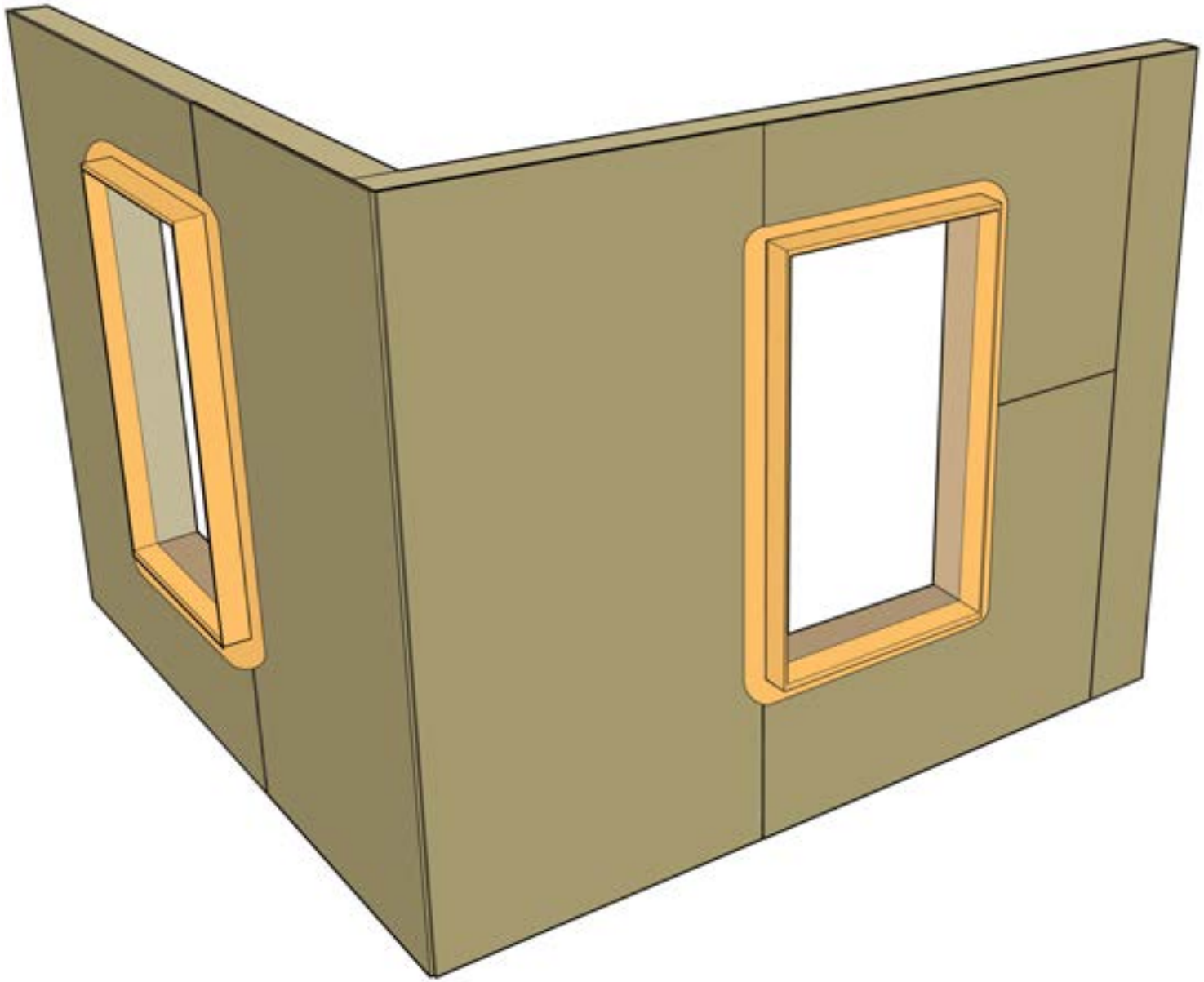


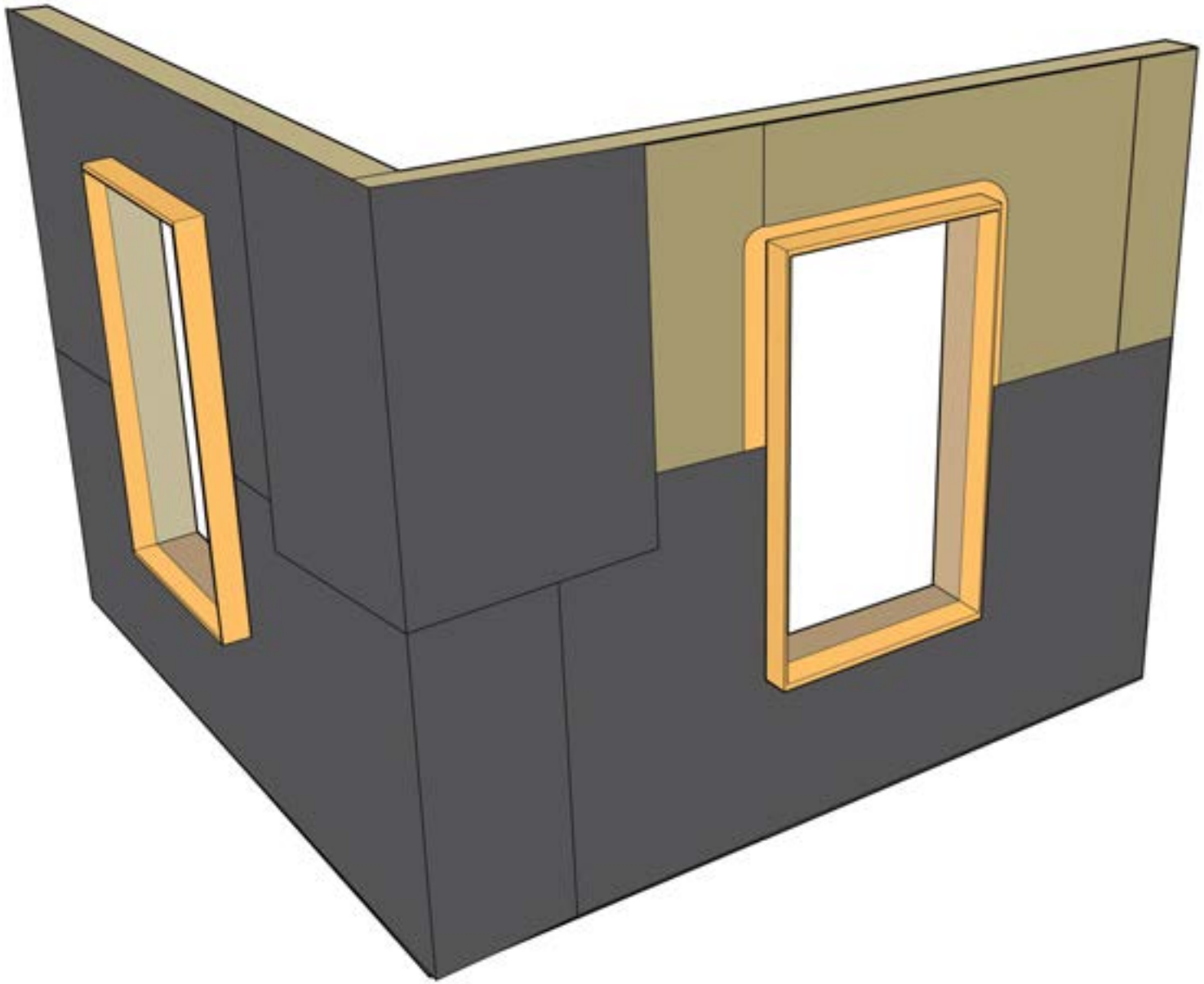


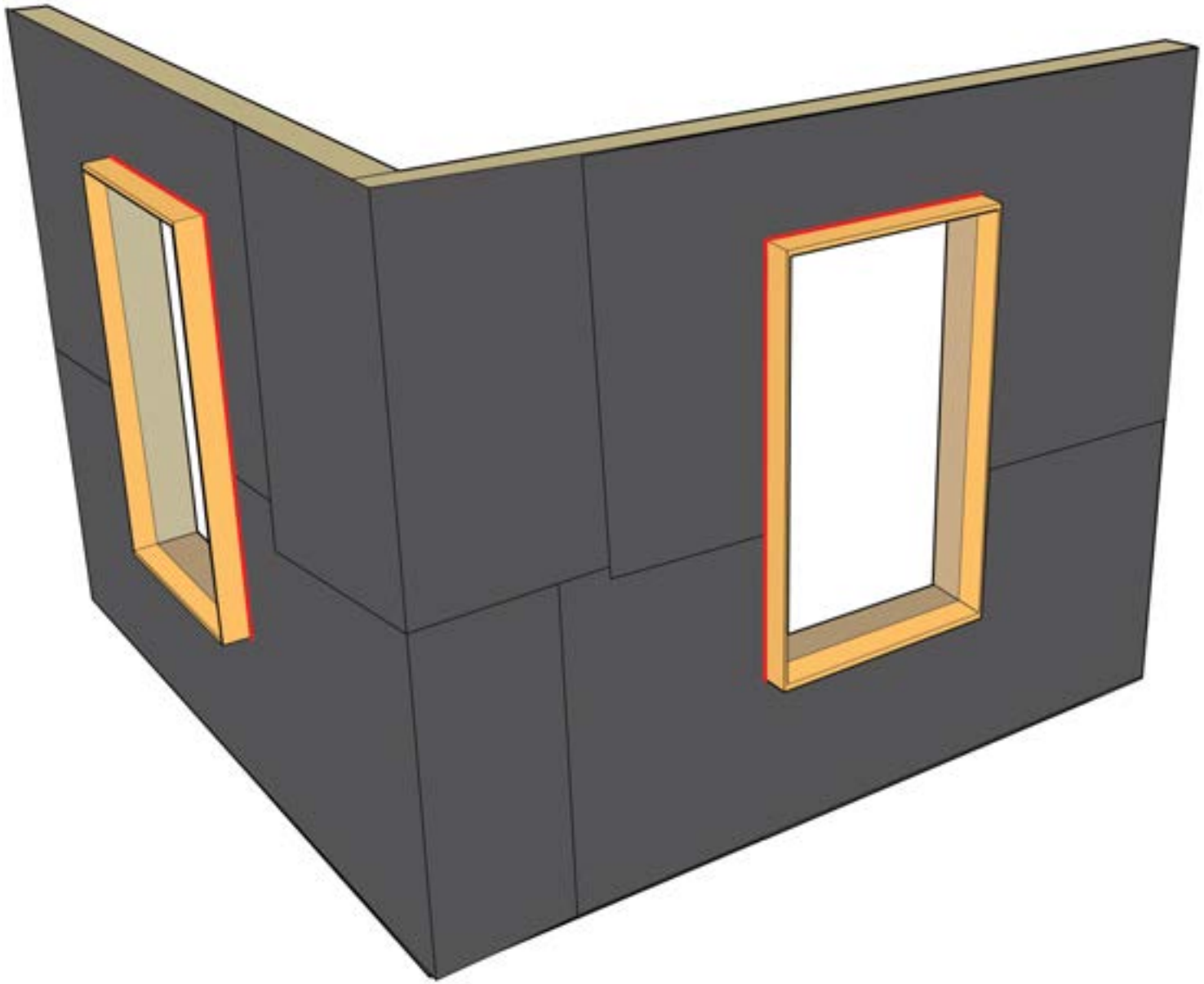


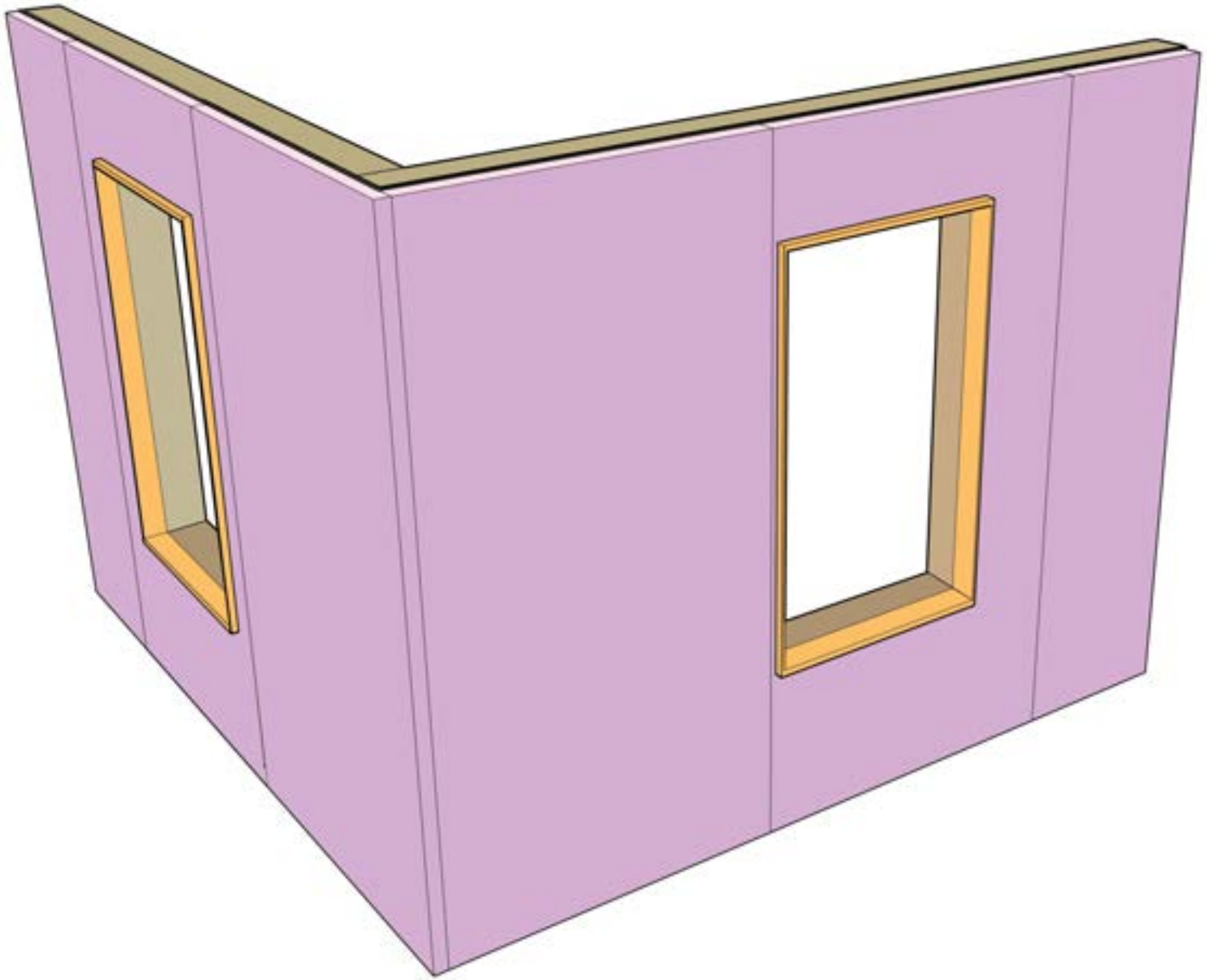


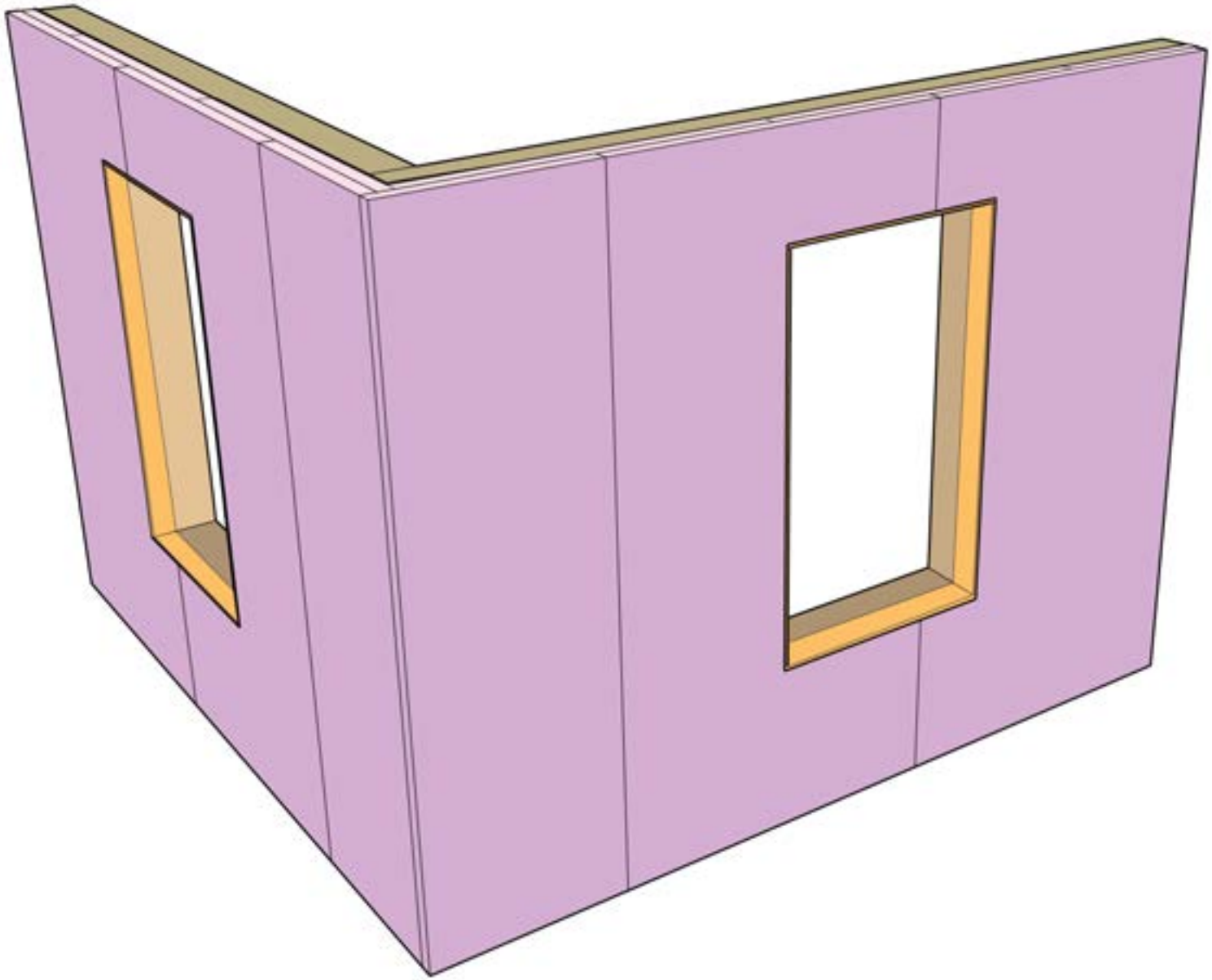


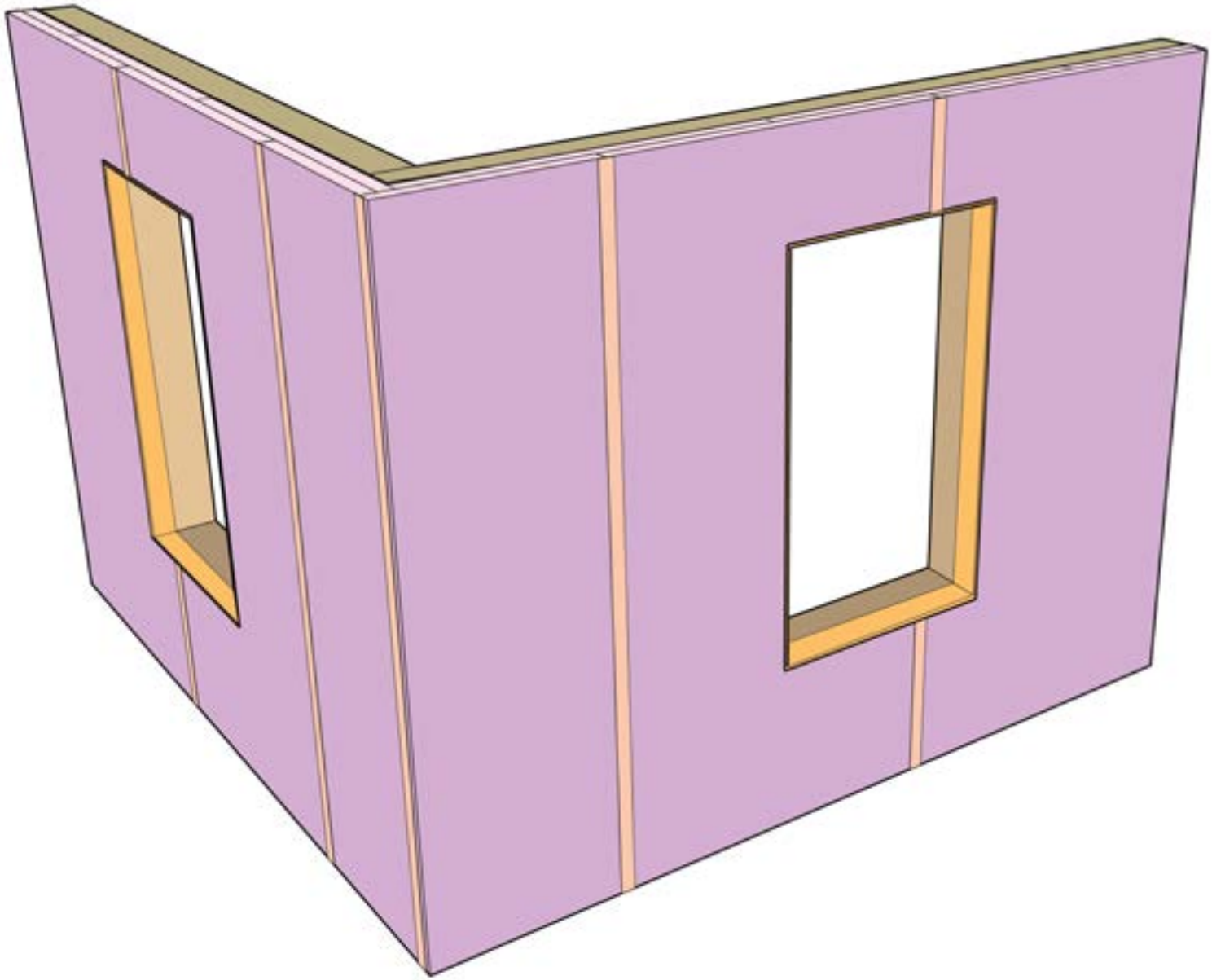


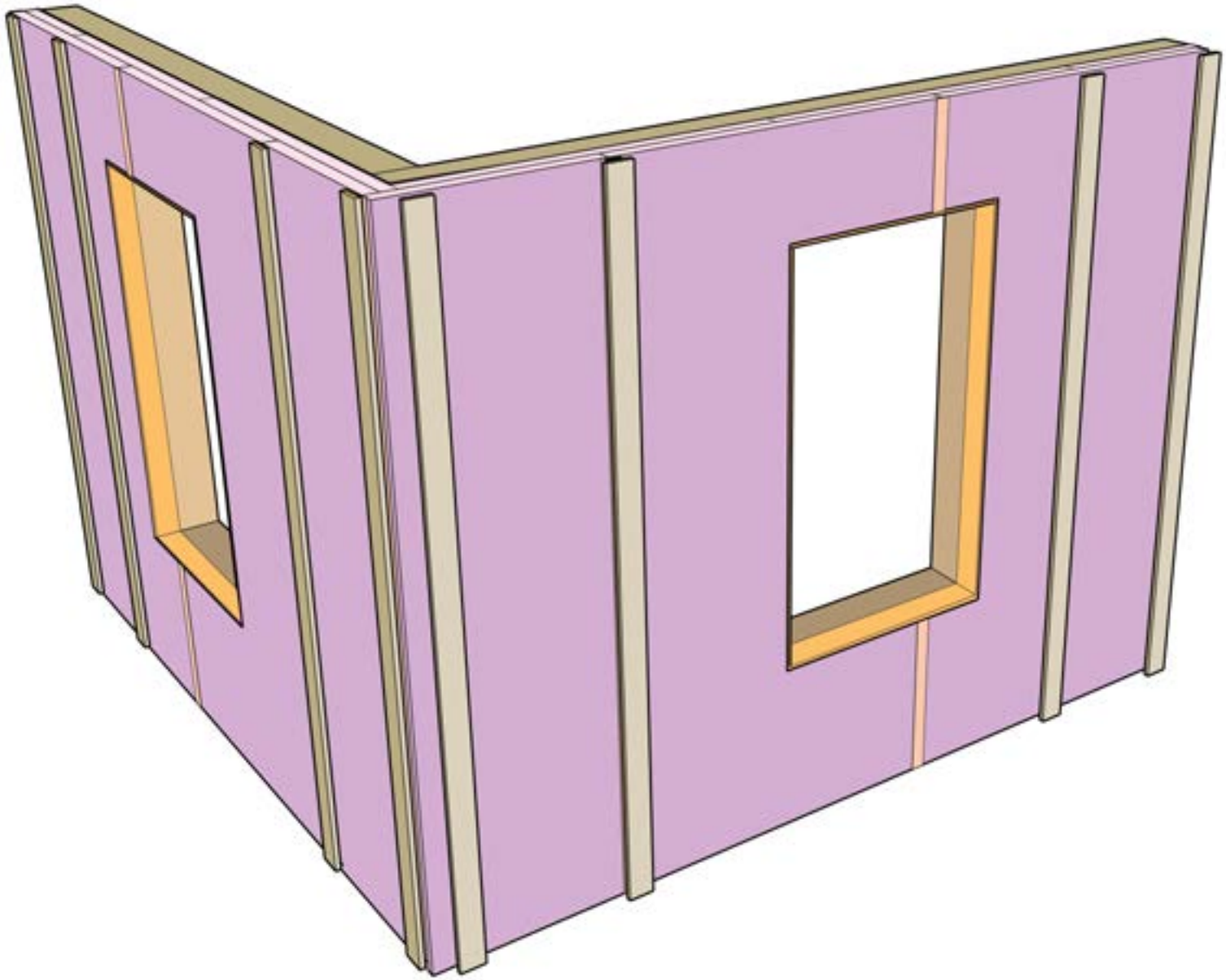


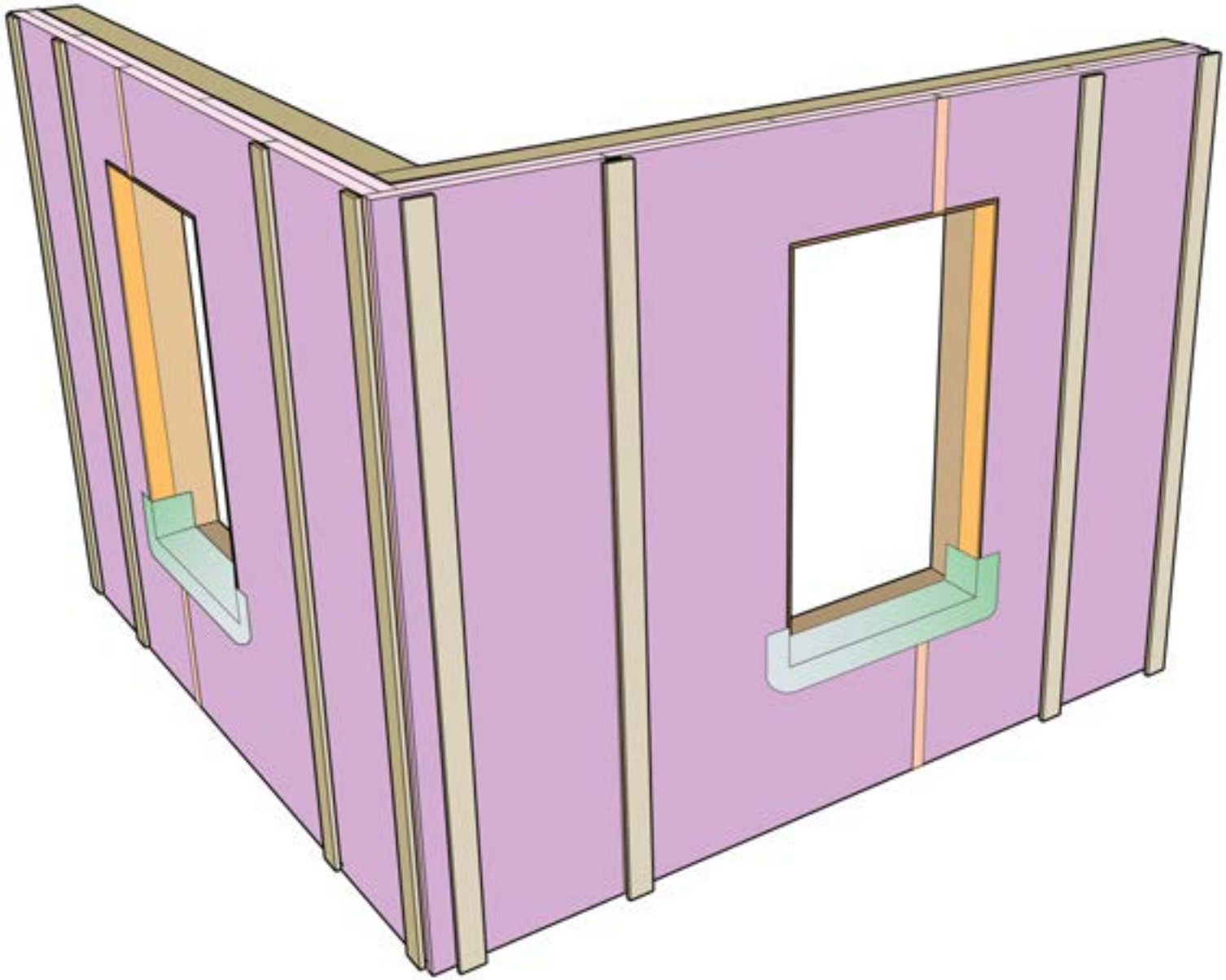


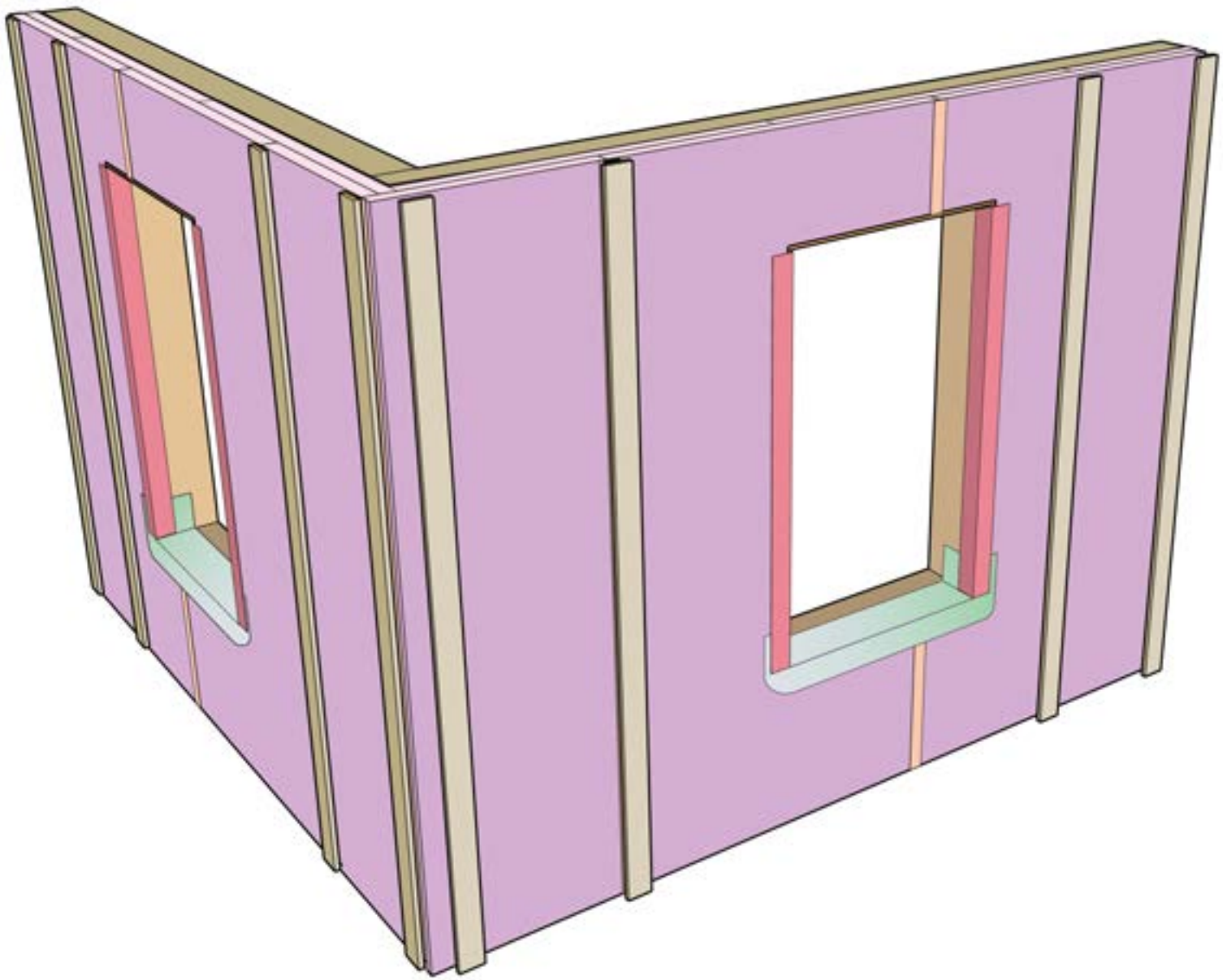


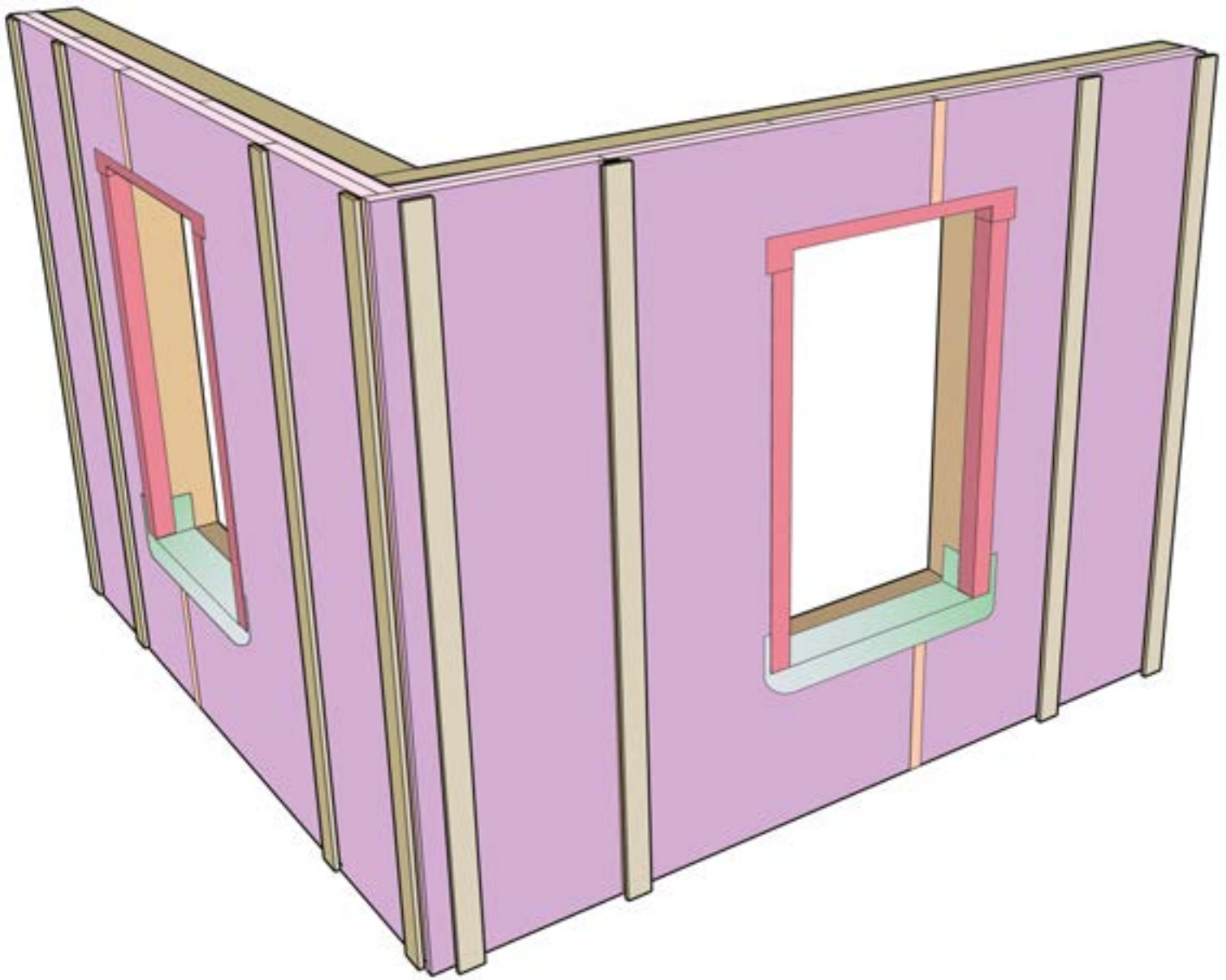


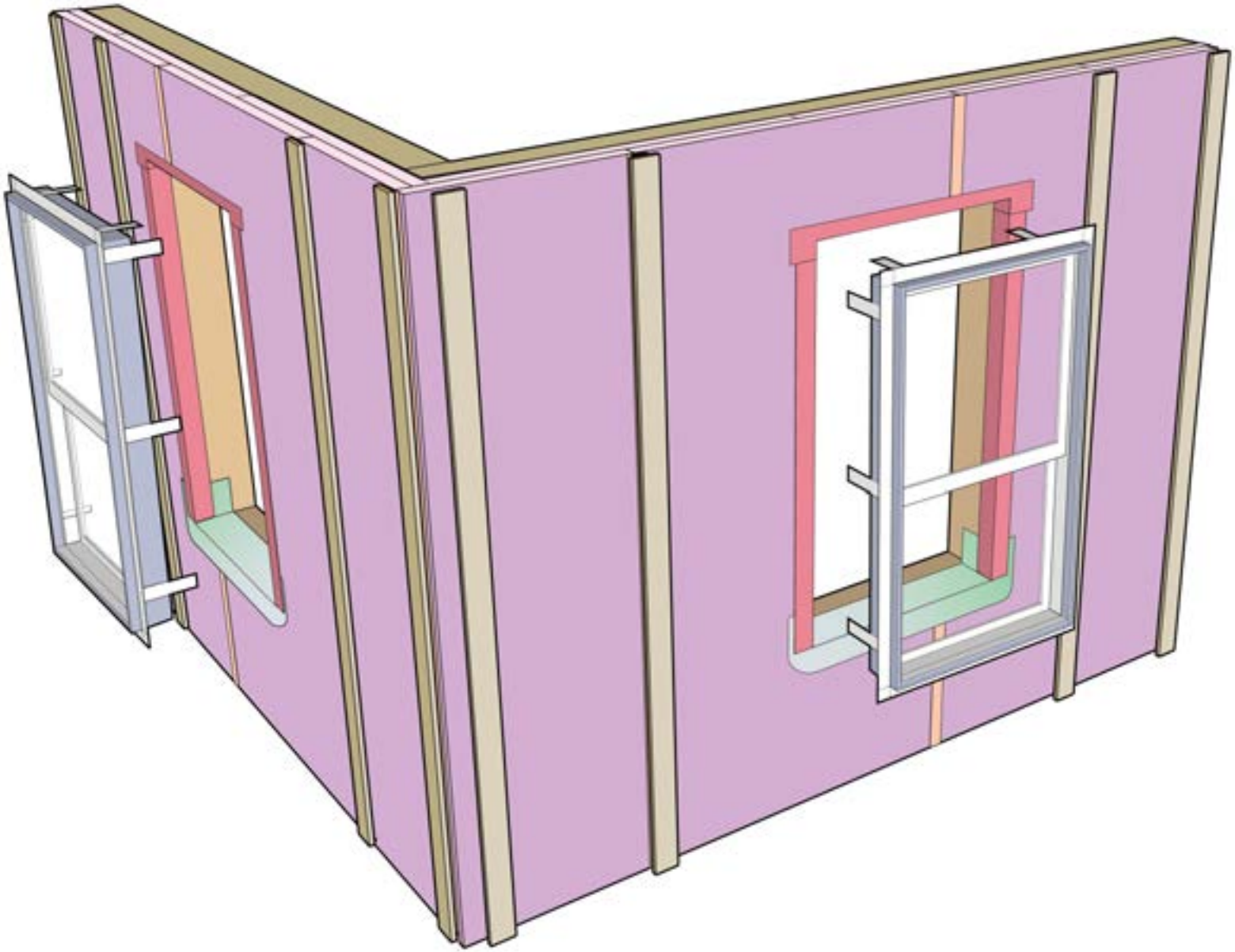


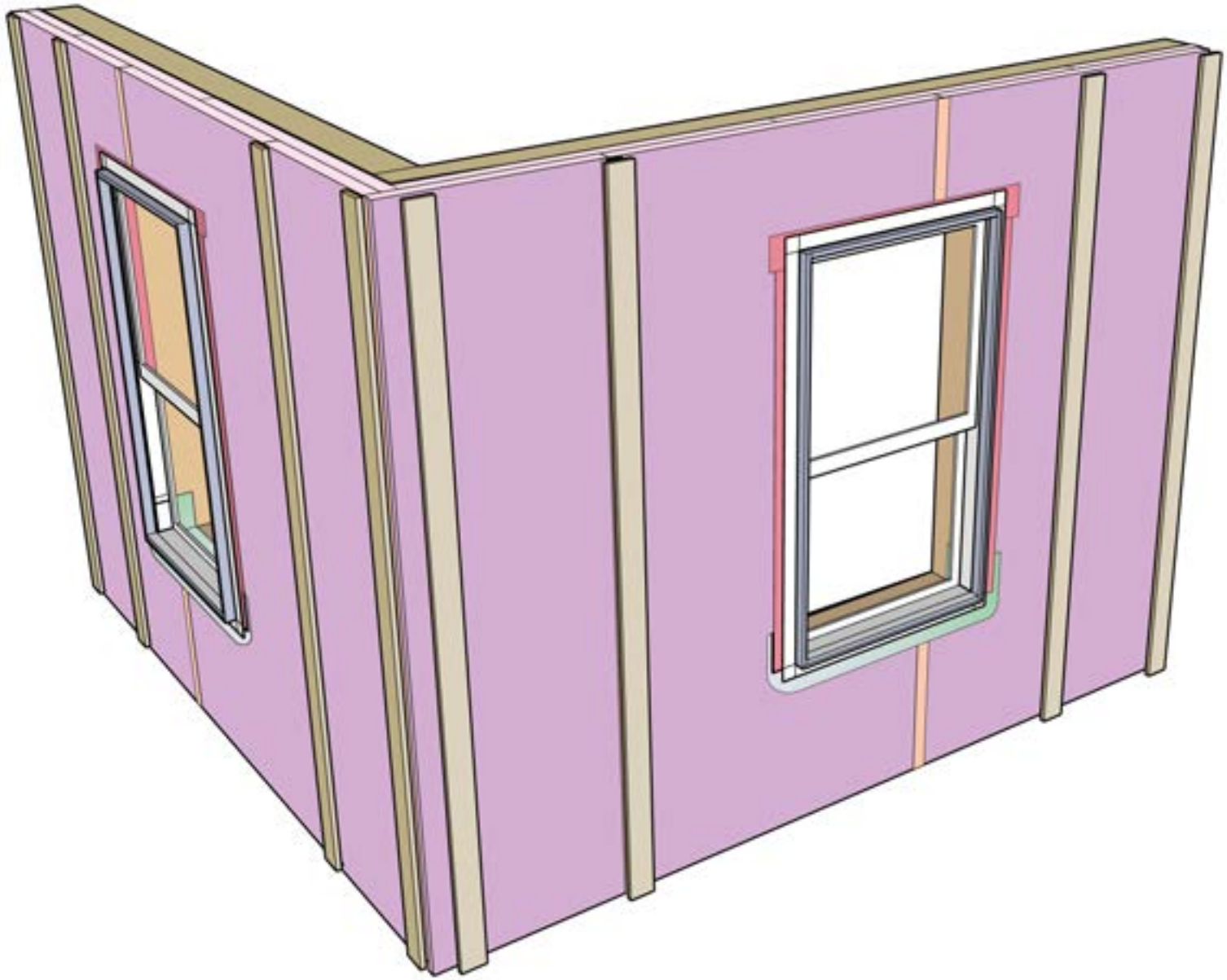


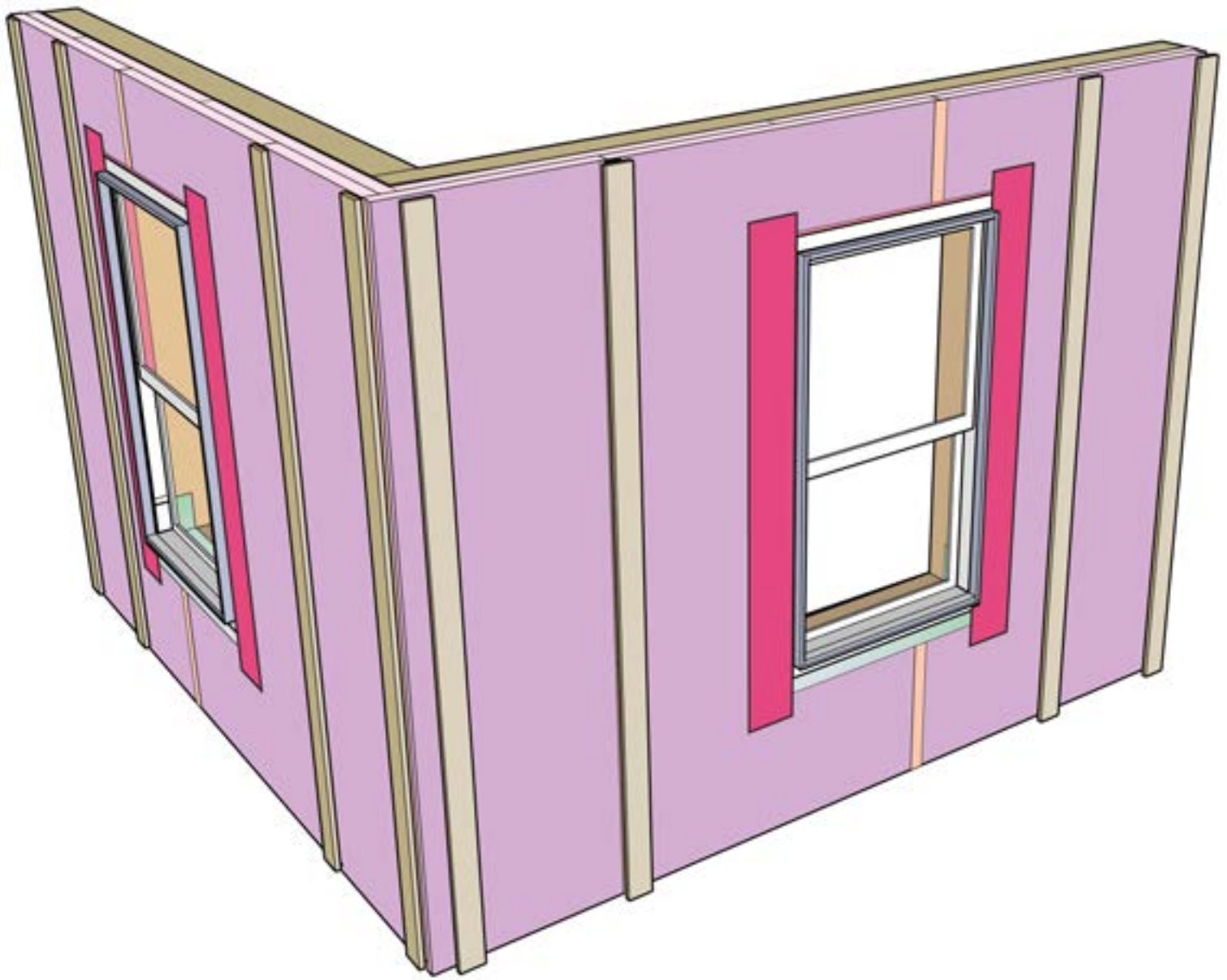


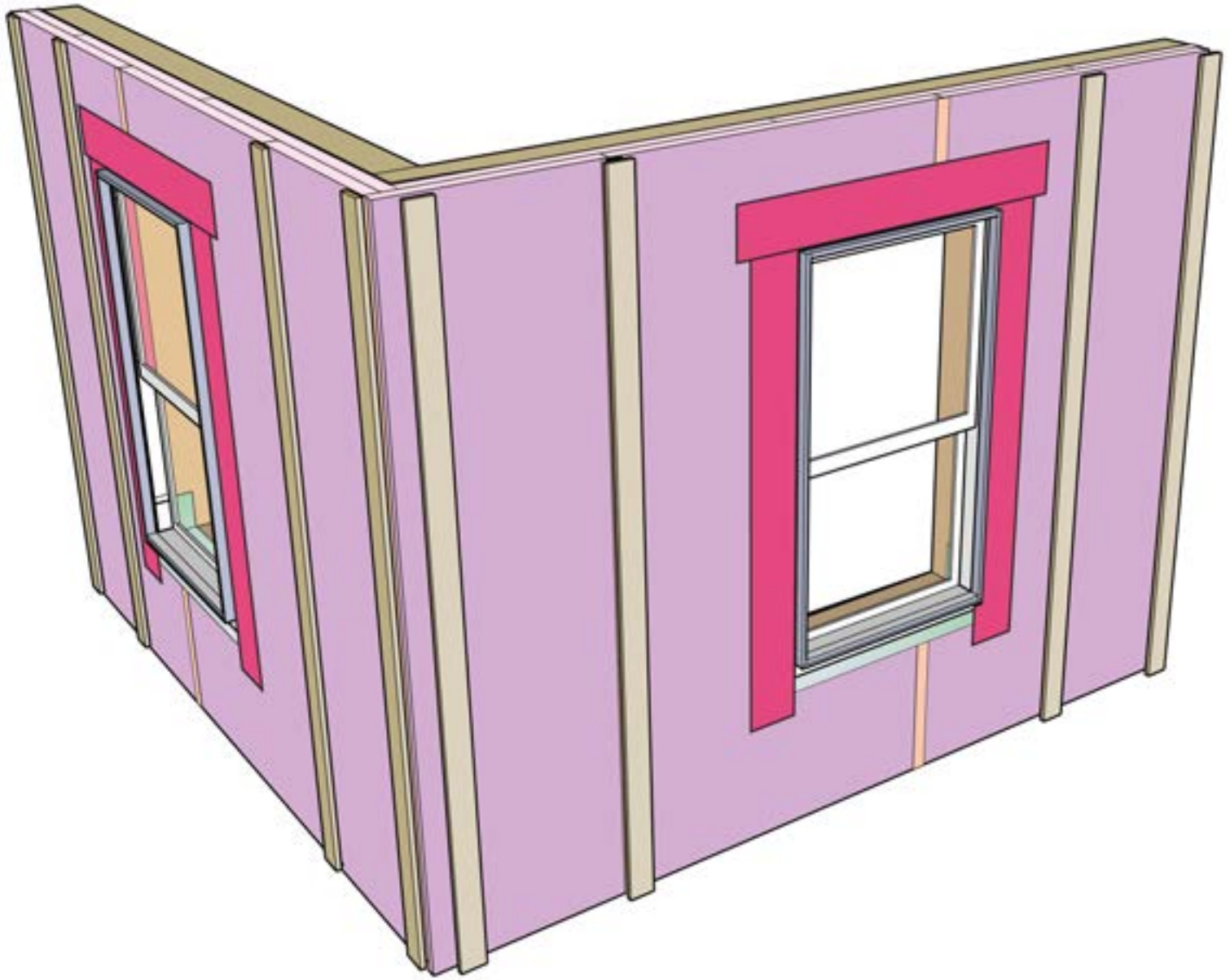


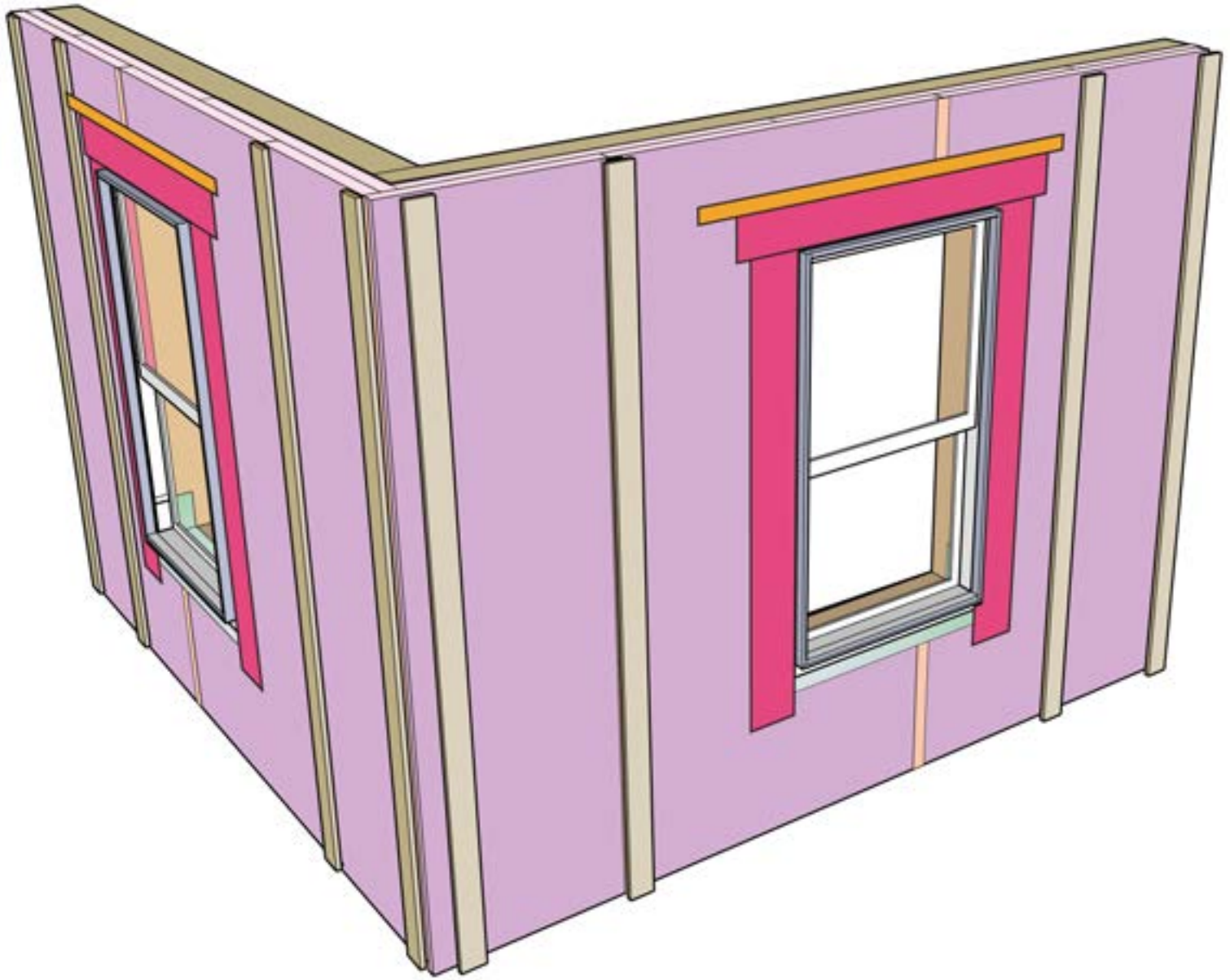


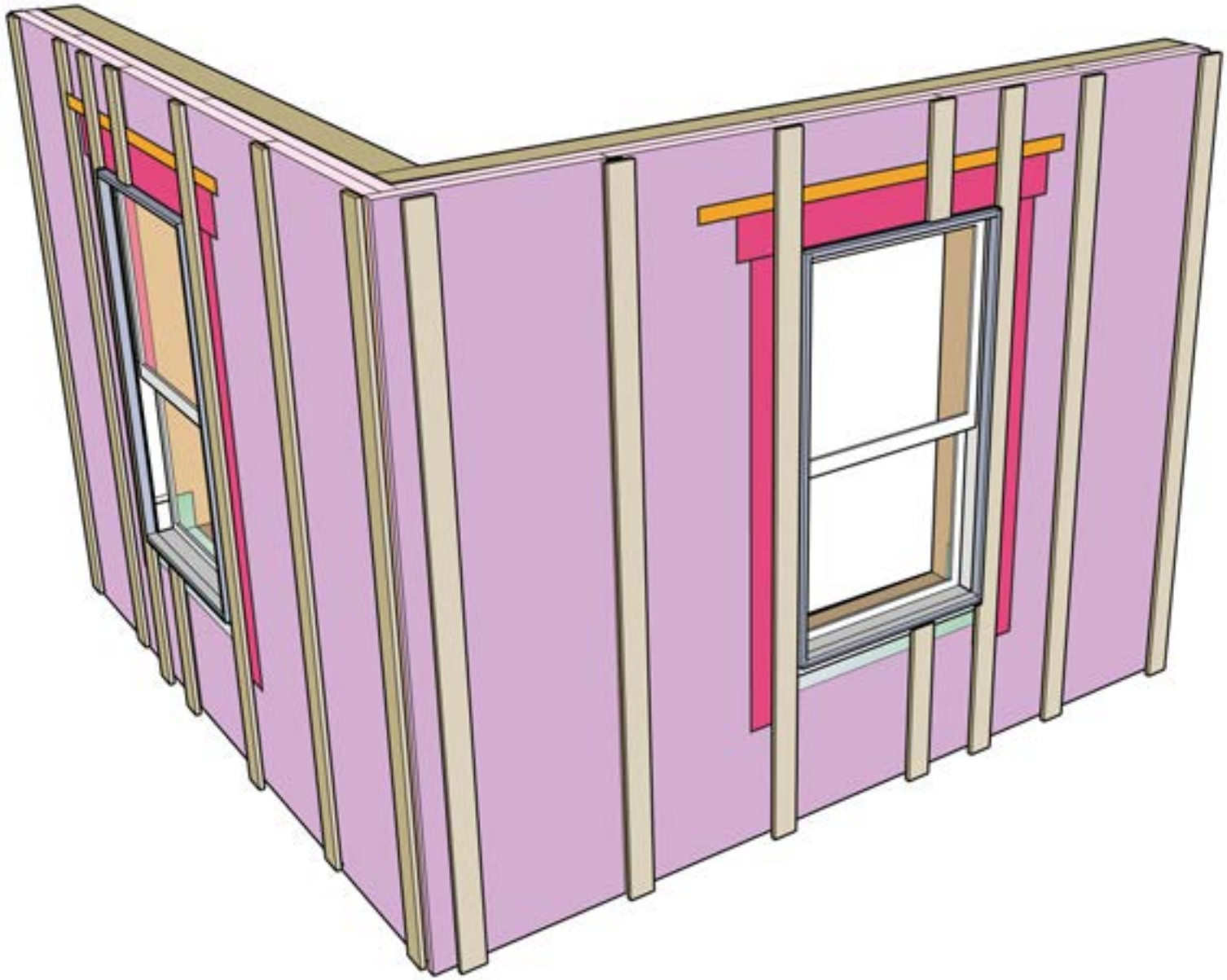


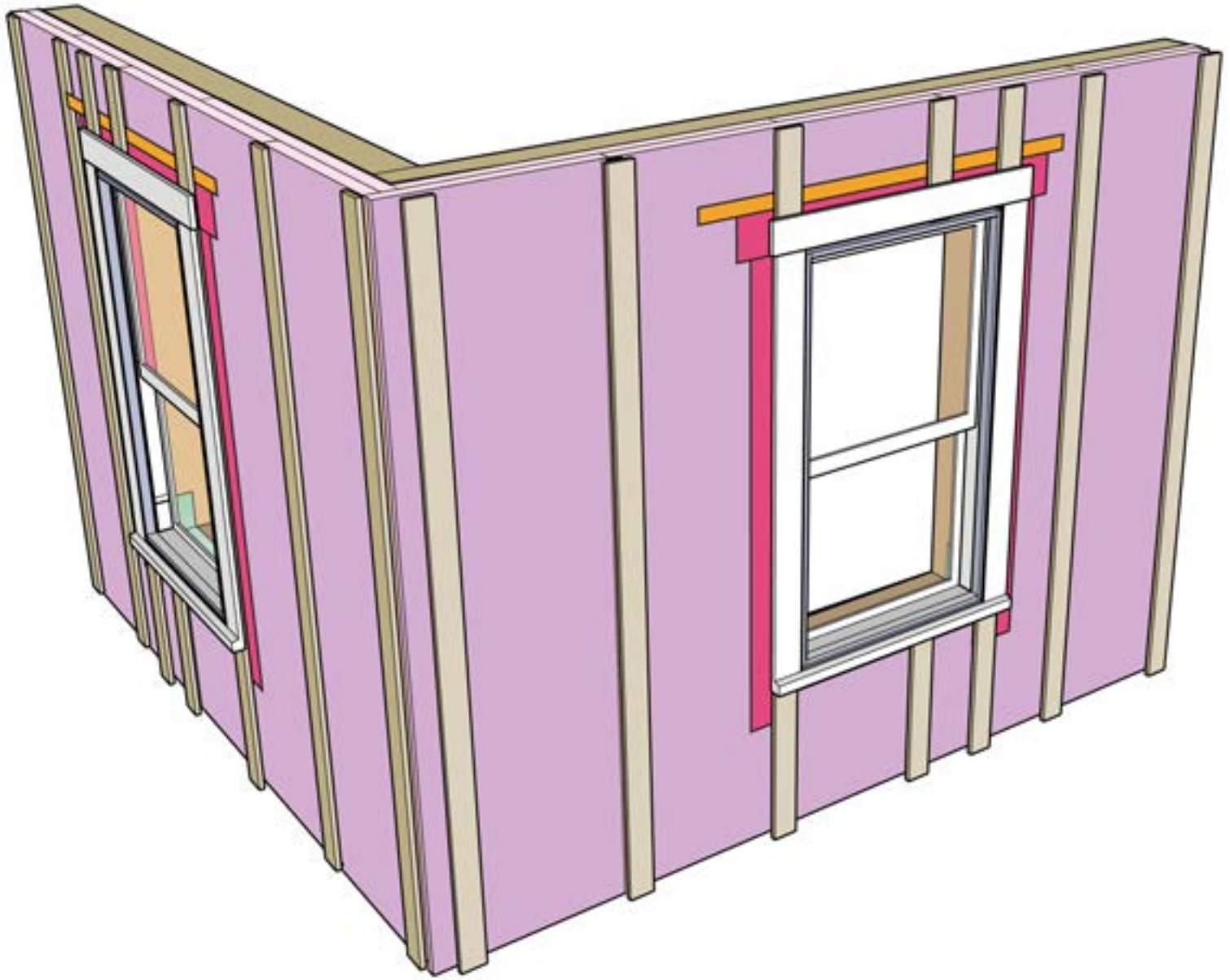


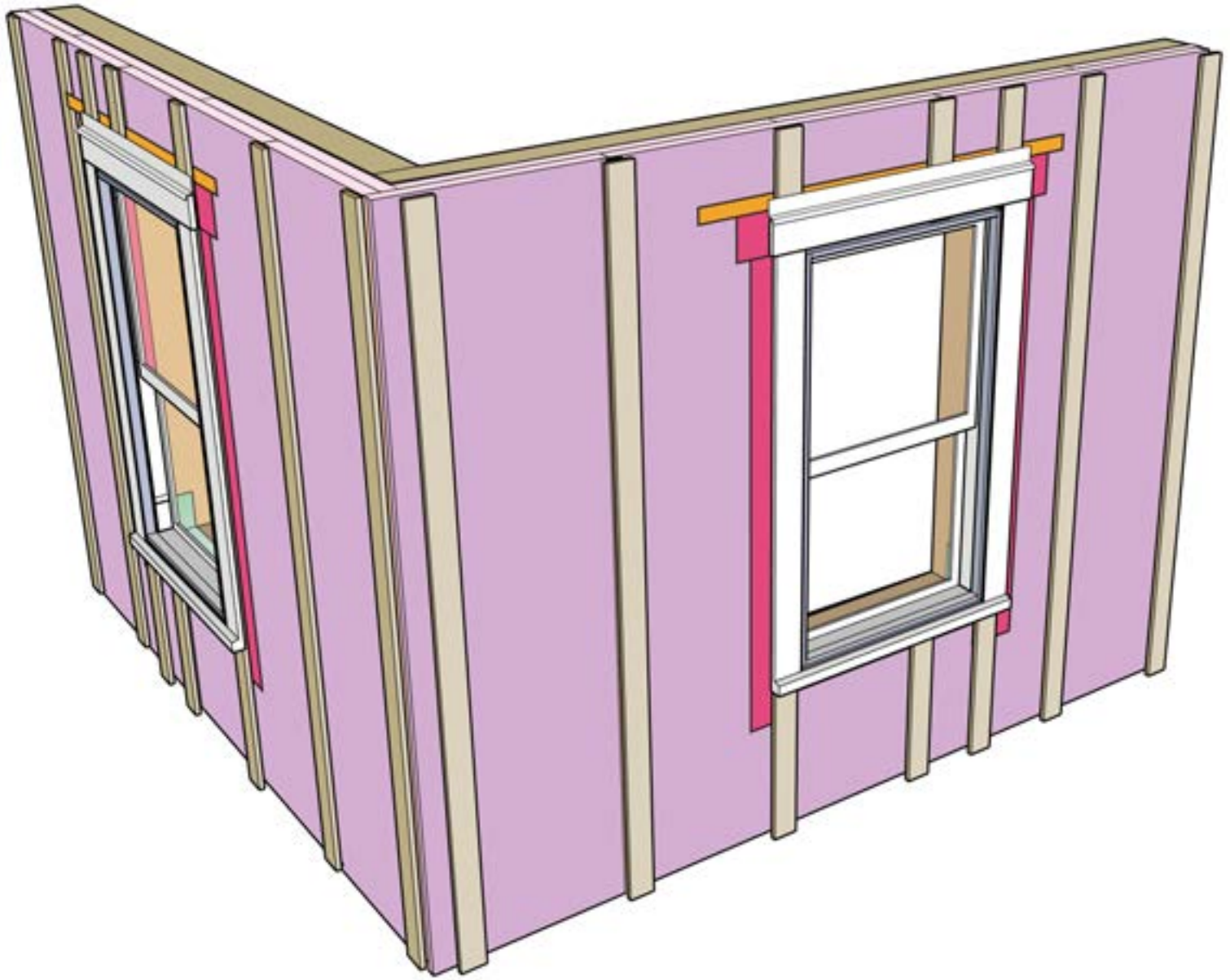


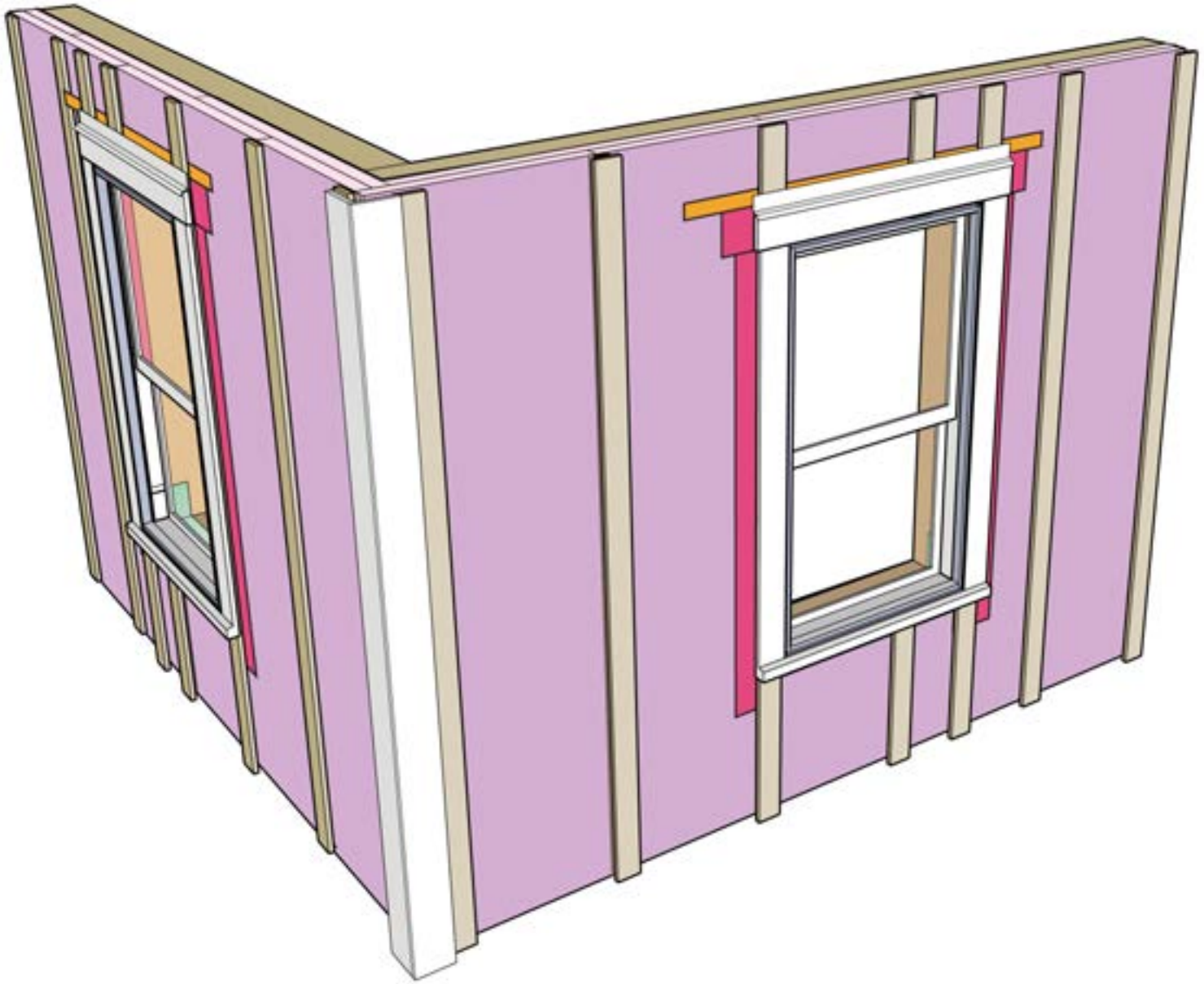










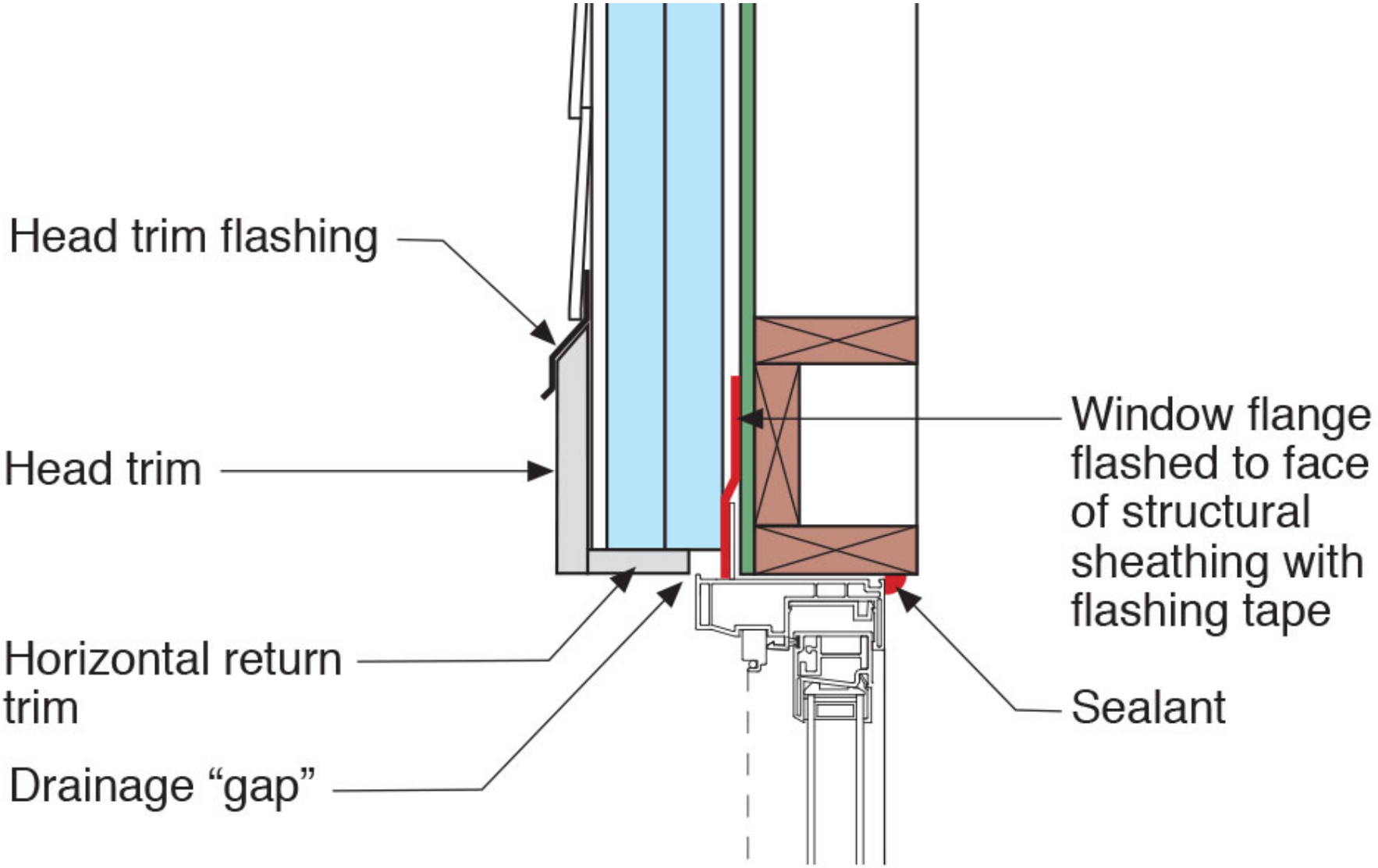


GRACE
Perm-A

ALS UNLIMITED INC.

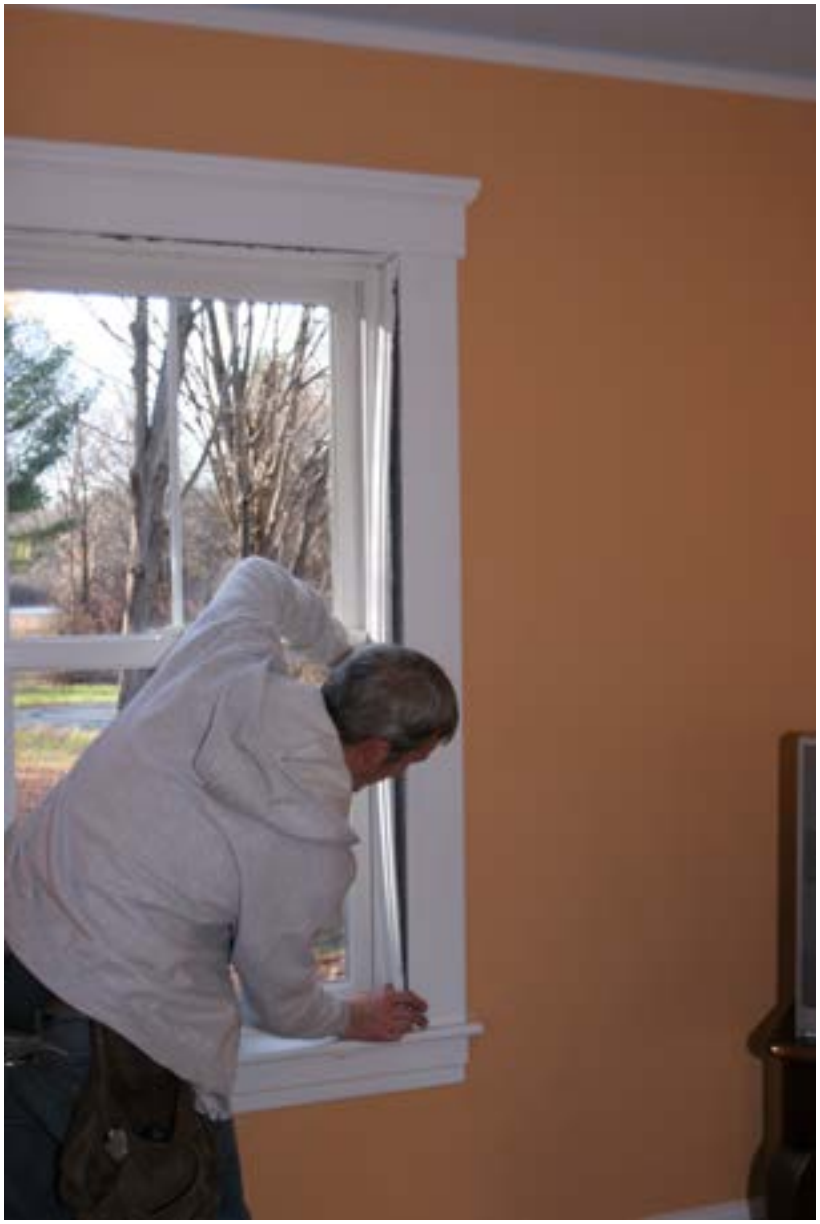
DOW

Anders

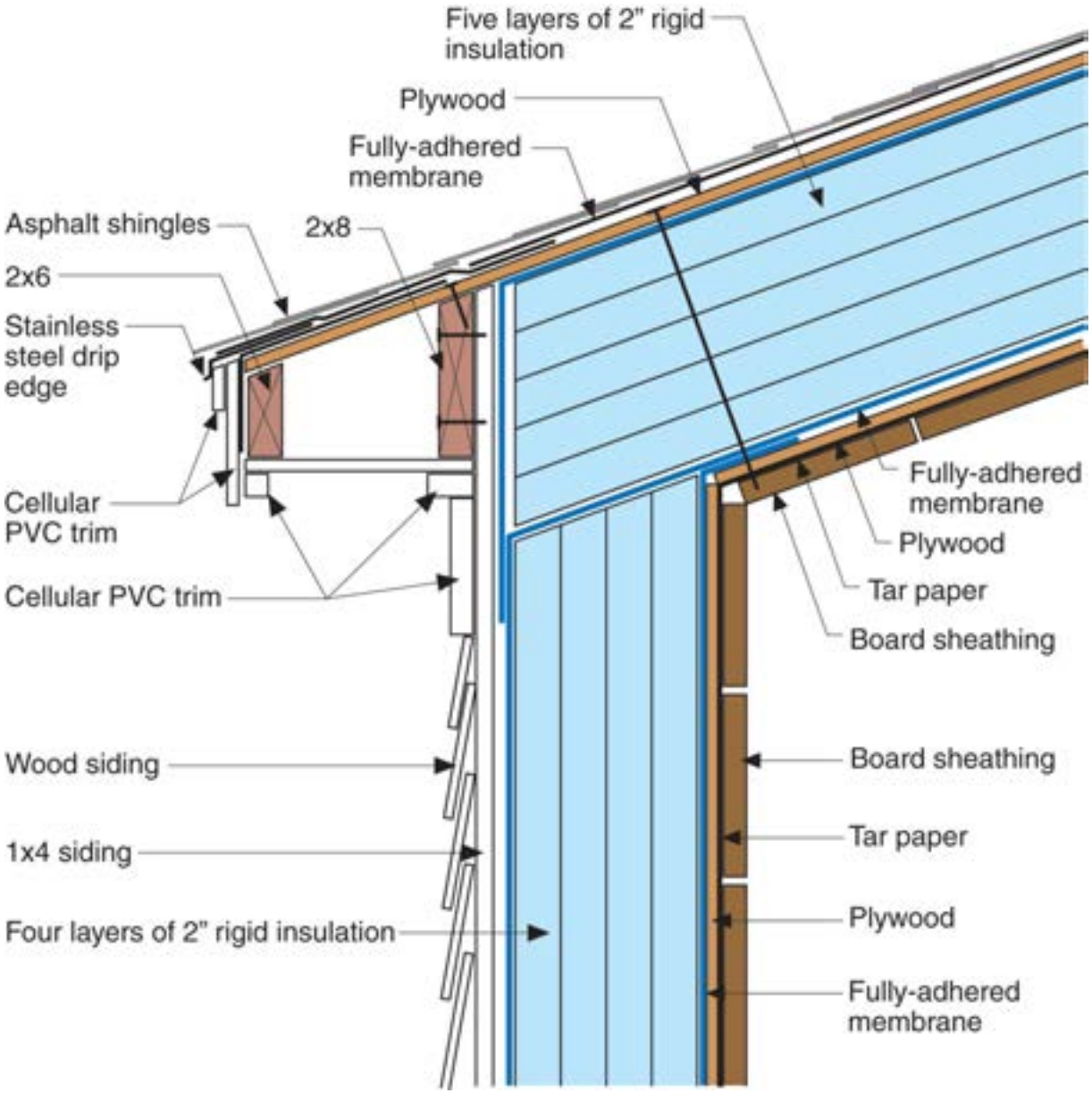

Head trim flashing
Head trim
Horizontal return trim
Drainage “gap”
Window flange flashed to face of structural sheathing with flashing tape
Sealant

GRACE VYCOR® PLUS
GRACE VYCOR® PLUS

0.32
0.33
0.54
DP25



DUPONT
DrainWra

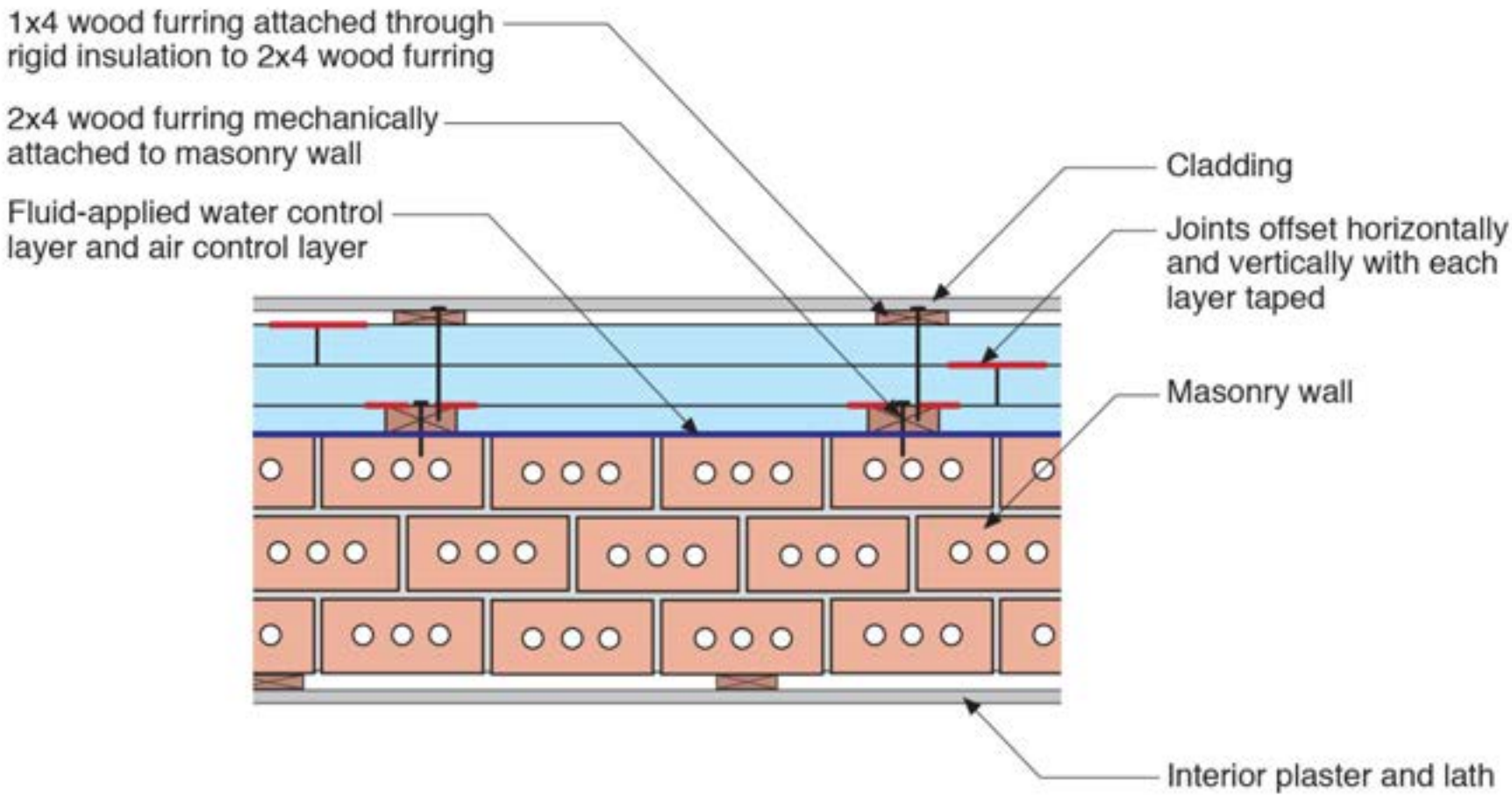

Five layers of 2" rigid insulation
Plywood
Fully-adhered membrane
Asphalt shingles
2x8
2x6
Stainless steel drip edge
Cellular PVC trim
Cellular PVC trim
Wood siding
1x4 siding
Four layers of 2" rigid insulation
Fully-adhered membrane
Plywood
Tar paper
Board sheathing
Board sheathing
Tar paper
Plywood
Fully-adhered membrane

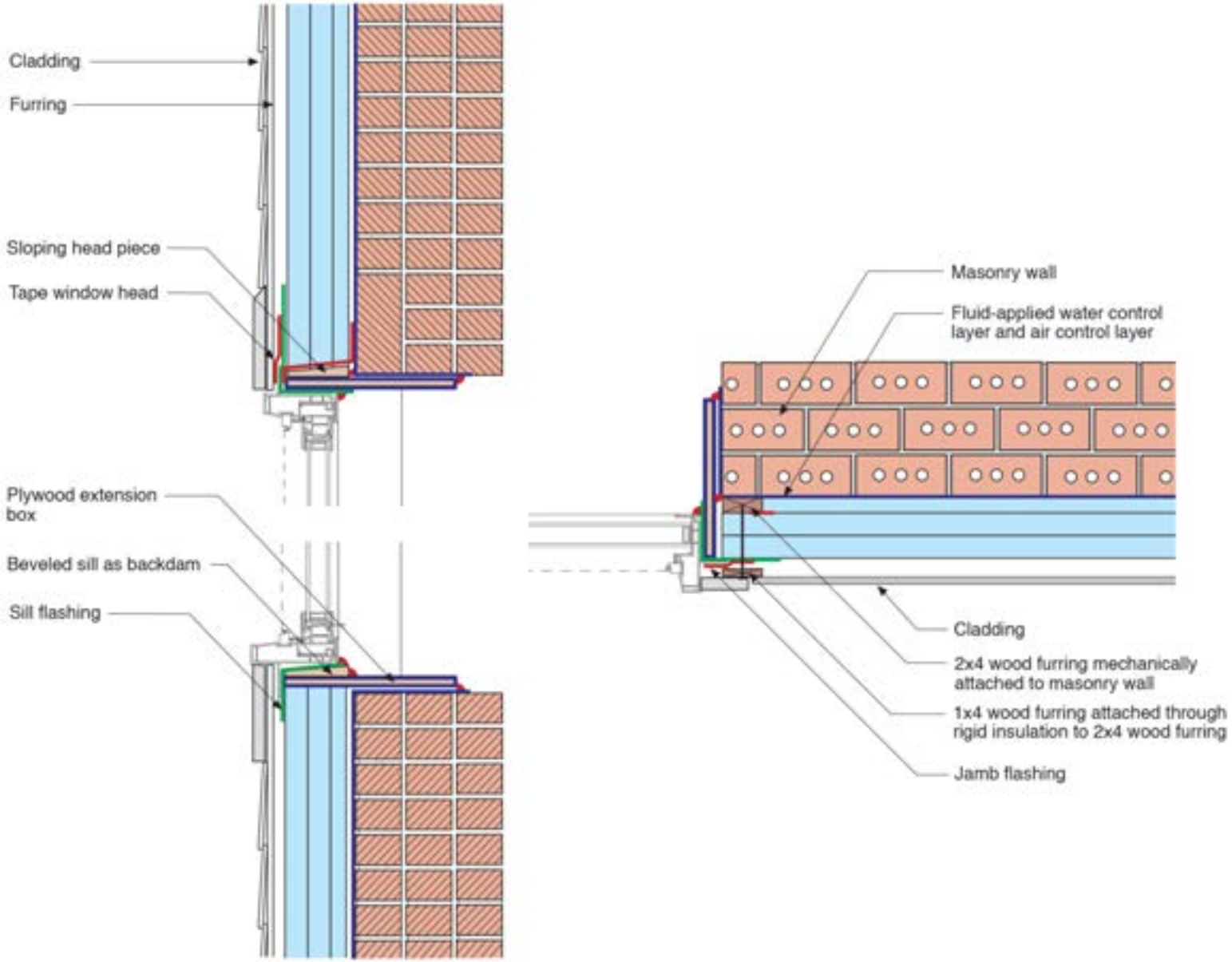
DOW
Super TUFF-R
Sup
Comm

Super TUFF-R

DOW
Super TUFF-R
Commercial Insulation
DOW
Super TUFF-R
Commercial Insulation
DOW
Super TUFF-R
Commercial Insulation

Lull

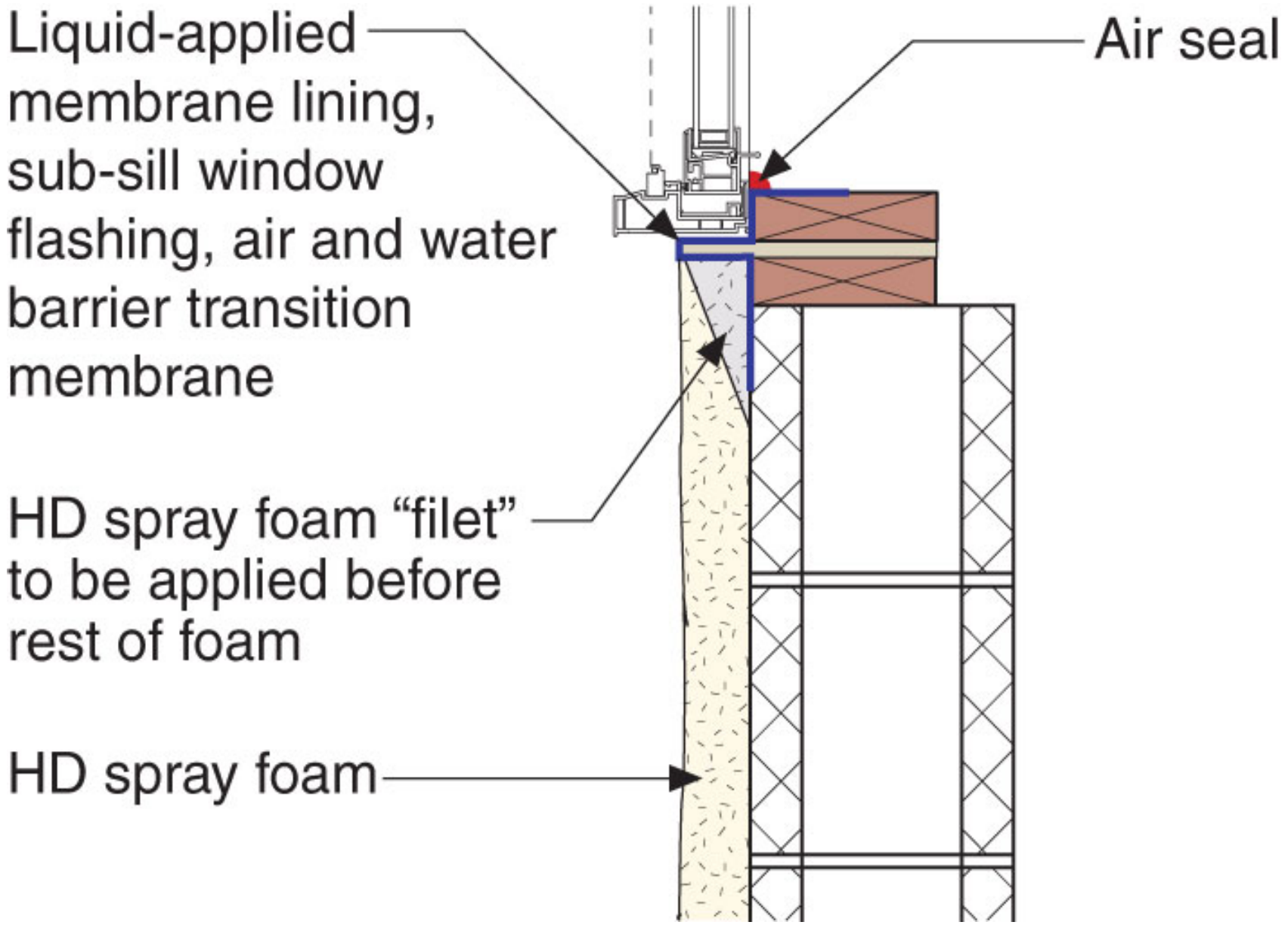

1x4 wood furring attached through rigid insulation to 2x4 wood furring
2x4 wood furring mechanically attached to masonry wall
Fluid-applied water control layer and air control layer
Cladding
Joints offset horizontally and vertically with each layer taped
Masonry wall
Interior plaster and lath

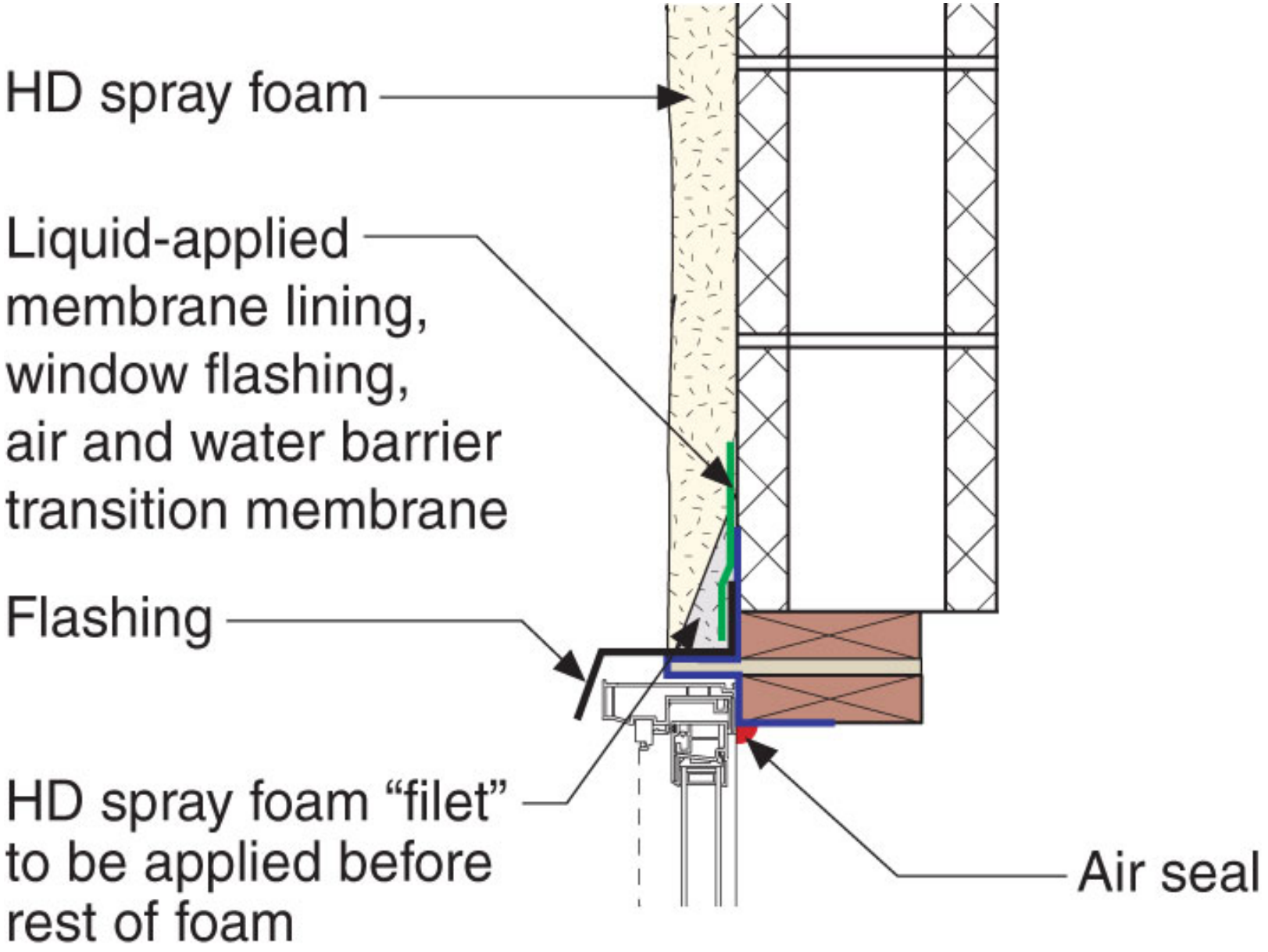

Cladding
Furring
Sloping head piece
Tape window head
Plywood extension box
Beveled sill as backdam
Sill flashing
Masonry wall
Fluid-applied water control layer and air control layer
Cladding
2x4 wood furring mechanically attached to masonry wall
1x4 wood furring attached through rigid insulation to 2x4 wood furring
Jamb flashing

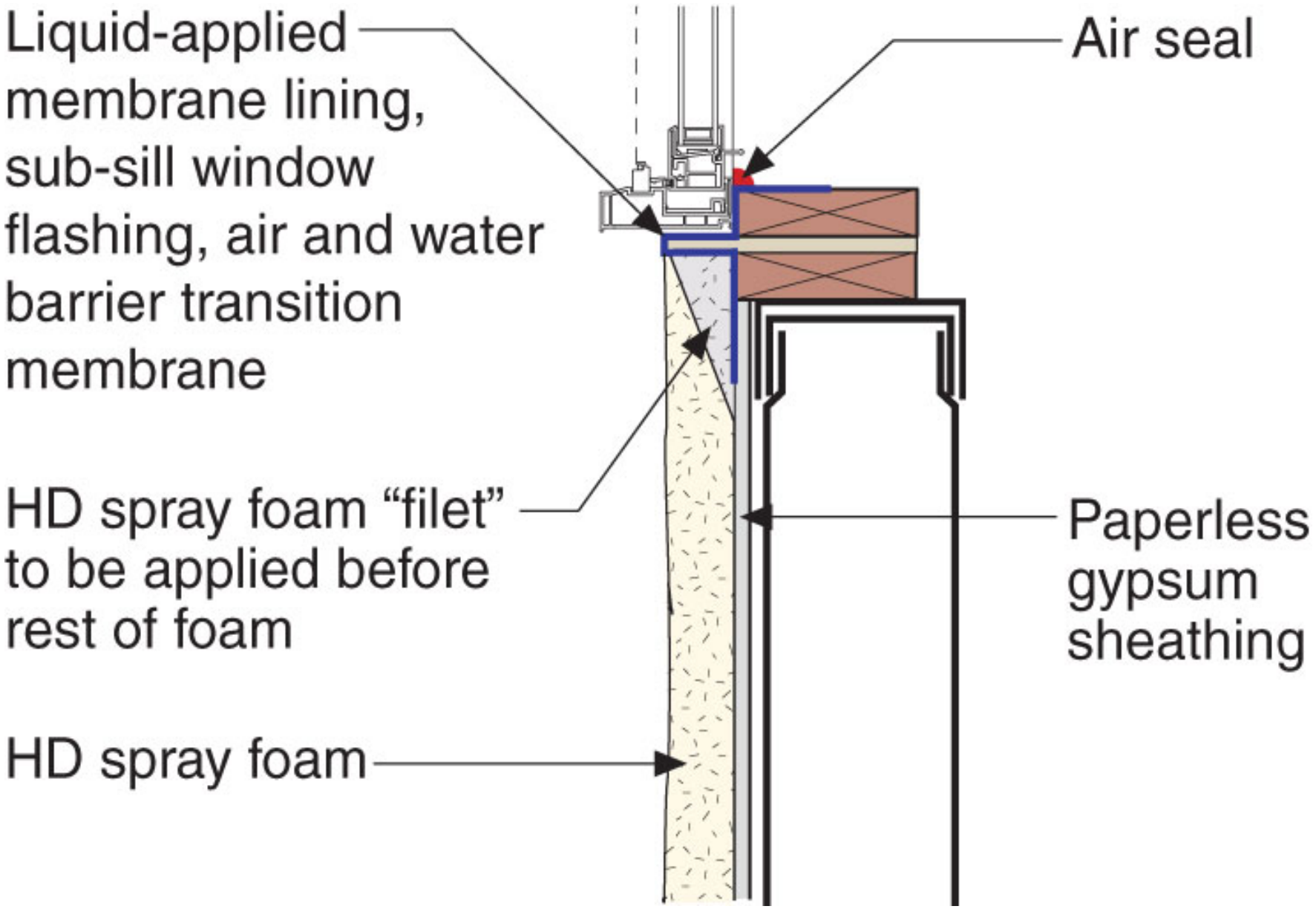
with ENERGY STAR
R-10
Seal and Insulate
with ENERGY STAR

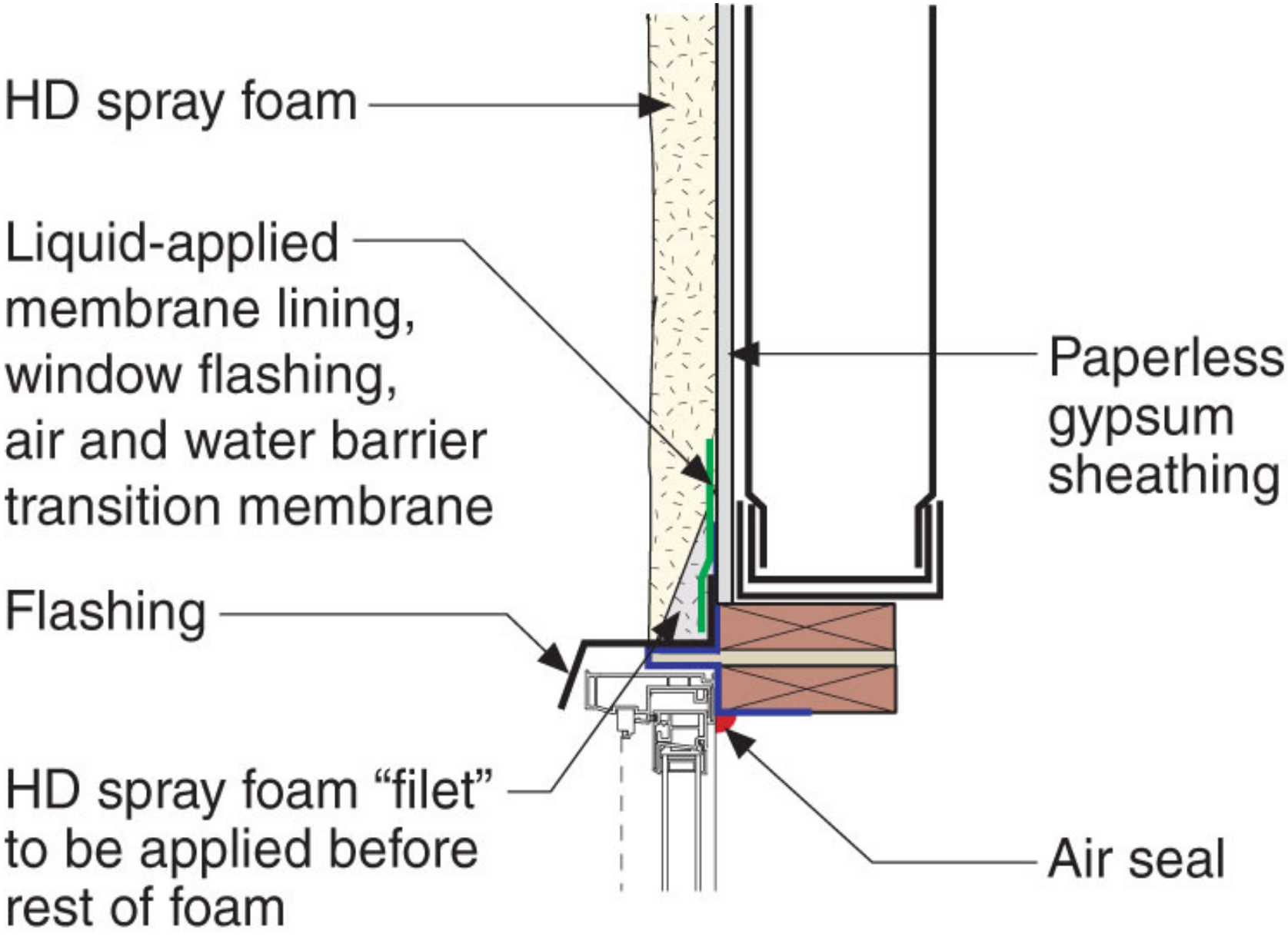
SPEED
HUMP

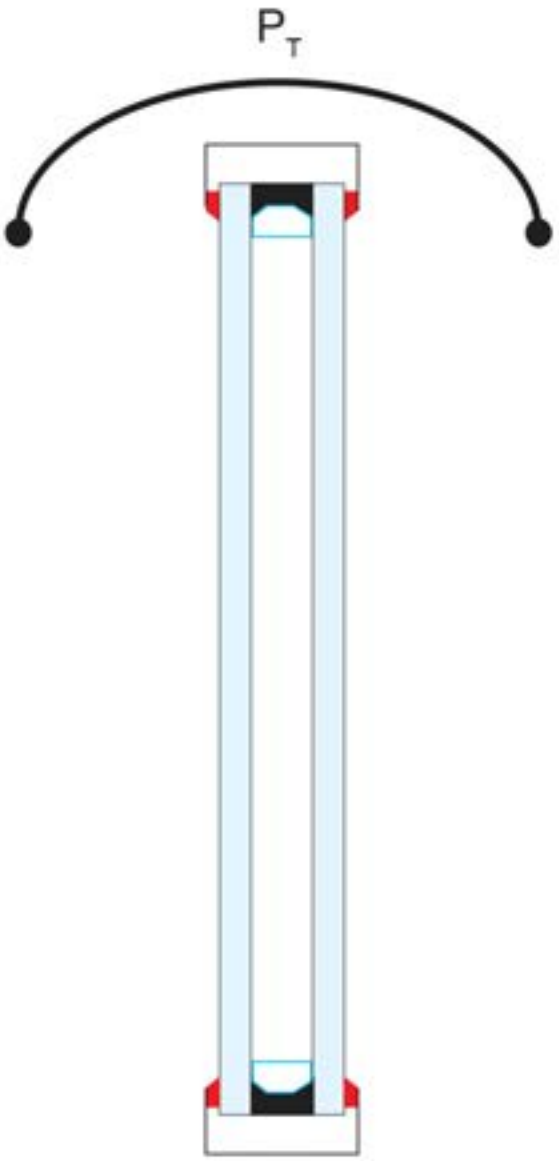
SPEED
HUMP


Liquid-applied membrane lining, sub-sill window flashing, air and water barrier transition membrane
Air seal
HD spray foam “filet” to be applied before rest of foam
HD spray foam


HD spray foam
Liquid-applied membrane lining, window flashing, air and water barrier transition membrane
Flashing
HD spray foam “filet” to be applied before rest of foam
Air seal

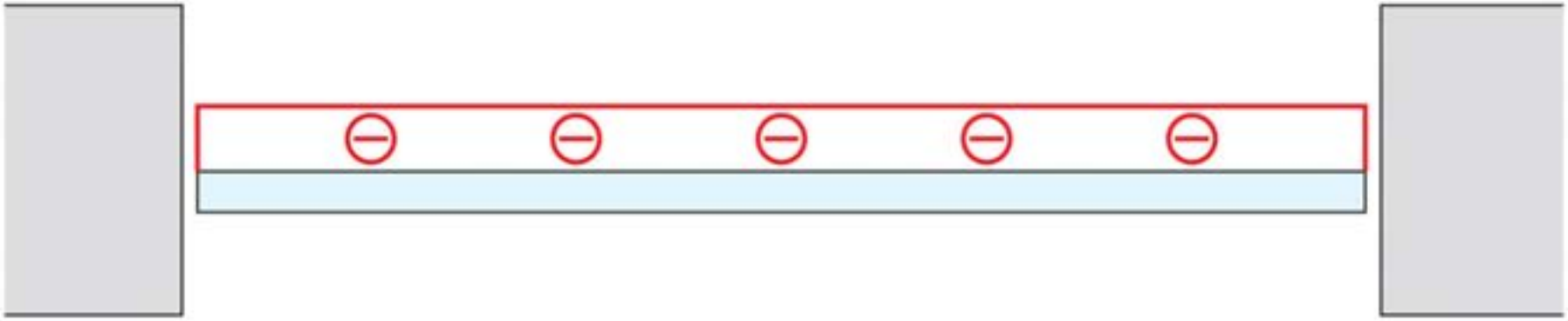

Liquid-applied membrane lining, sub-sill window flashing, air and water barrier transition membrane
Air seal
HD spray foam "filet" to be applied before rest of foam
Paperless gypsum sheathing
HD spray foam

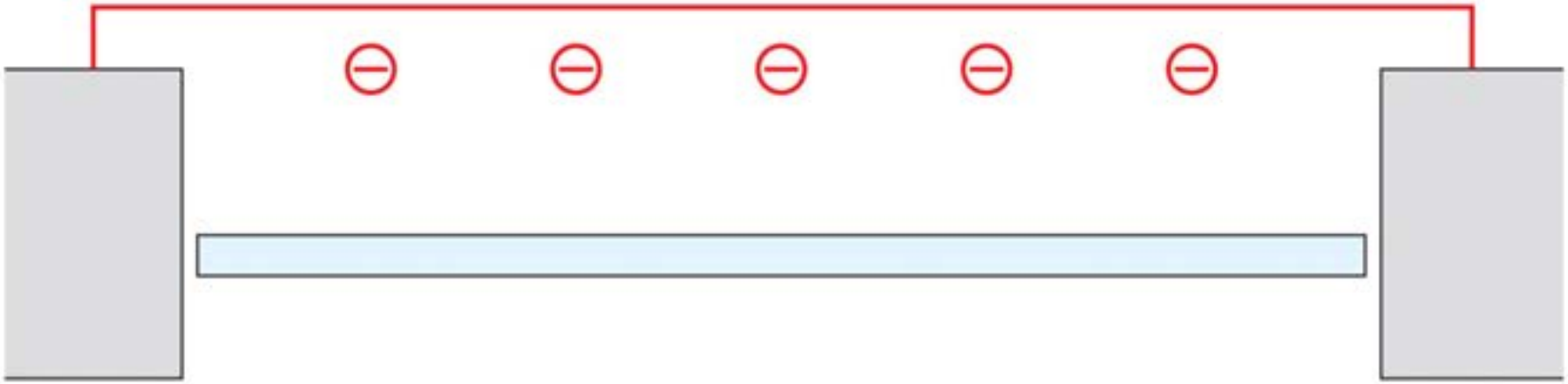

HD spray foam
Liquid-applied membrane lining, window flashing, air and water barrier transition membrane
Flashing
HD spray foam “filet” to be applied before rest of foam
Paperless gypsum sheathing
Air seal

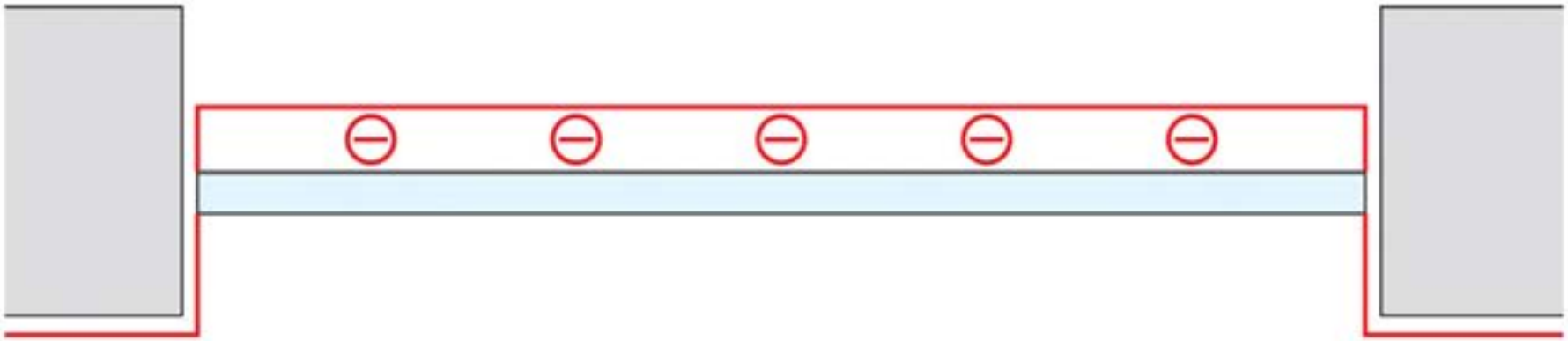


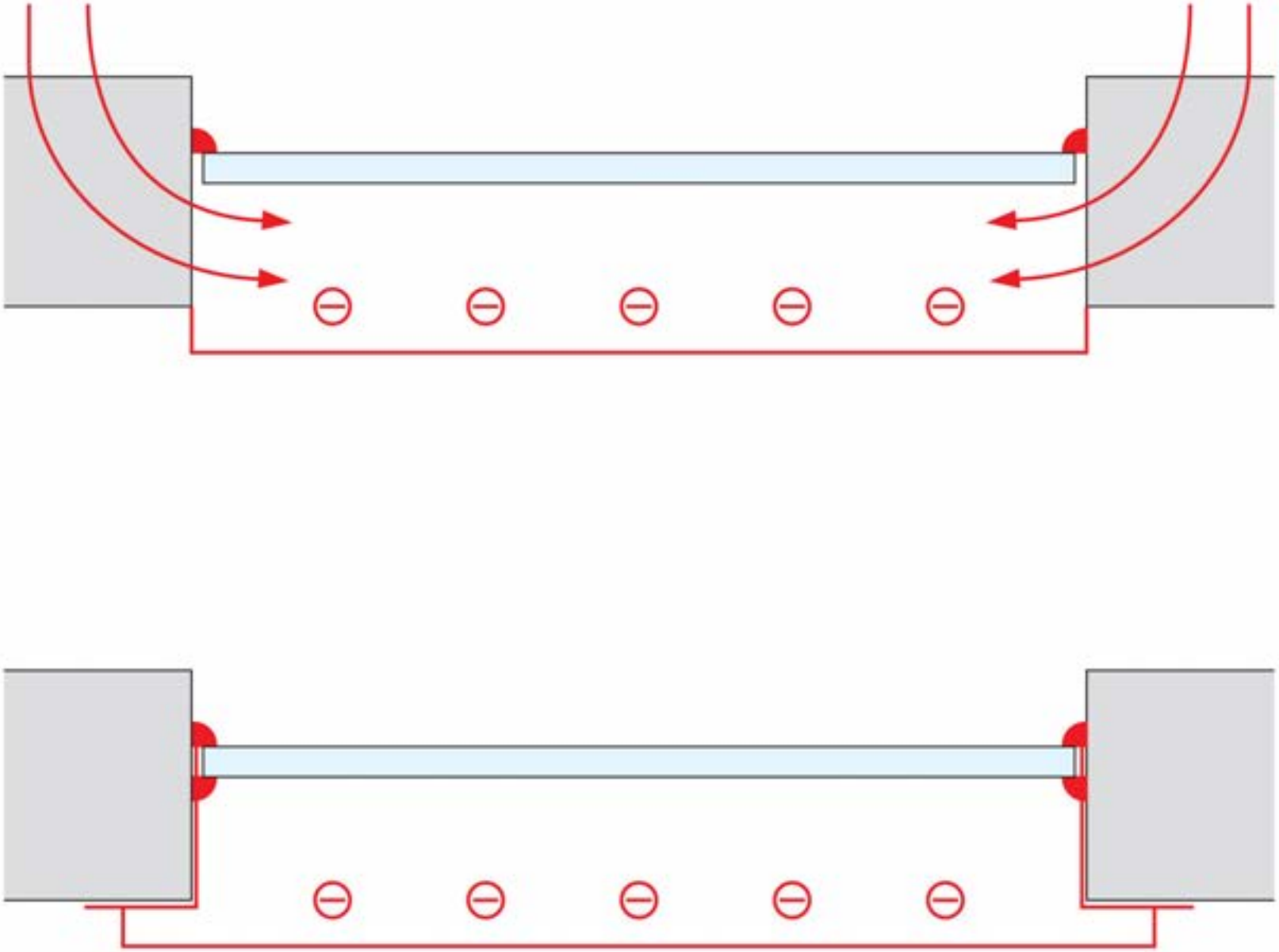
We assume a window unit is a single layer.

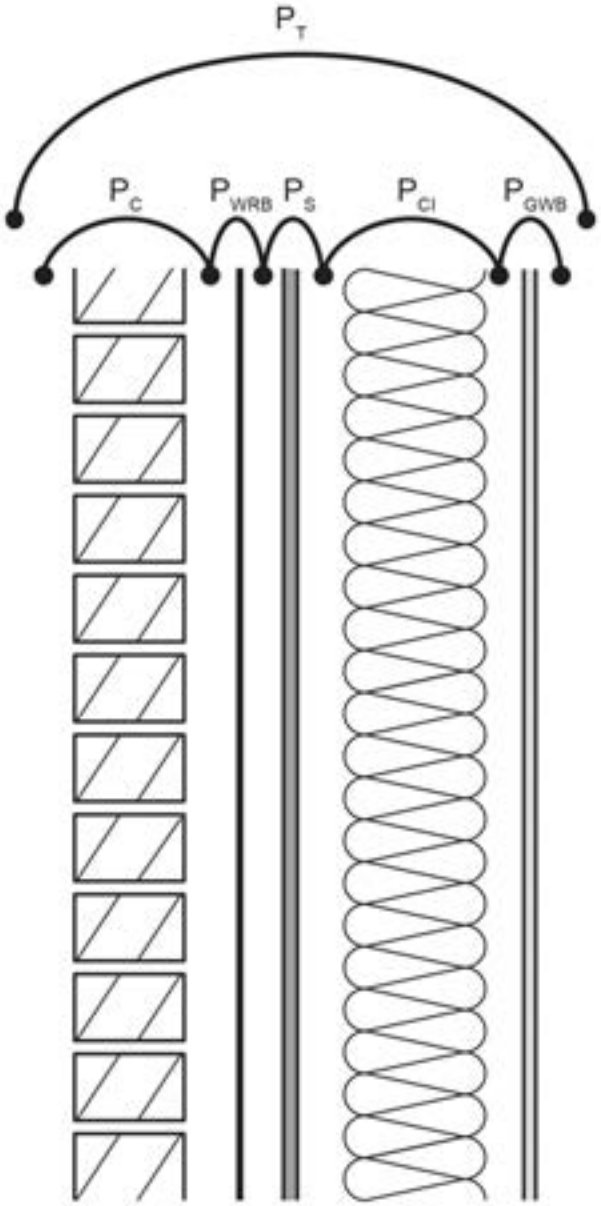
Under this assumption, it does not matter which side of the assembly we establish the ΔP.









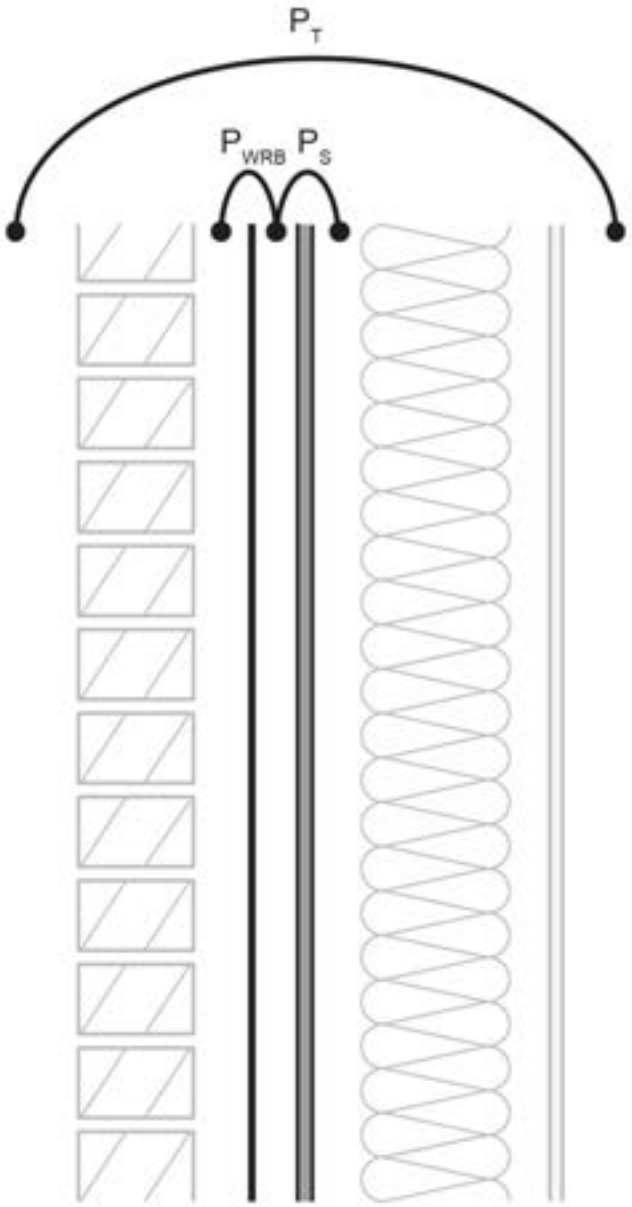


$P_T = P_C + P_{WRB} + P_S + P_{CI} + P_{GWB}$

Not all layers equally "tight"

ΔP across each layer depends on the side of the wall the pressure is induced

Removing a layer changes everything



$$P_T = P_{WRB} + P_S$$

is very different than

$$P_T = P_C + P_{WRB} + P_S + P_{CI} + P_{GWB}$$