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

Building Science

Adventures In Building Science

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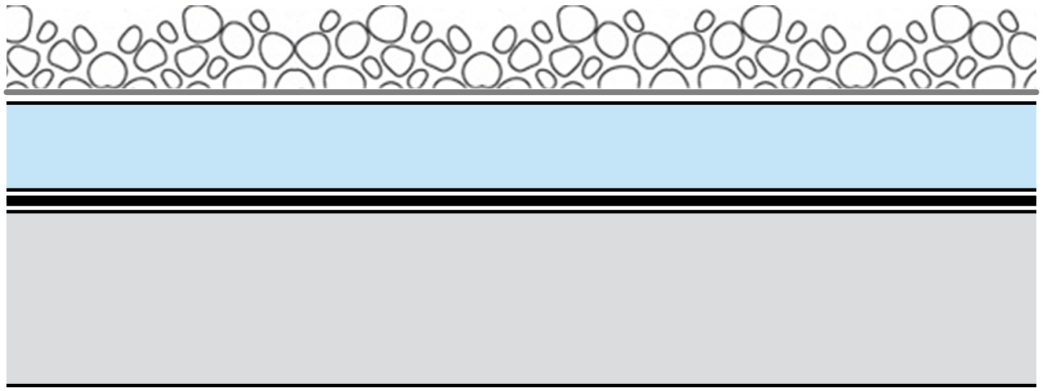
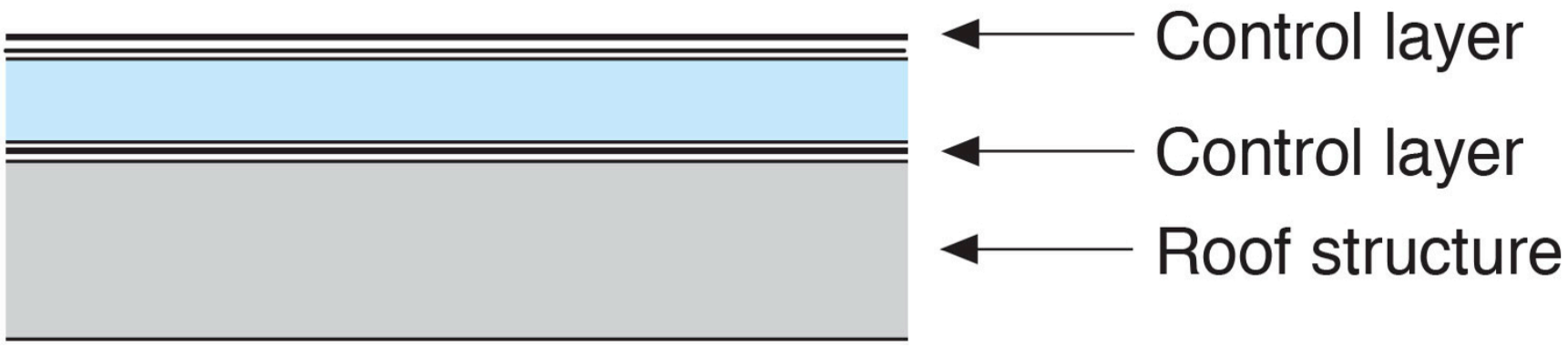
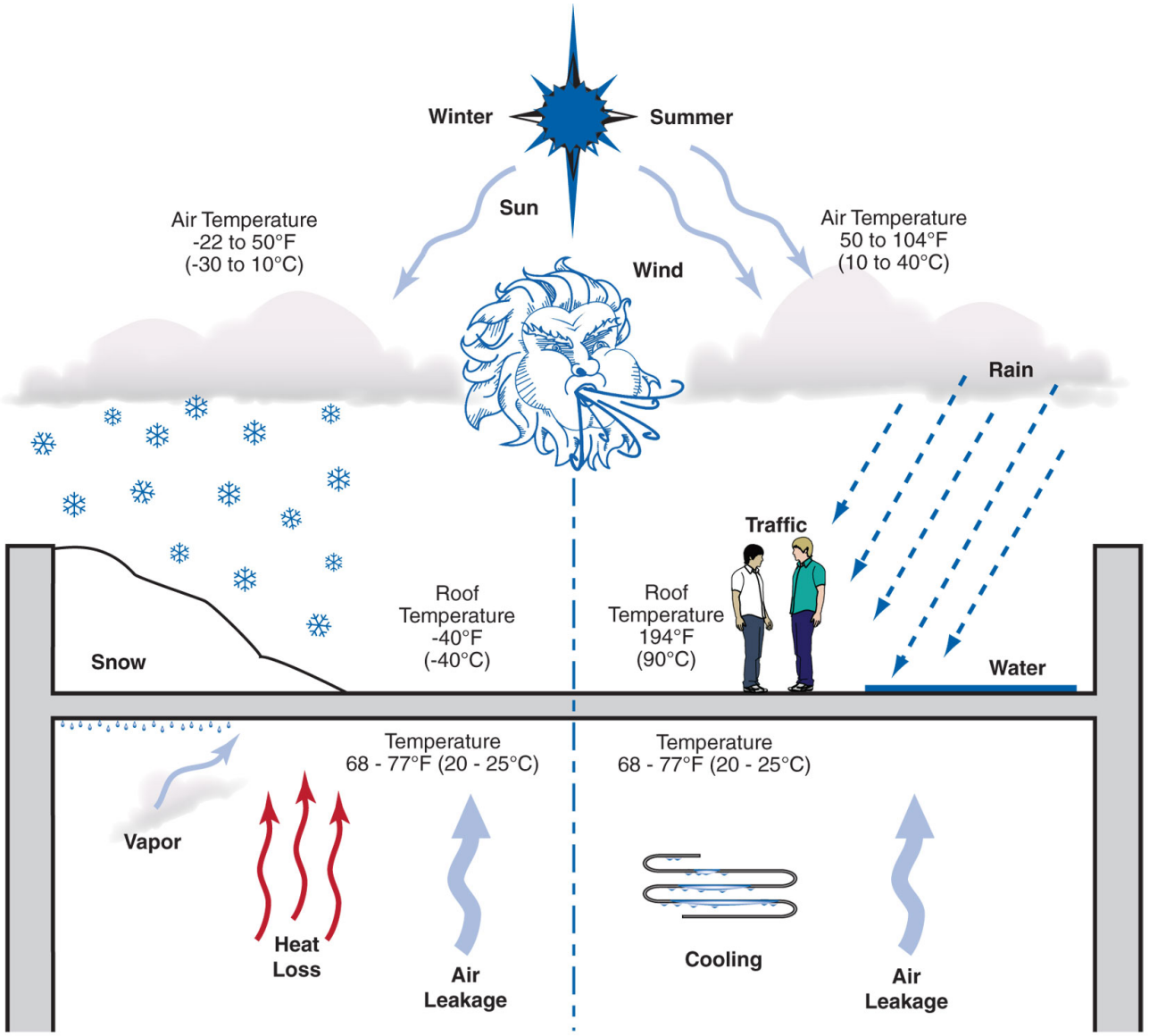
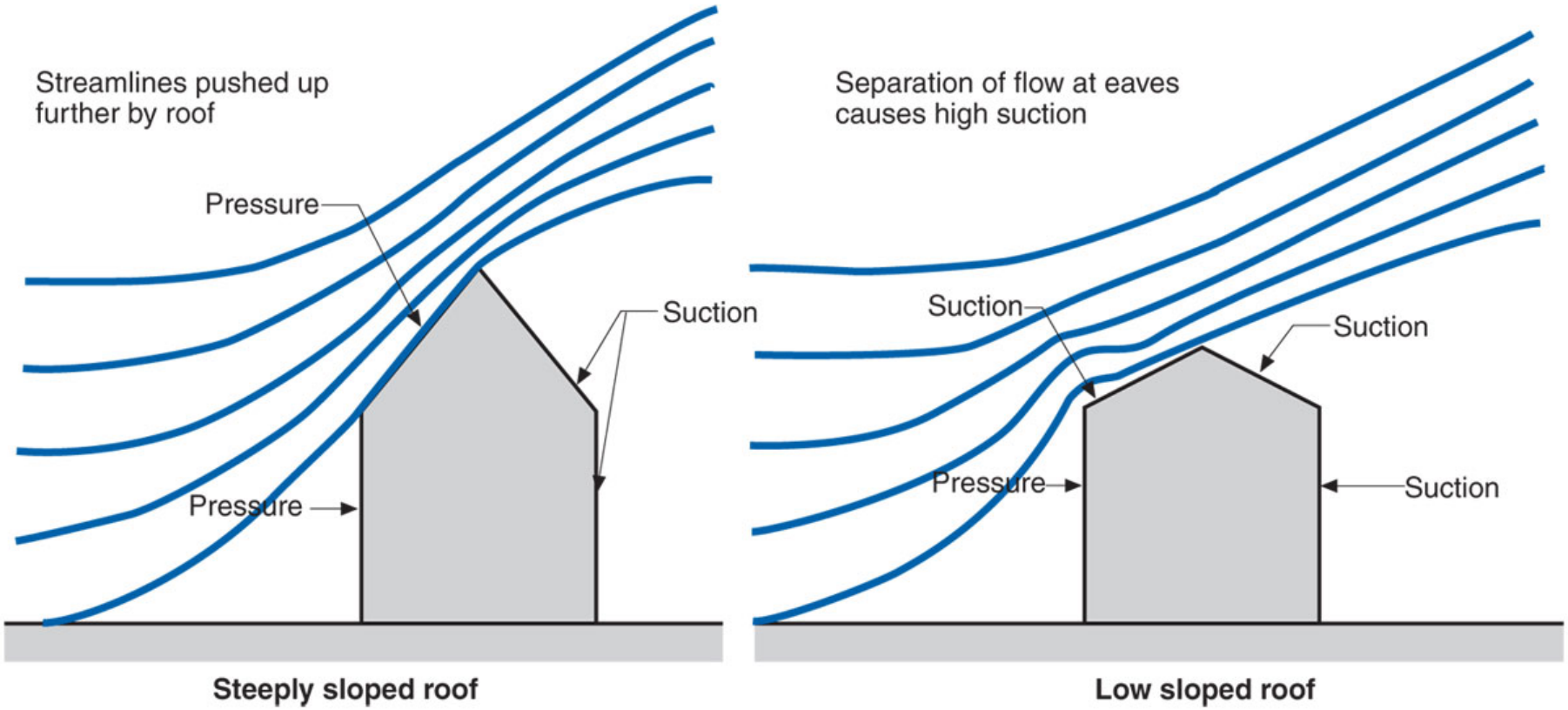
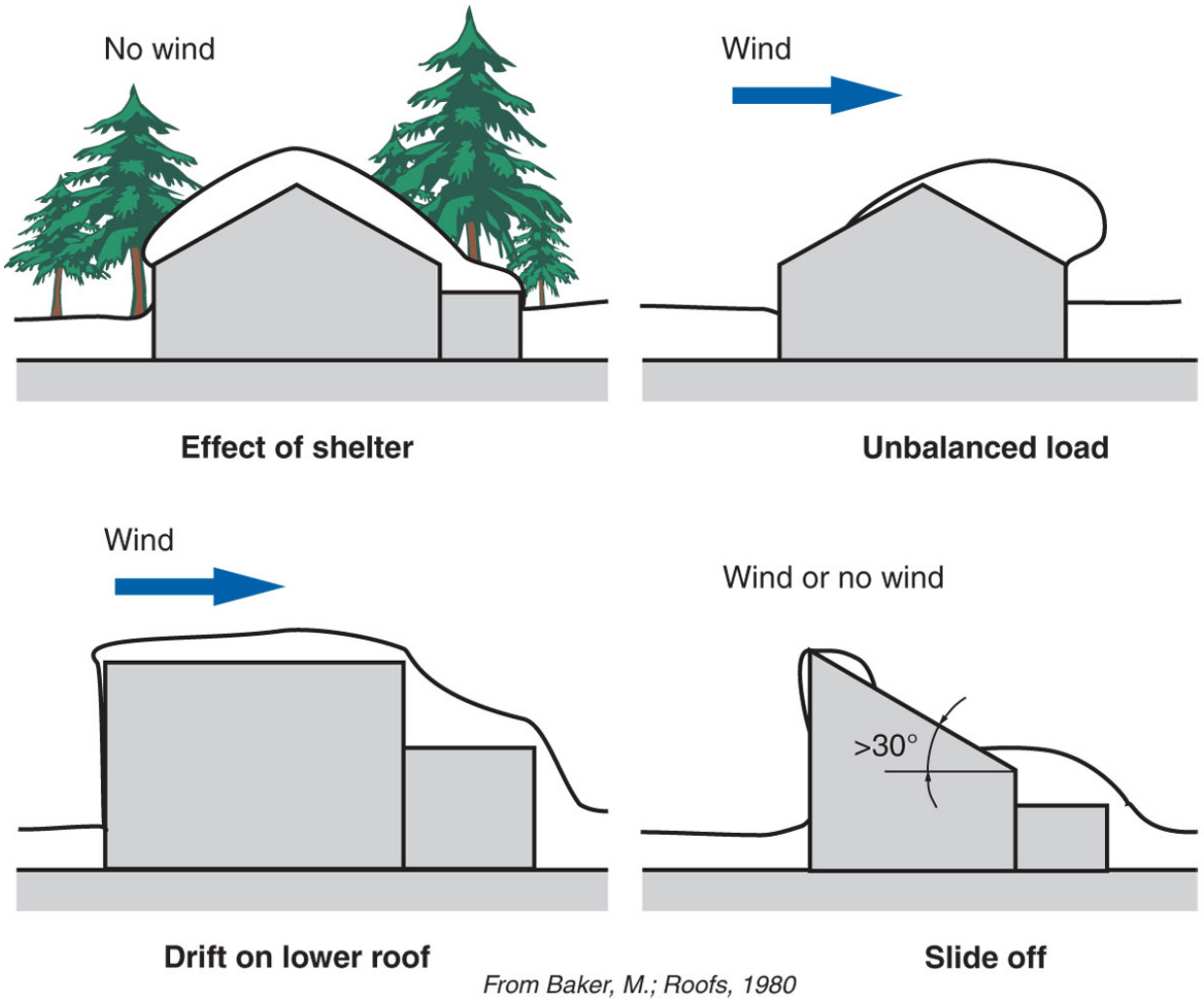

Ballast
Filter fabric
Control layers
Roof structure


Control layer
Control layer
Roof structure

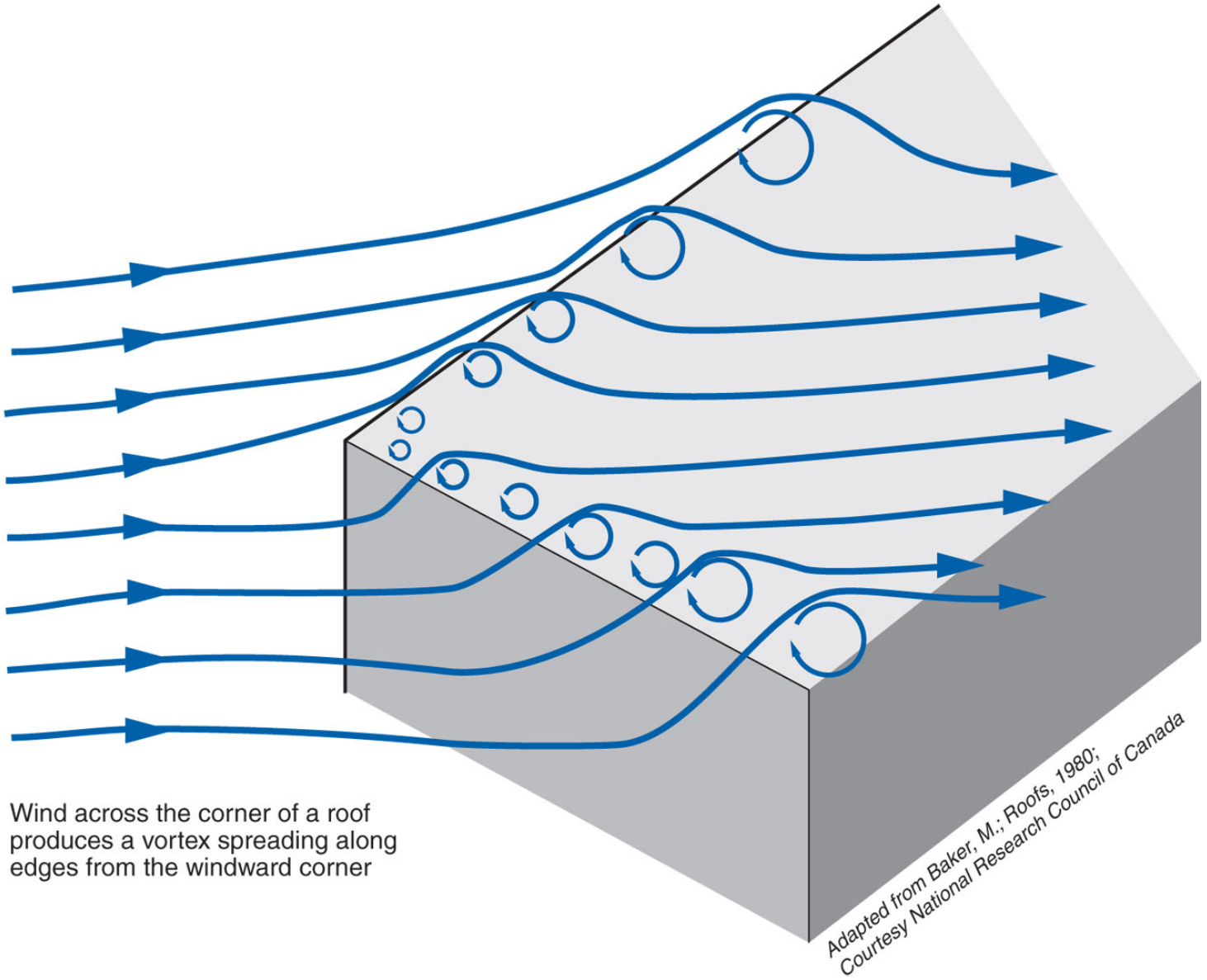


Adapted from Baker, M.; Roofs, 1980;
Courtesy National Research Council of Canada


Streamlines pushed up
further by roof
Pressure
Suction
Pressure
Steeply sloped roof
Separation of flow at eaves
causes high suction
Suction
Suction
Pressure
Suction
Low sloped roof

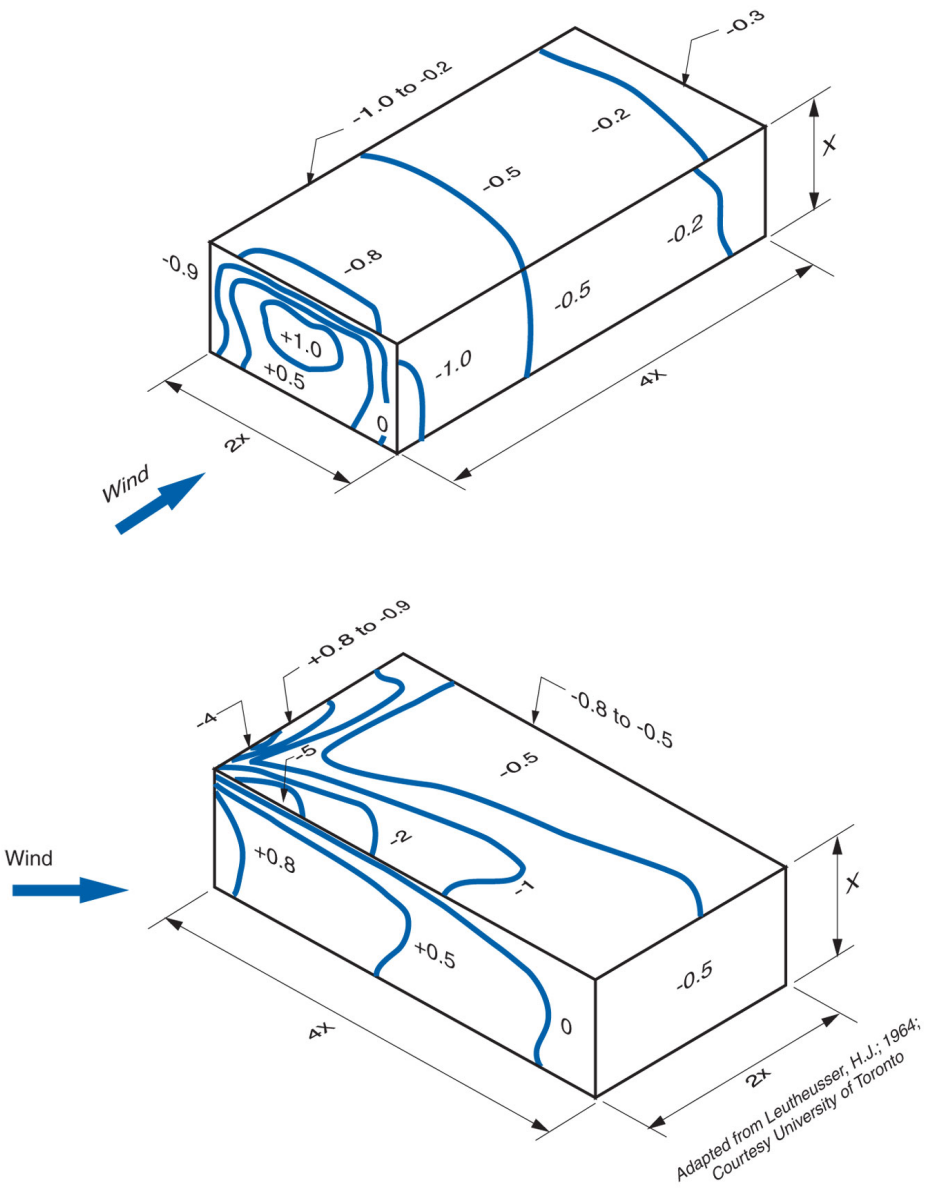


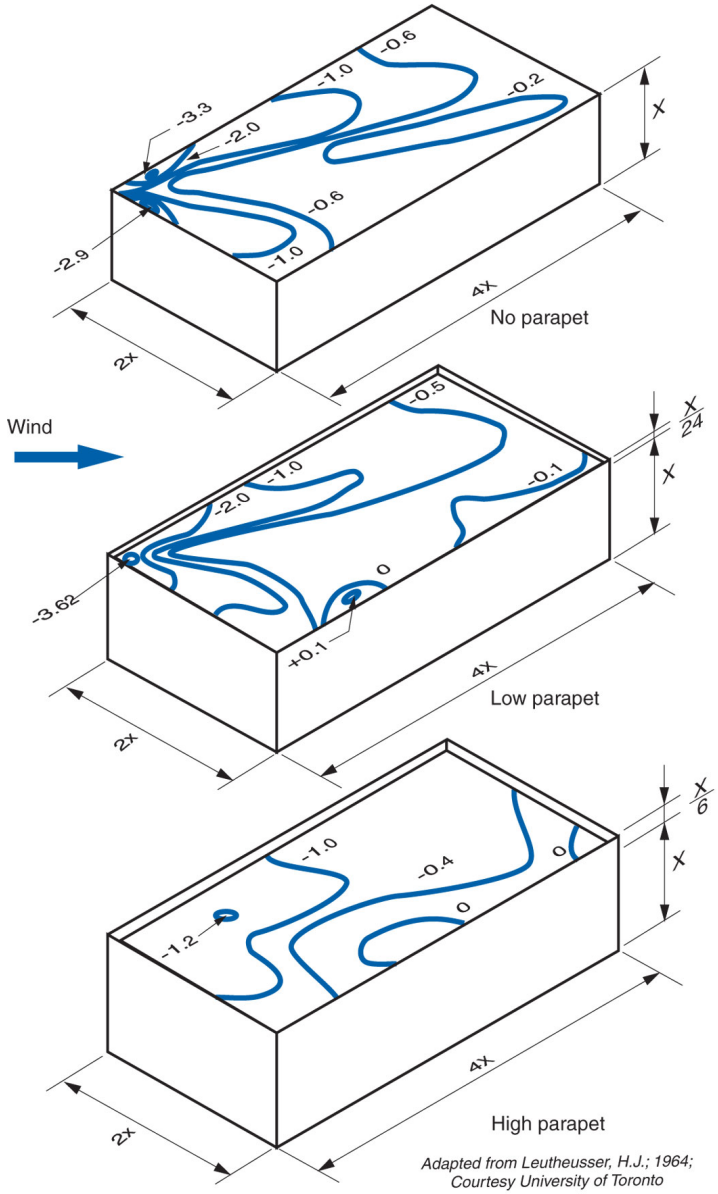
From Baker, M.; Roofs, 1980



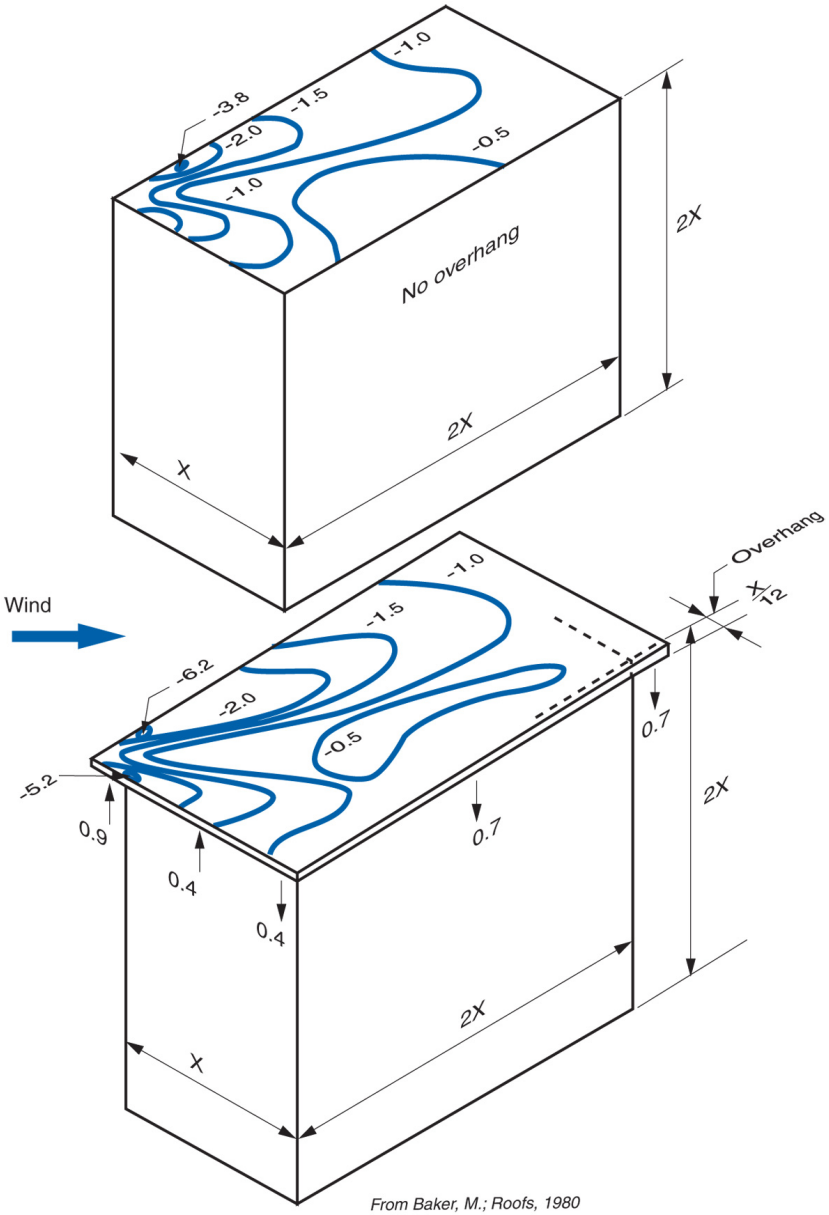
Wind across the corner of a roof produces a vortex spreading along edges from the windward corner

Adapted from Baker, M.; Roofs, 1980; Courtesy National Research Council of Canada

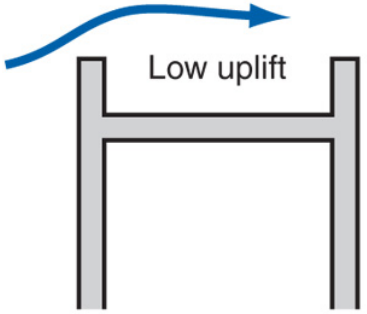

-0.3
-1.0 to -0.2
-0.2
-0.5
X
-0.9
-0.8
-0.2
+1.0
+0.5
-0.5
-1.0
0
4x
2x
Wind
+0.8 to -0.9
-0.8 to -0.5
-4
-5
-0.5
Wind
+0.8
-2
-1
X
+0.5
-0.5
0
4x
2x
Adapted from Leutheusser, H.J.; 1964;
Courtesy University of Toronto



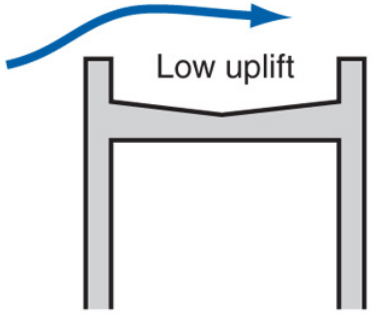
Adapted from Leutheusser, H.J.; 1964; Courtesy University of Toronto



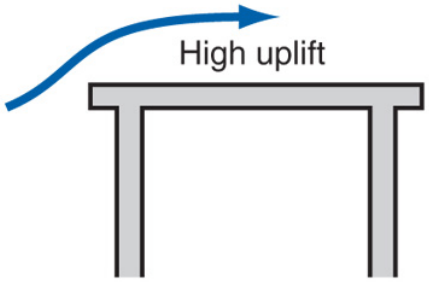
From Baker, M.; Roofs, 1980



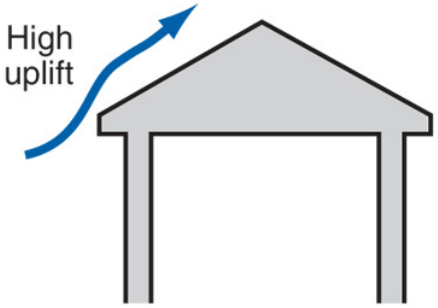
Flat roof with parapets
blow-off hazard: low
slippage hazard: low



Sloped roof with parapets
blow-off hazard: low
slippage hazard: medium

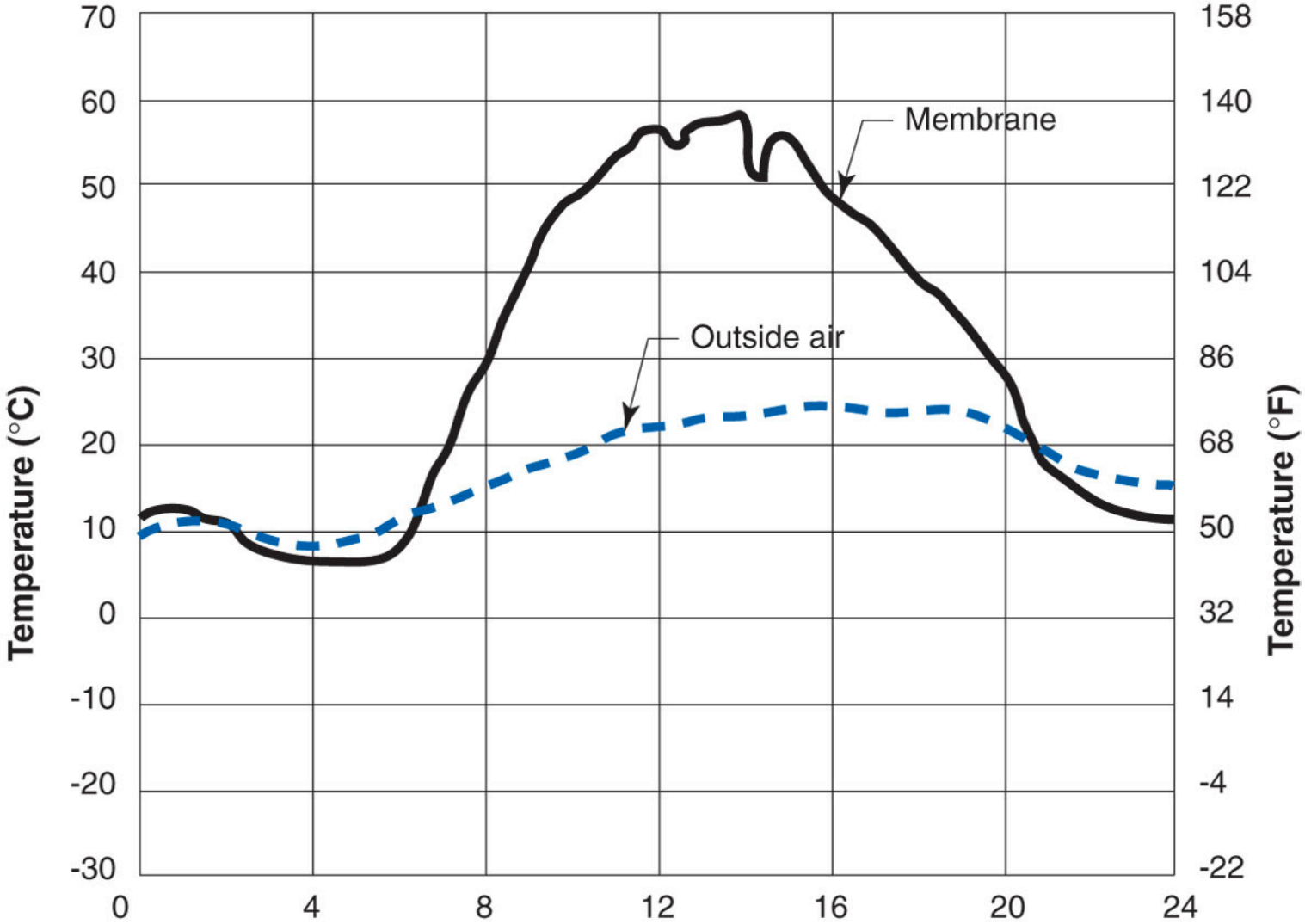


Flat roof or overhang
blow off hazard: high
slippage hazard: low

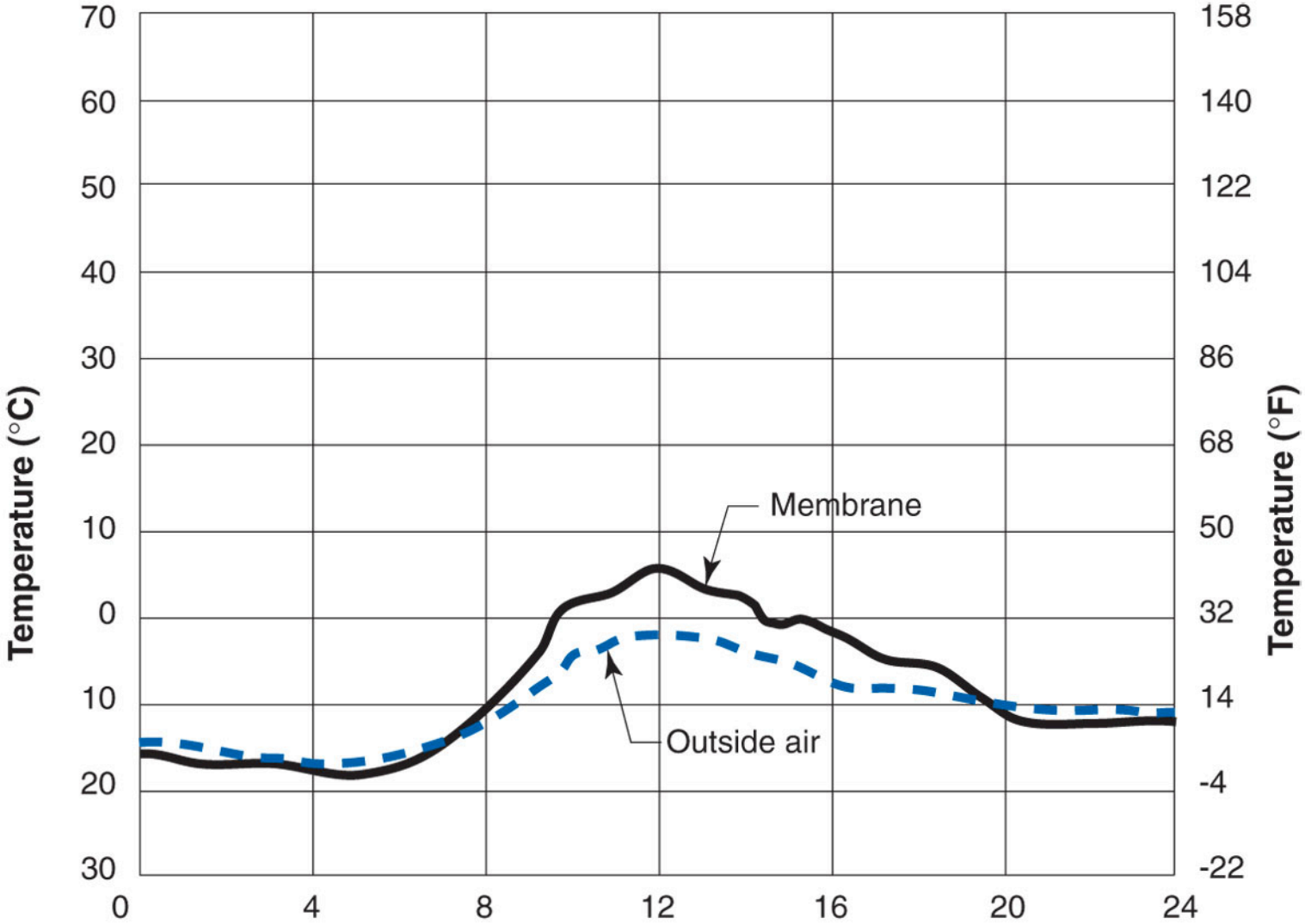


Outward sloping roof
blow-off hazard: high
slippage hazard: high

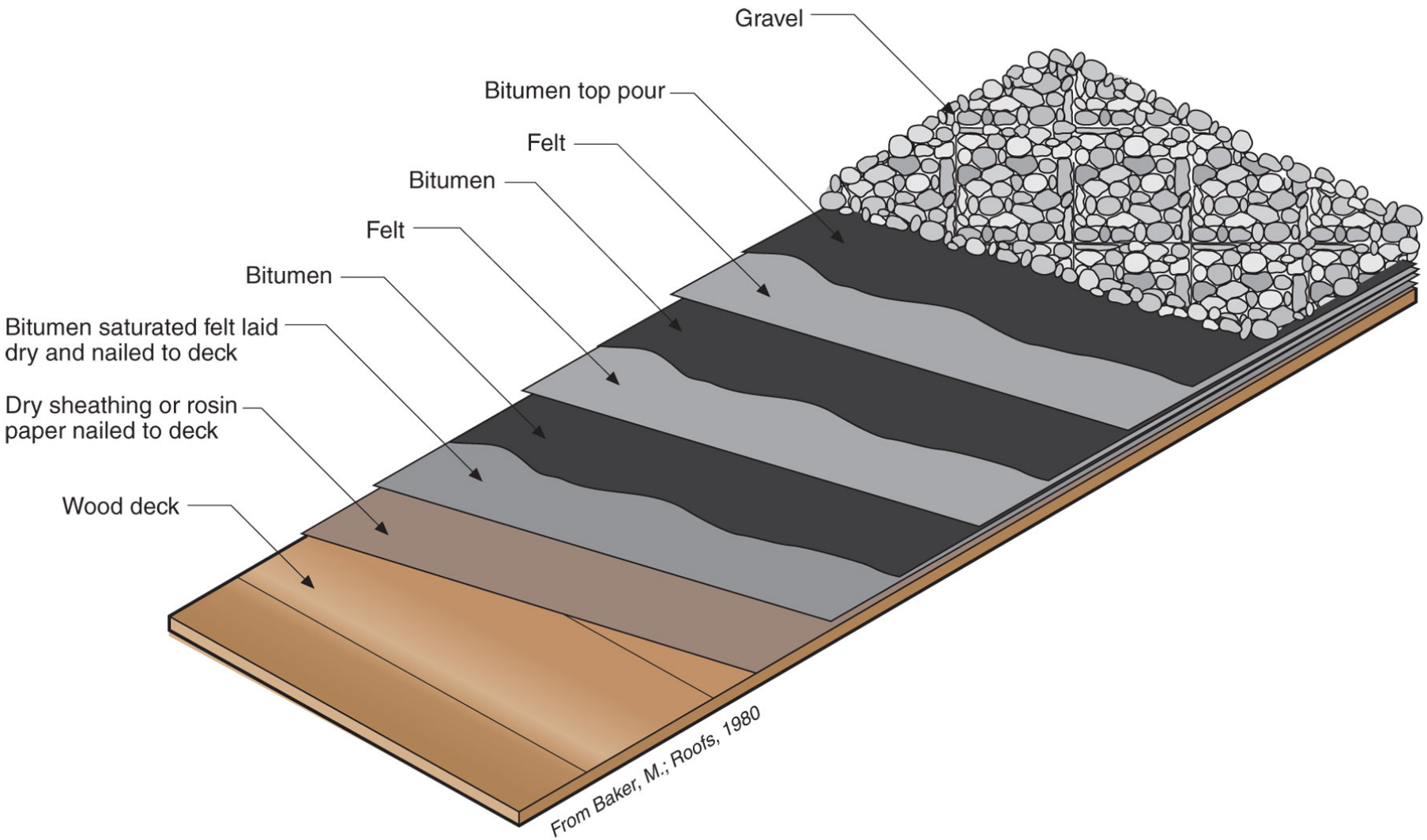
From Baker, M.; Roofs, 1980

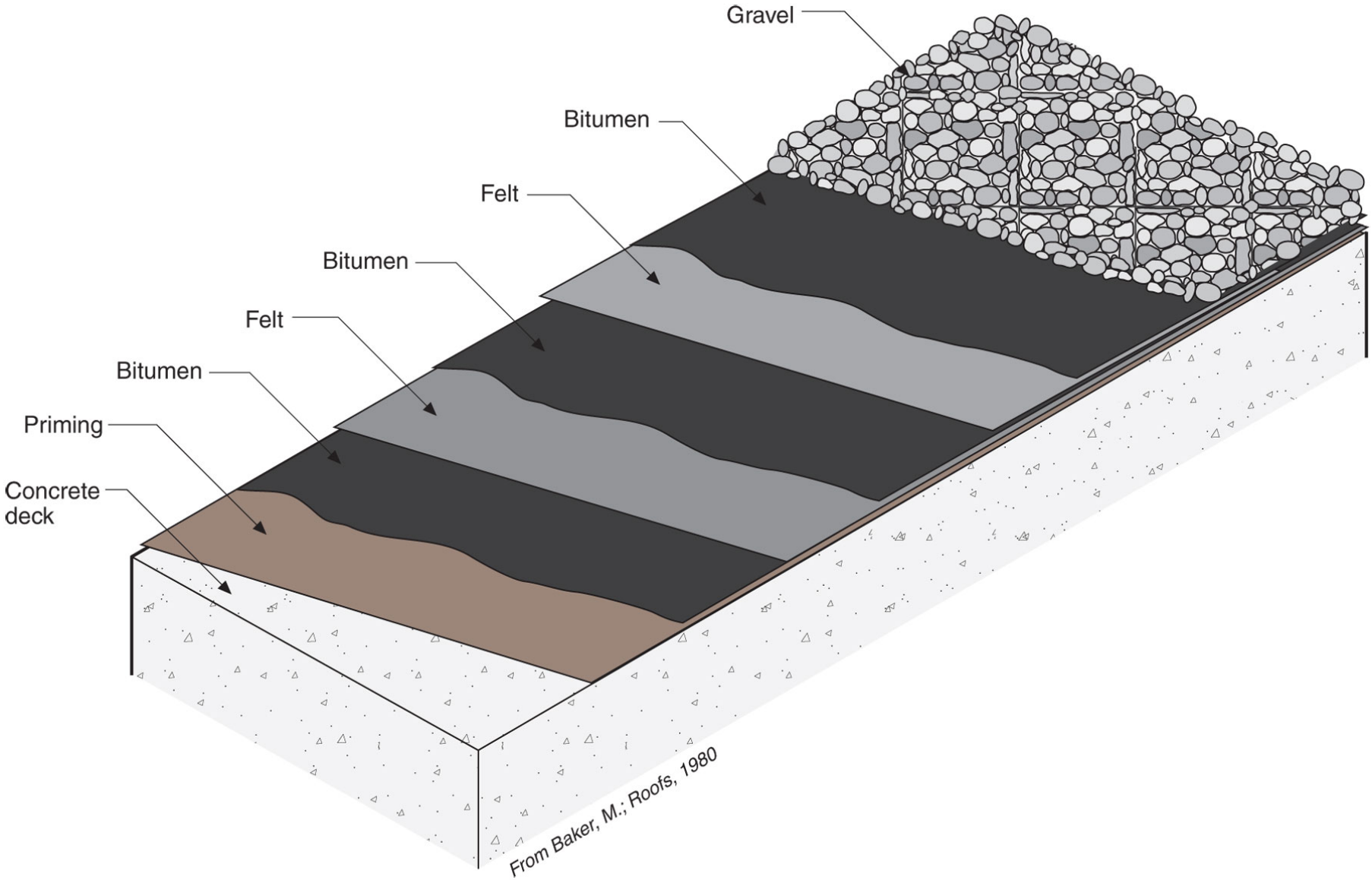


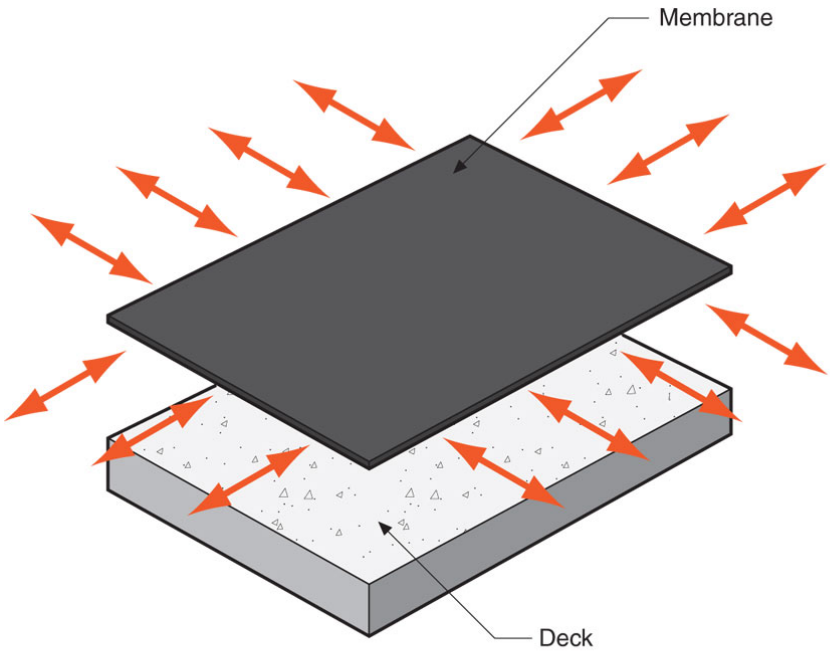
From Baker, M.; Roofs, 1980

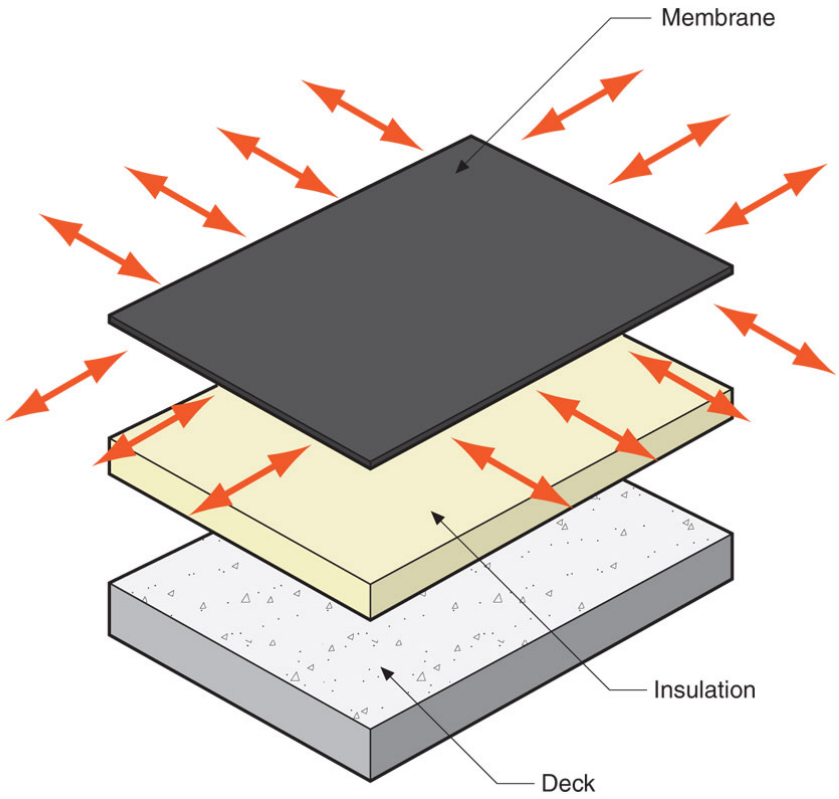


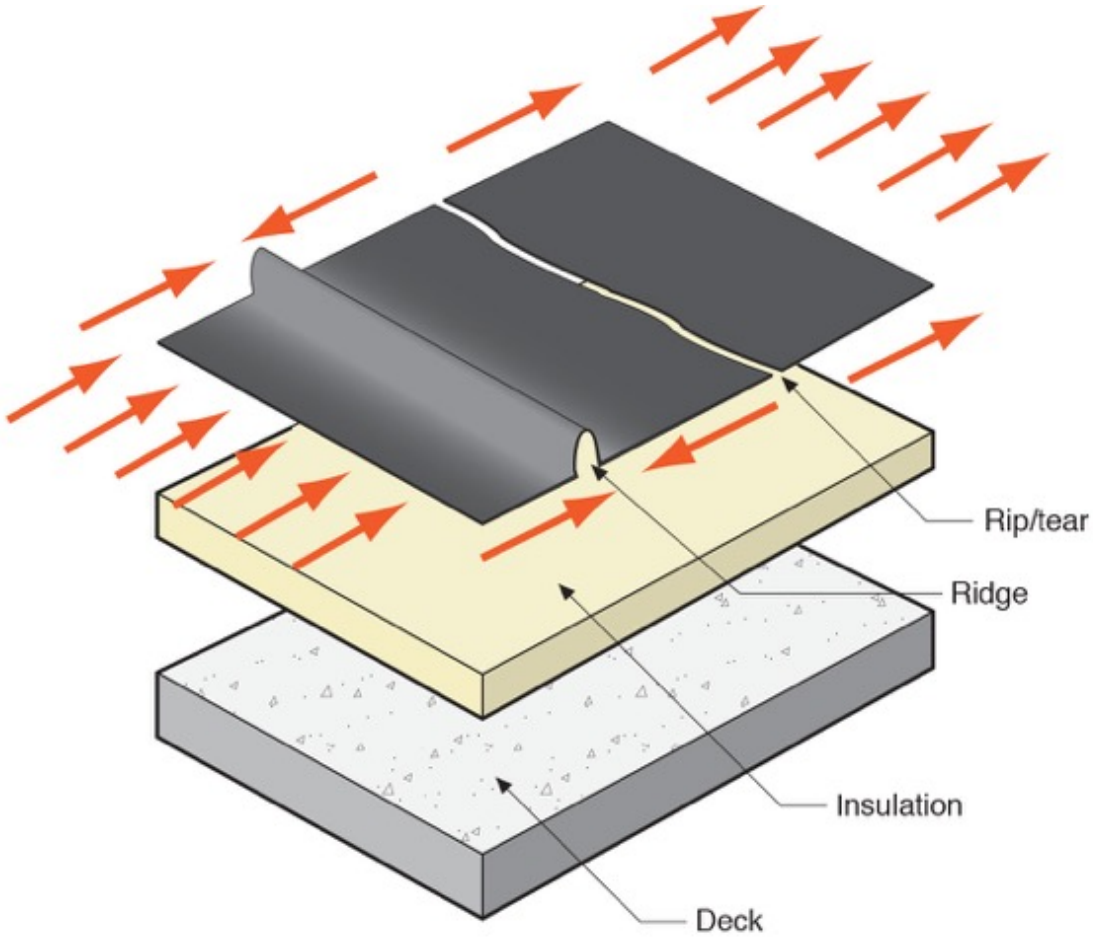
From Baker, M.; Roofs, 1980

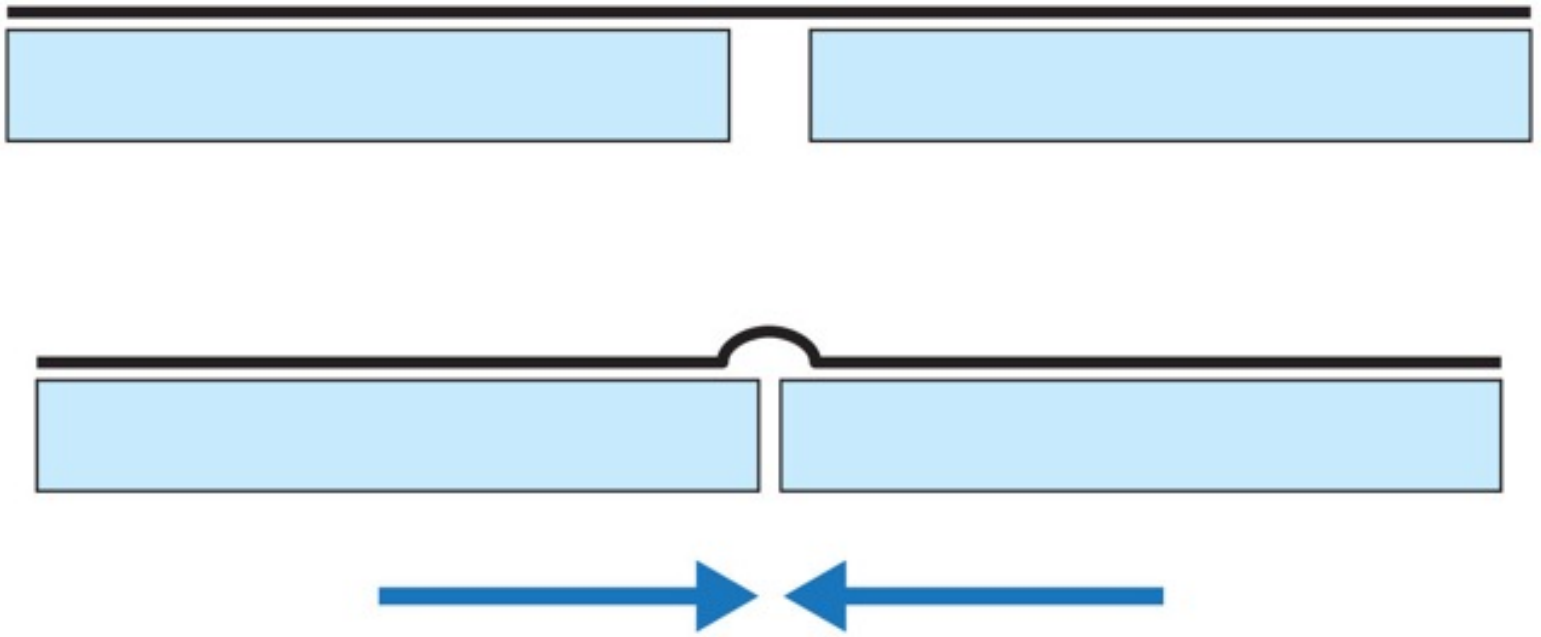

Gravel
Bitumen top pour
Felt
Bitumen
Felt
Bitumen
Bitumen saturated felt laid dry and nailed to deck
Dry sheathing or rosin paper nailed to deck
Wood deck
From Baker, M.; Roofs, 1980

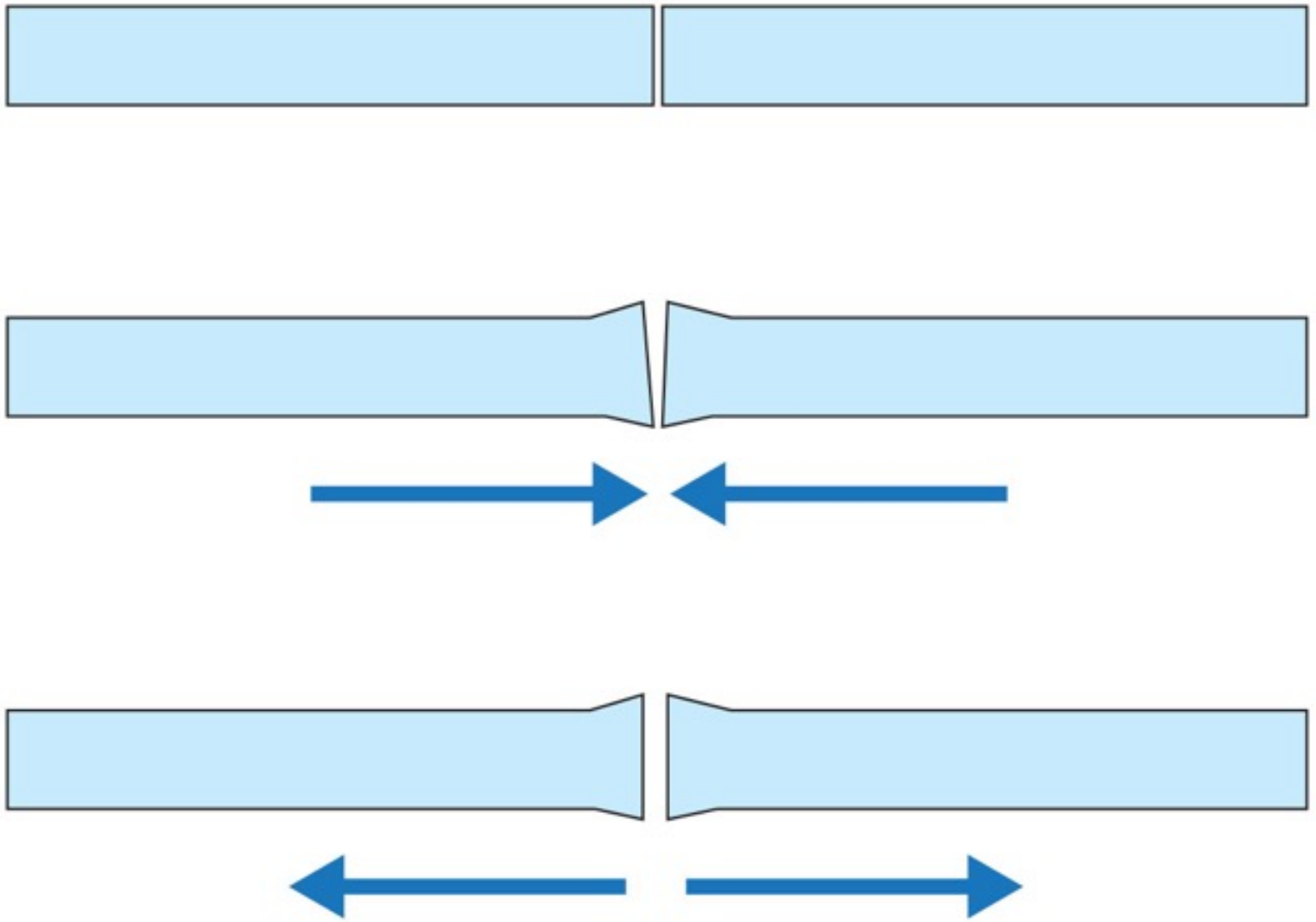

Gravel
Bitumen
Felt
Bitumen
Felt
Bitumen
Priming
Concrete deck
From Baker, M.; Roofs, 1980

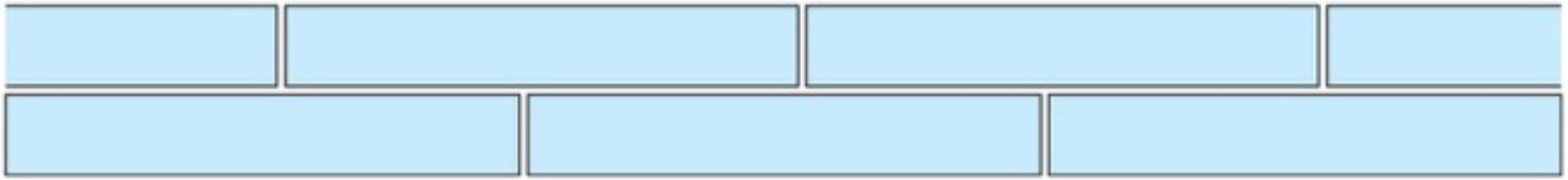

Membrane
Deck

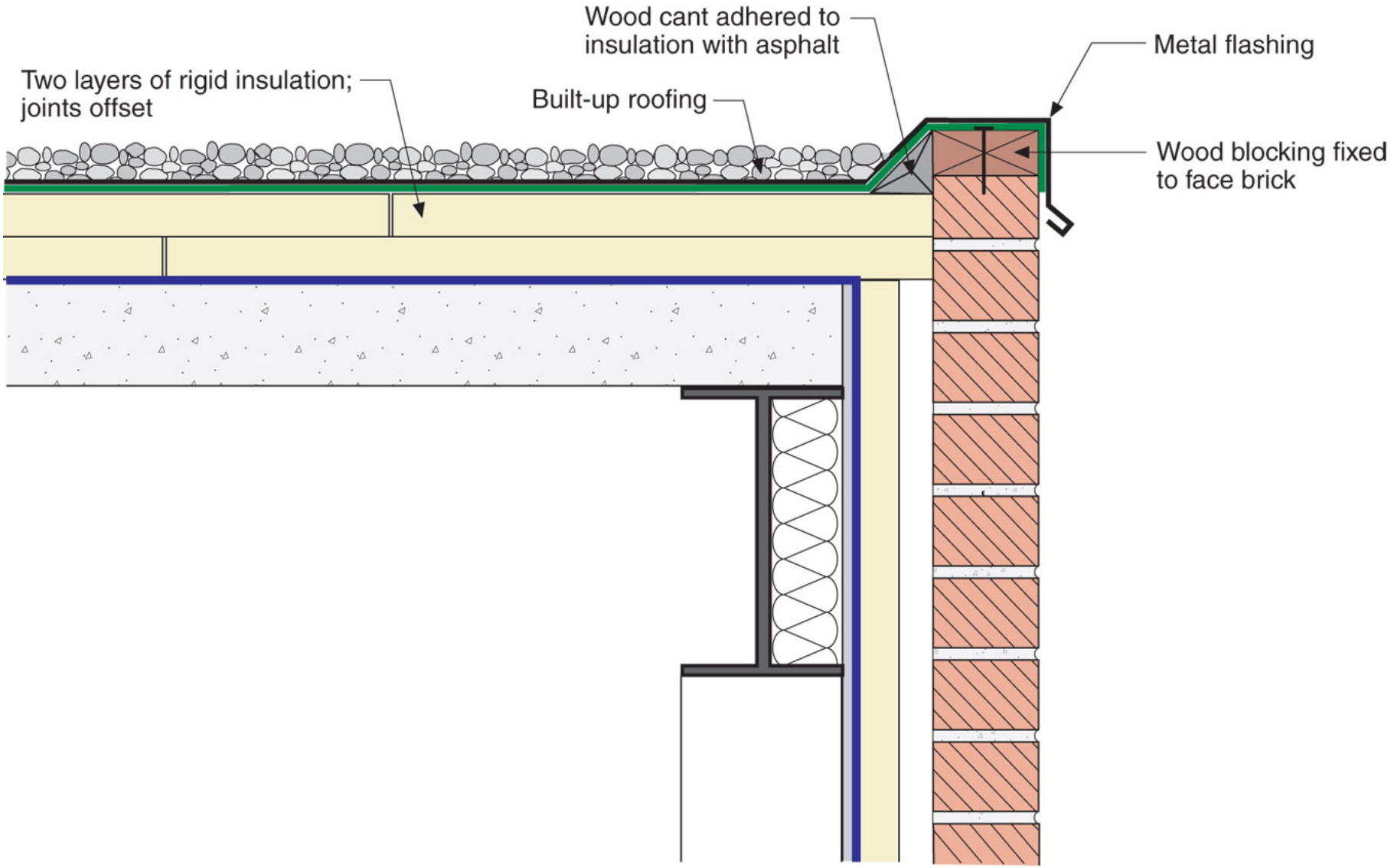

Membrane
Insulation
Deck


Rip/tear
Ridge
Insulation
Deck

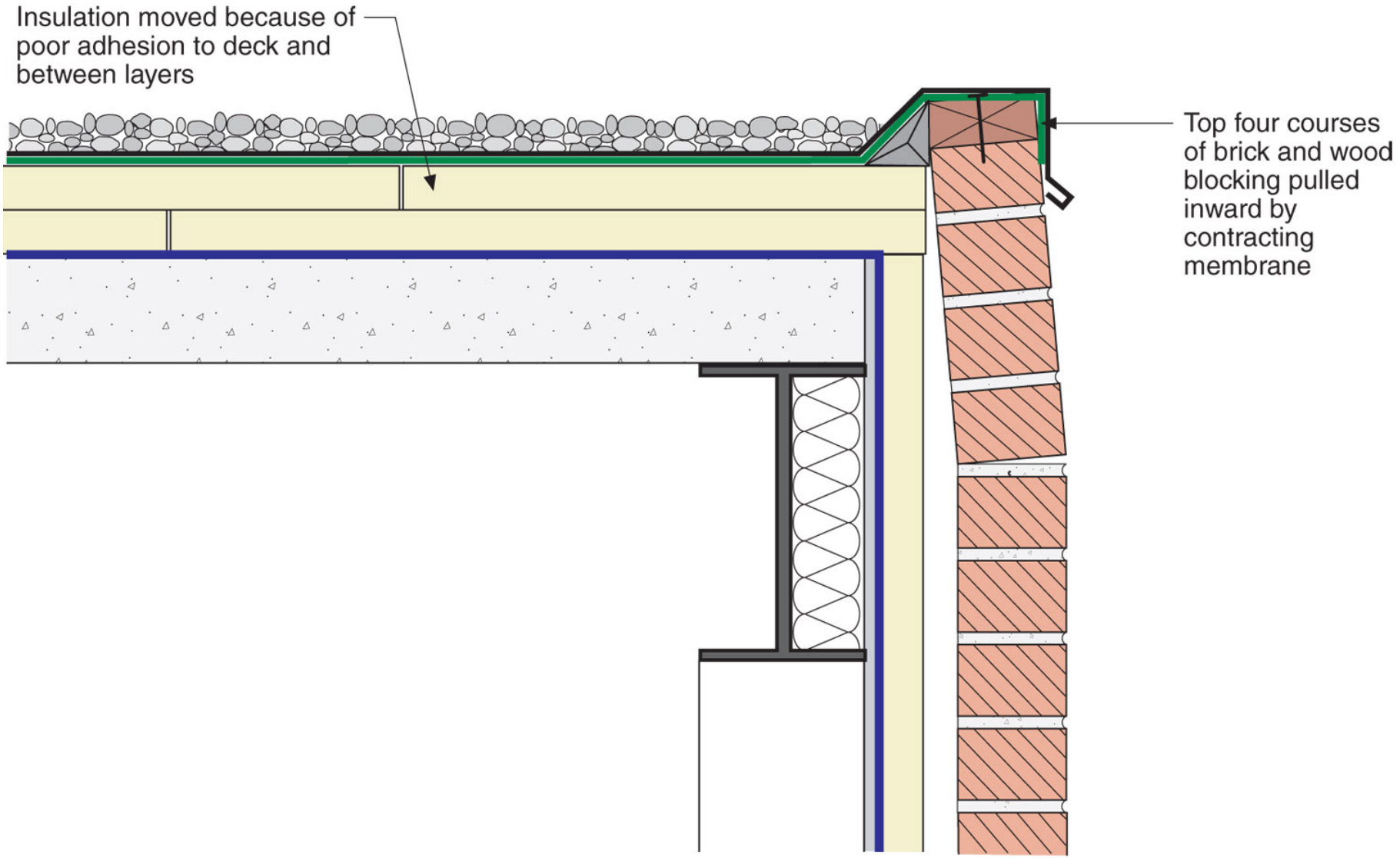




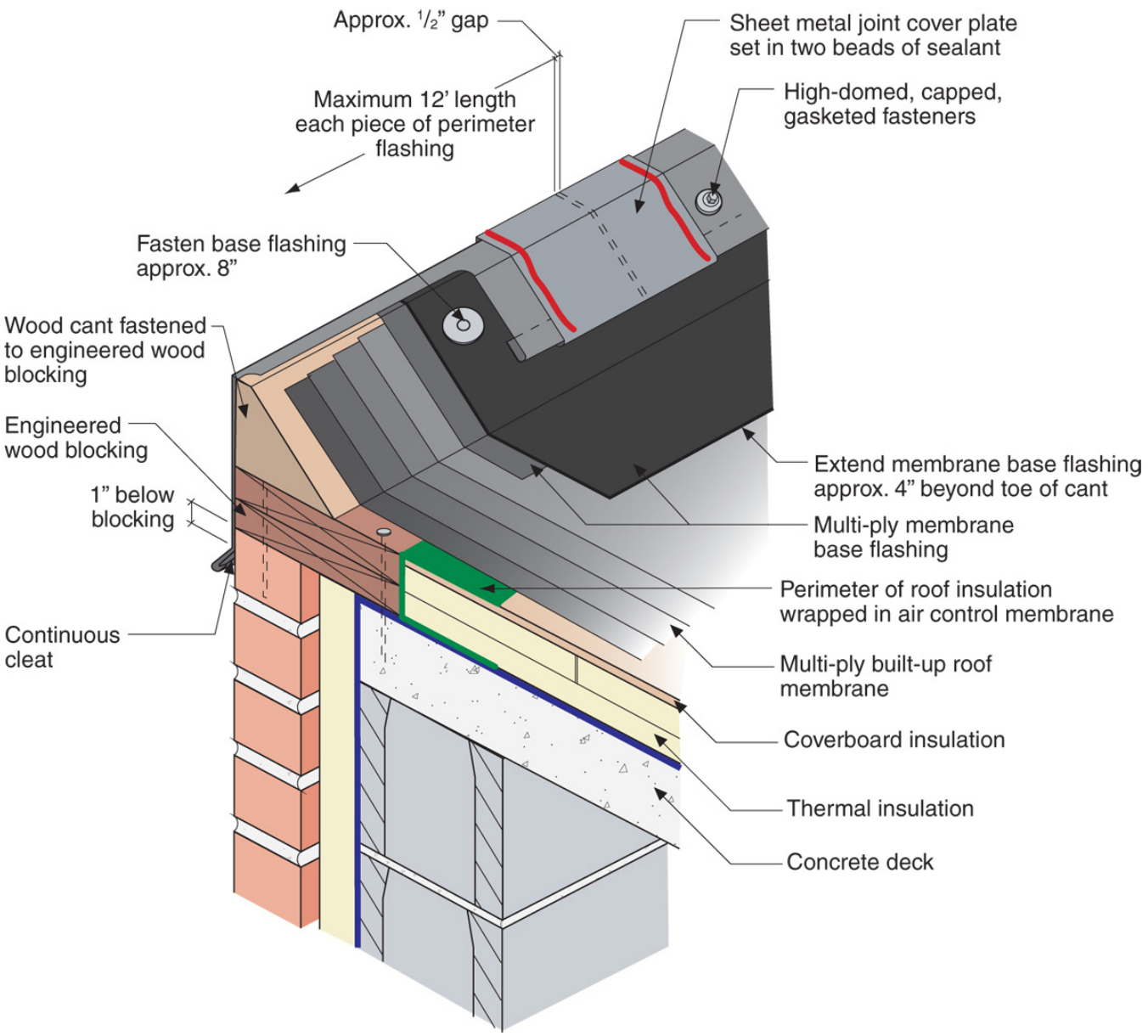


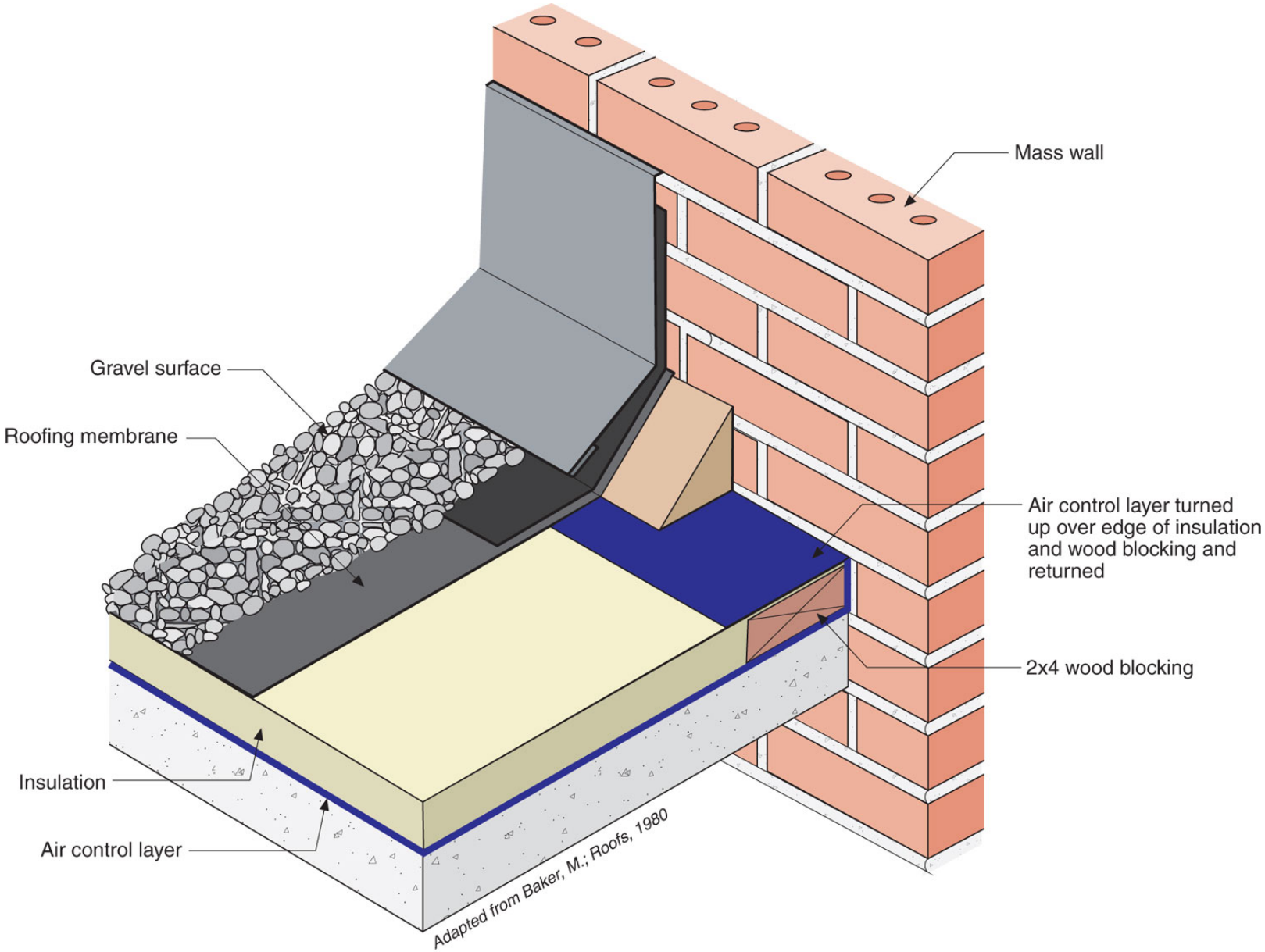


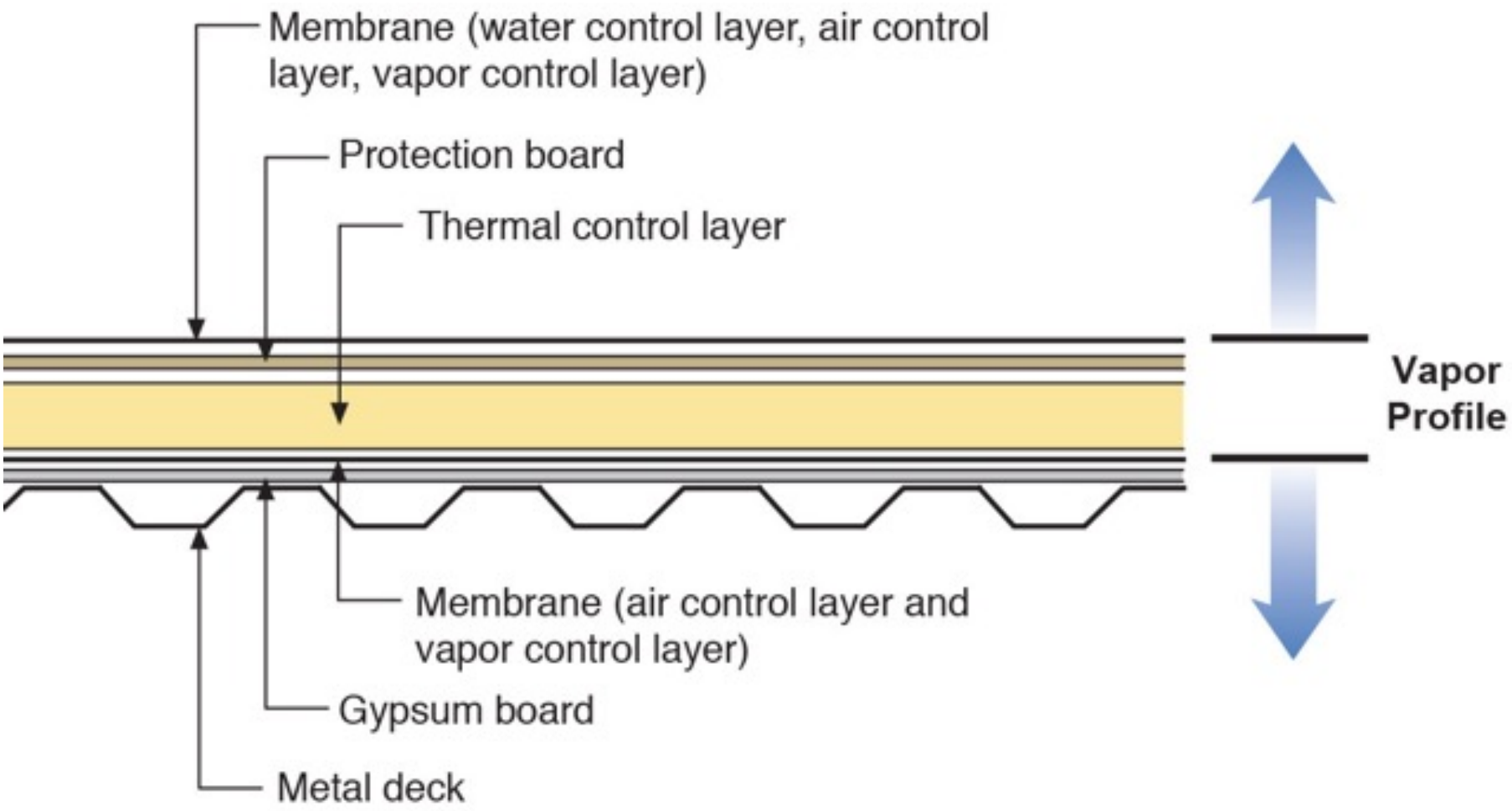
Adapted from Baker, M.; Roofs, 1980

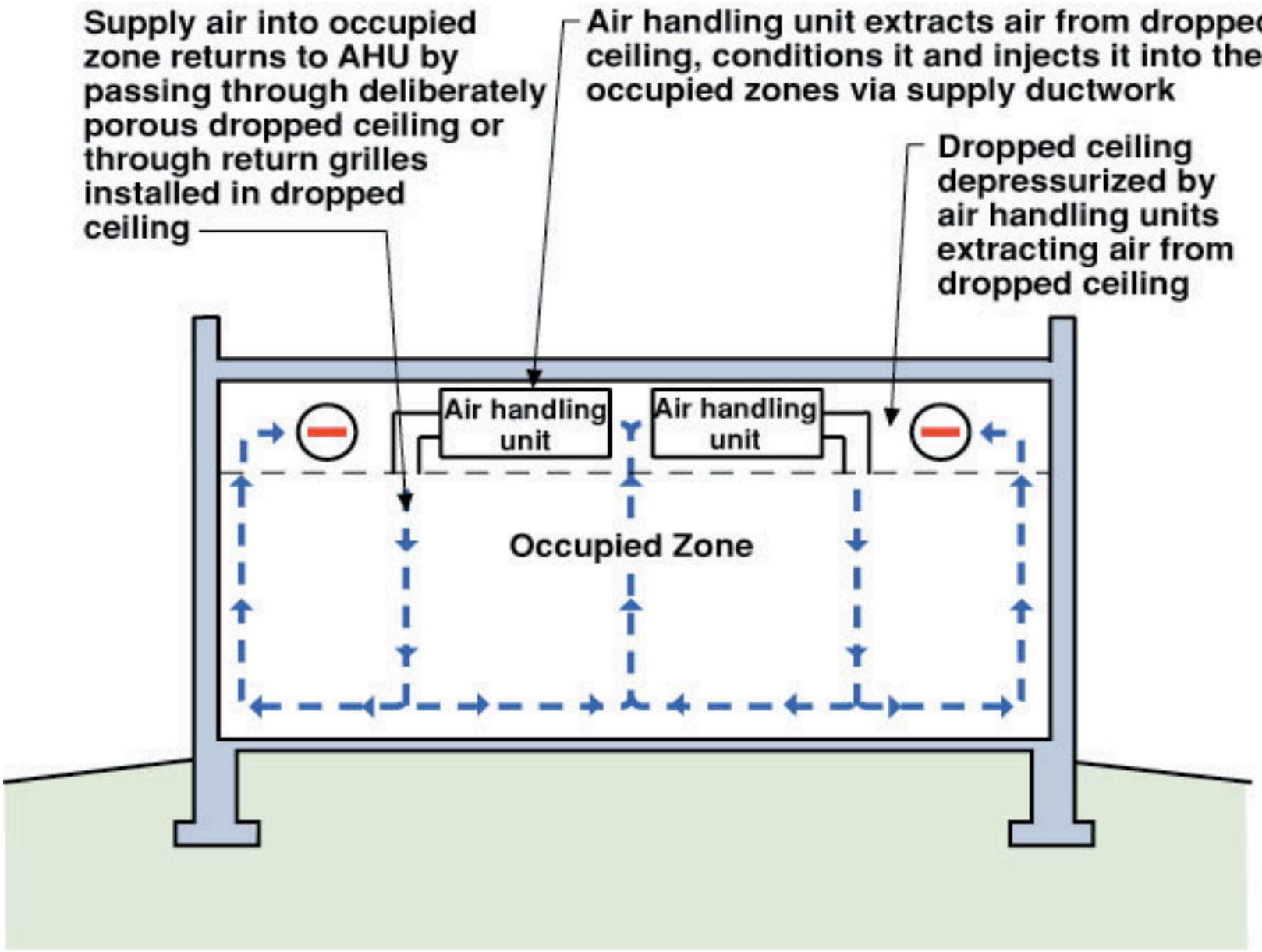


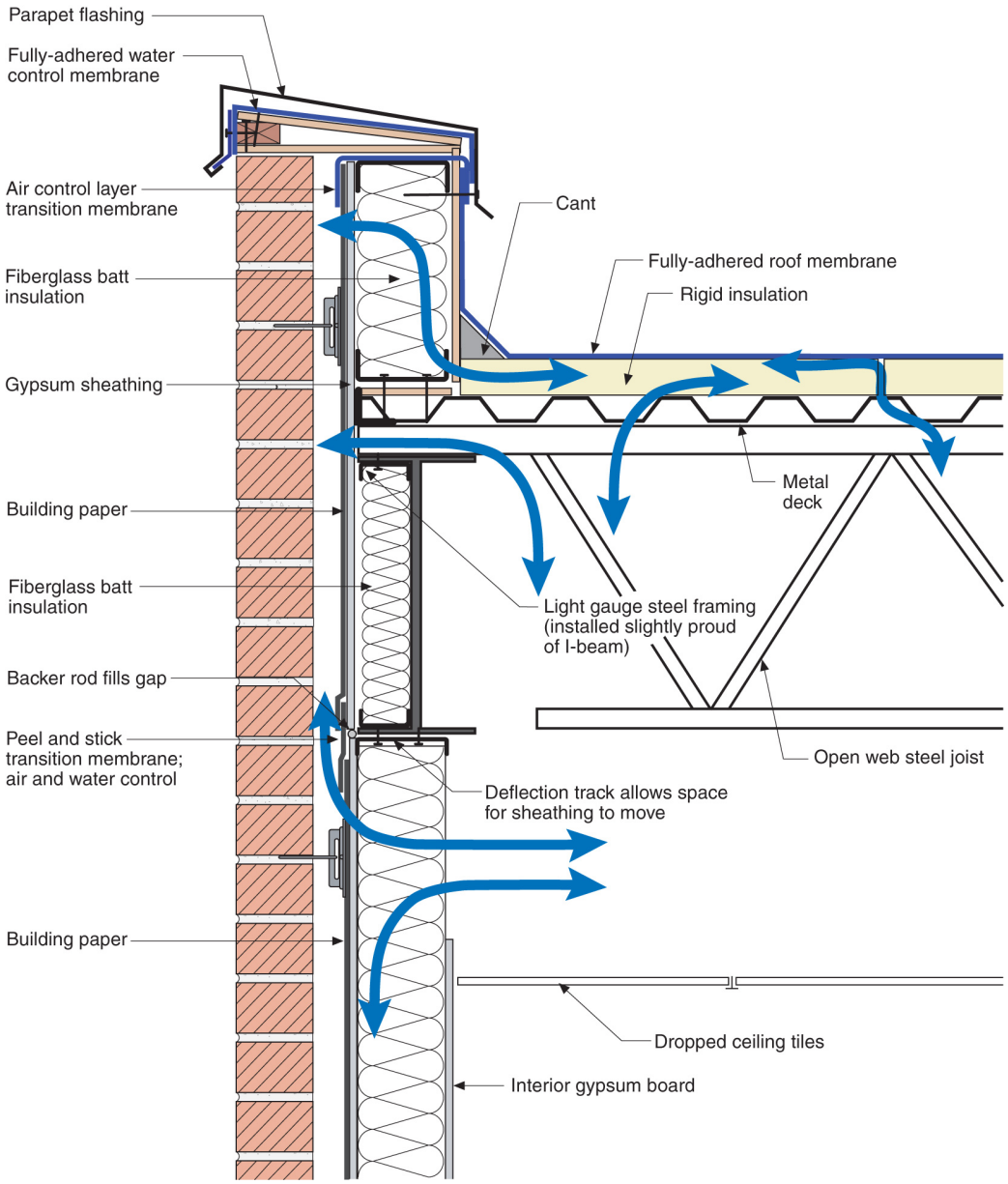
Adapted from Baker, M.; Roofs, 1980;
Courtesy National Research Council of Canada

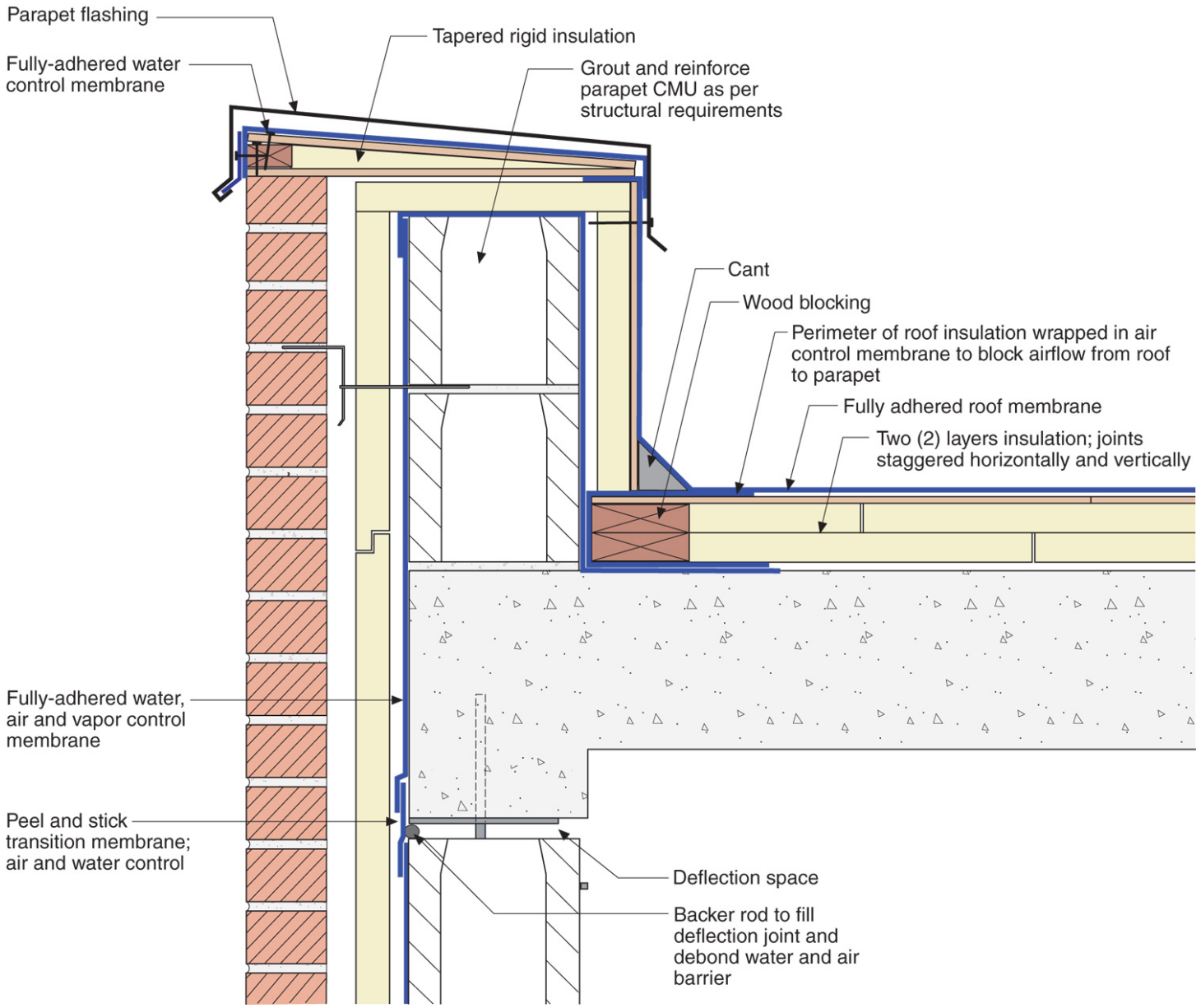

Approx. ½" gap
Maximum 12' length each piece of perimeter flashing
Sheet metal joint cover plate set in two beads of sealant
High-domed, capped, gasketed fasteners
Fasten base flashing approx. 8"
Wood cant fastened to engineered wood blocking
Engineered wood blocking
1" below blocking
Continuous cleat
Extend membrane base flashing approx. 4" beyond toe of cant
Multi-ply membrane base flashing
Perimeter of roof insulation wrapped in air control membrane
Multi-ply built-up roof membrane
Coverboard insulation
Thermal insulation
Concrete deck

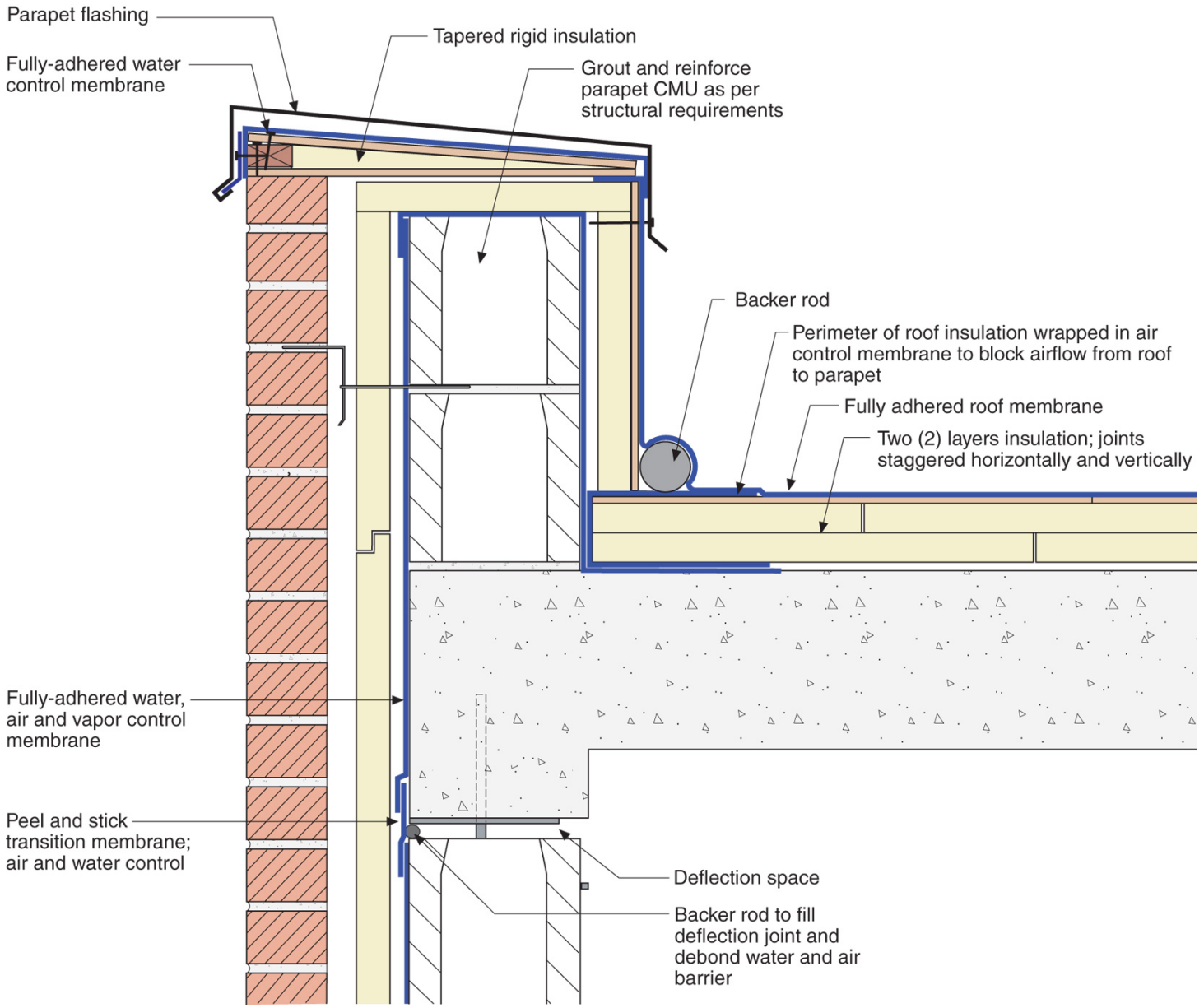

Mass wall
Gravel surface
Roofing membrane
Air control layer turned up over edge of insulation and wood blocking and returned
2x4 wood blocking
Insulation
Air control layer
Adapted from Baker, M.; Roofs, 1980

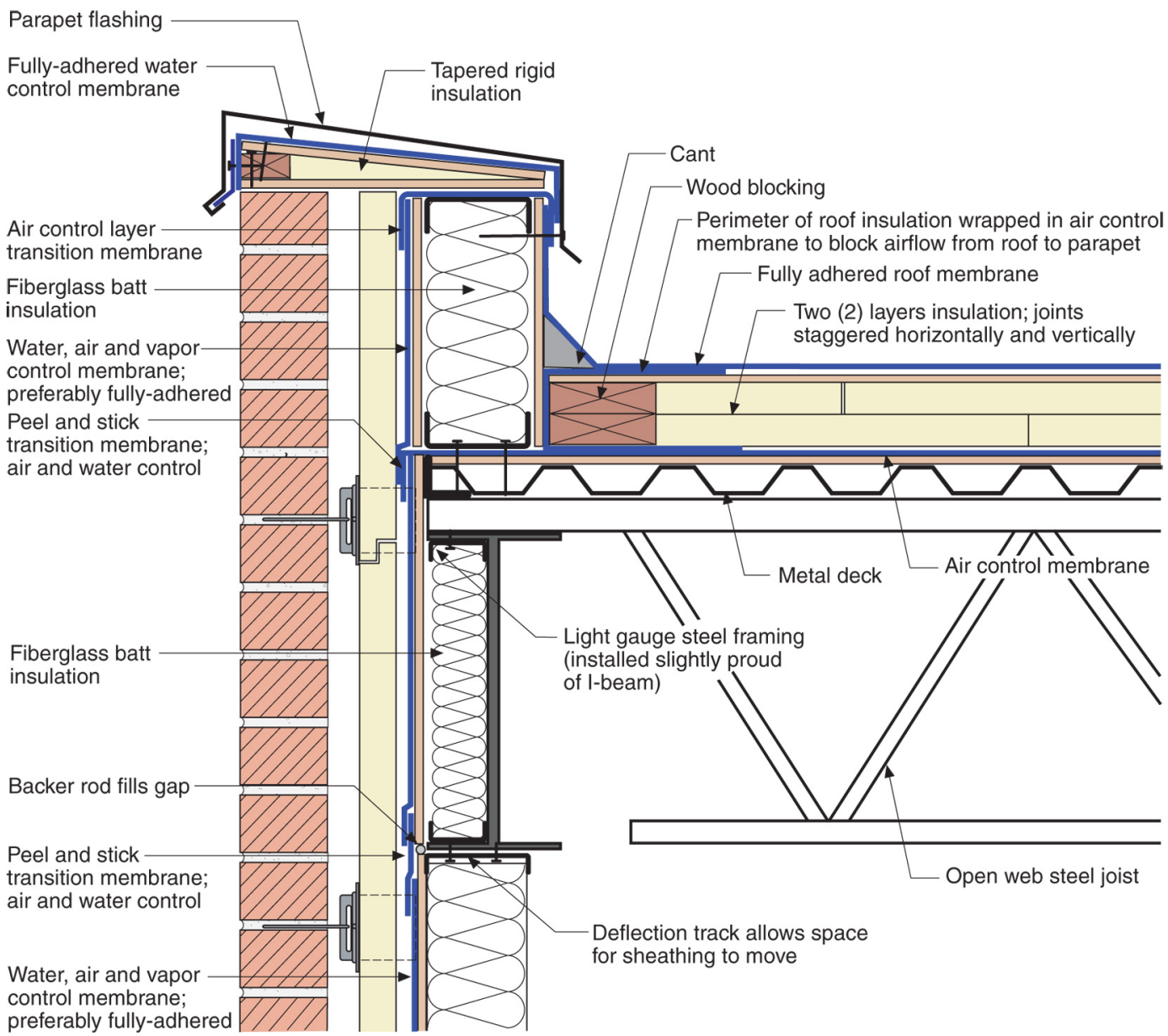

Membrane (water control layer, air control layer, vapor control layer)
Protection board
Thermal control layer
Membrane (air control layer and vapor control layer)
Gypsum board
Metal deck
Vapor Profile

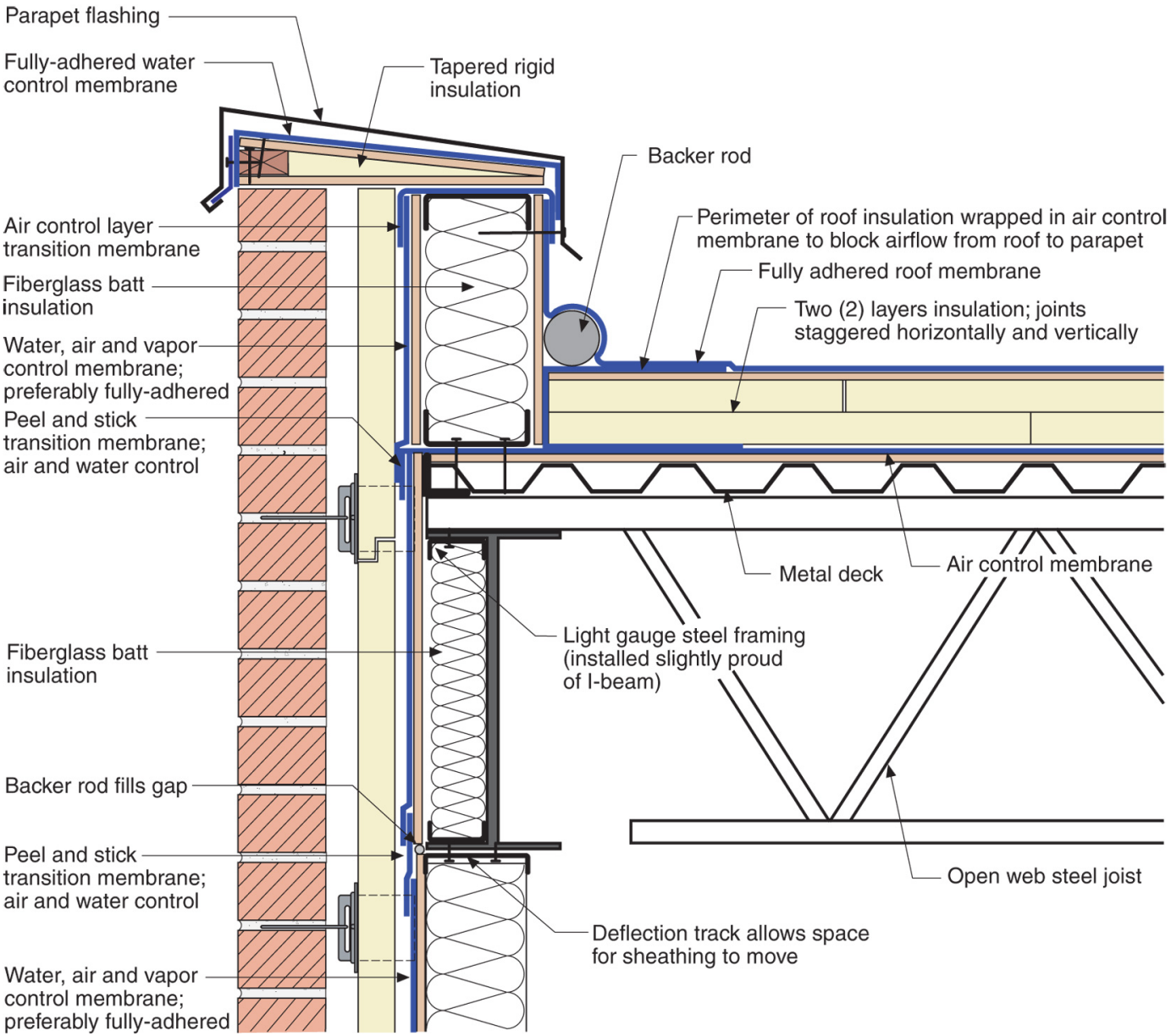

Supply air into occupied zone returns to AHU by passing through deliberately porous dropped ceiling or through return grilles installed in dropped ceiling
Air handling unit extracts air from dropped ceiling, conditions it and injects it into the occupied zones via supply ductwork
Dropped ceiling depressurized by air handling units extracting air from dropped ceiling
Air handling unit
Air handling unit
Occupied Zone

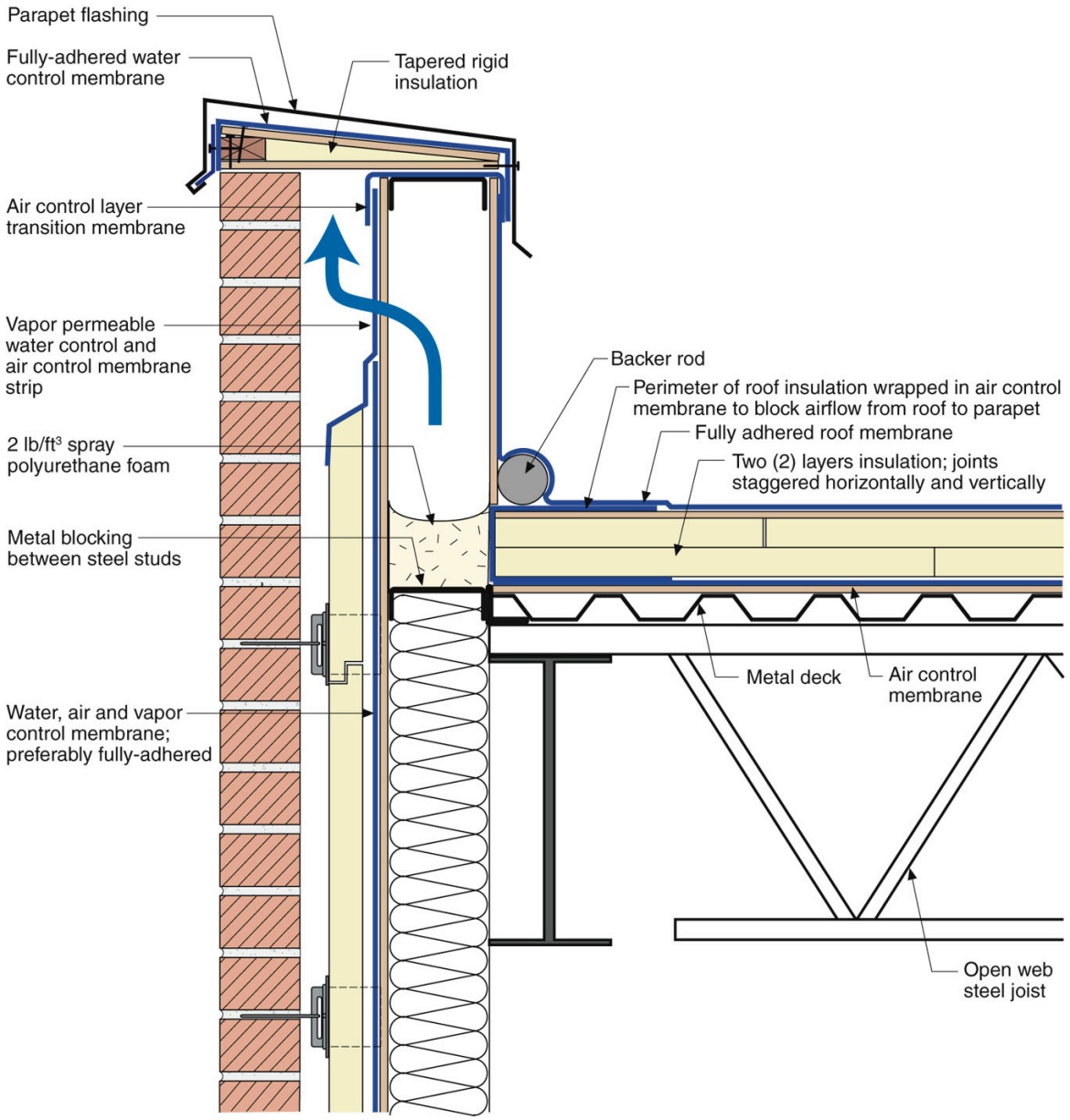

Parapet flashing
Fully-adhered water control membrane
Air control layer transition membrane
Fiberglass batt insulation
Gypsum sheathing
Building paper
Fiberglass batt insulation
Backer rod fills gap
Peel and stick transition membrane; air and water control
Building paper
Cant
Fully-adhered roof membrane
Rigid insulation
Metal deck
Light gauge steel framing (installed slightly proud of I-beam)
Open web steel joist
Deflection track allows space for sheathing to move
Dropped ceiling tiles
Interior gypsum board

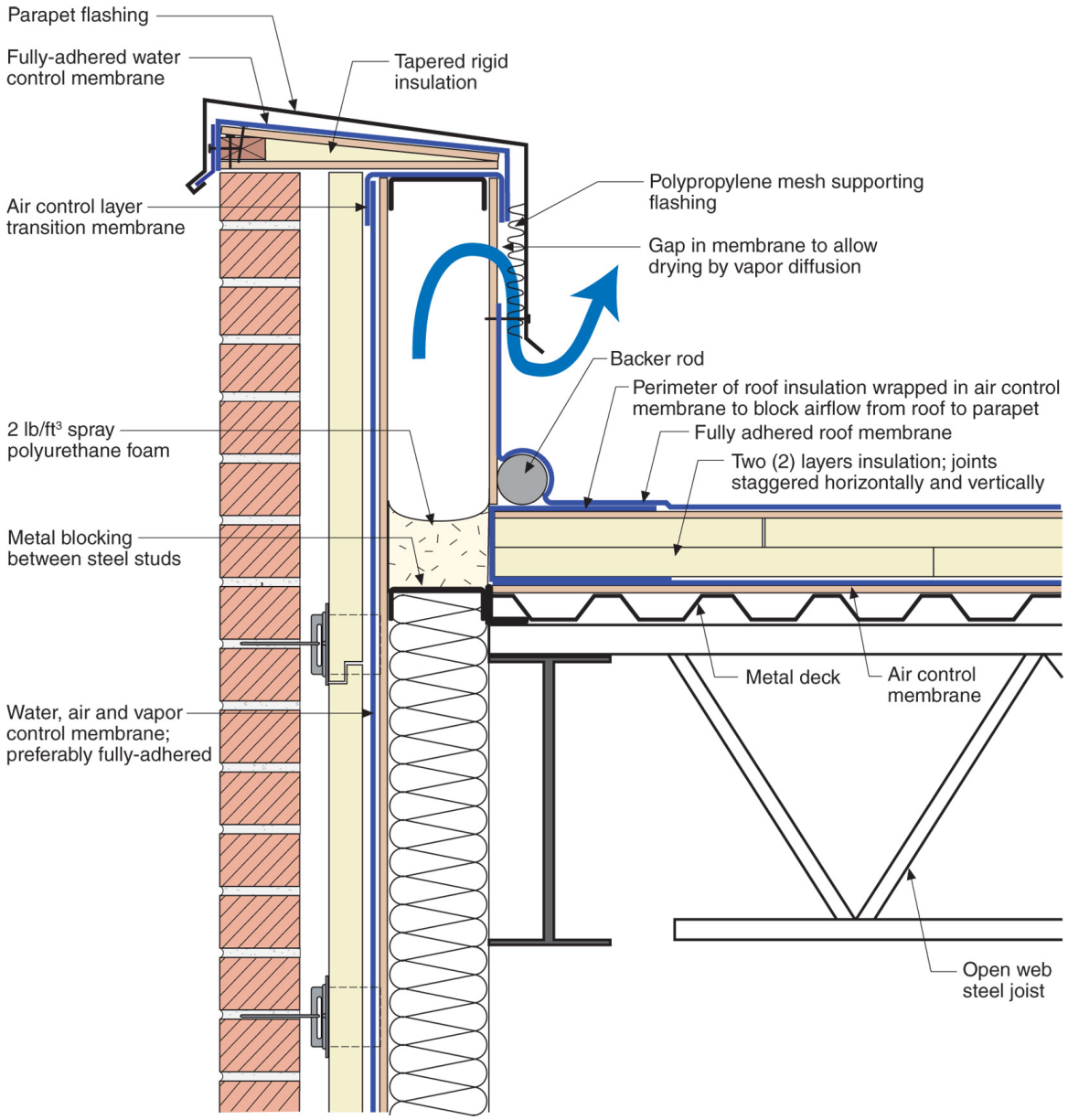

Parapet flashing
Fully-adhered water control membrane
Tapered rigid insulation
Grout and reinforce parapet CMU as per structural requirements
Cant
Wood blocking
Perimeter of roof insulation wrapped in air control membrane to block airflow from roof to parapet
Fully adhered roof membrane
Two (2) layers insulation; joints staggered horizontally and vertically
Fully-adhered water, air and vapor control membrane
Peel and stick transition membrane; air and water control
Deflection space
Backer rod to fill deflection joint and debond water and air barrier

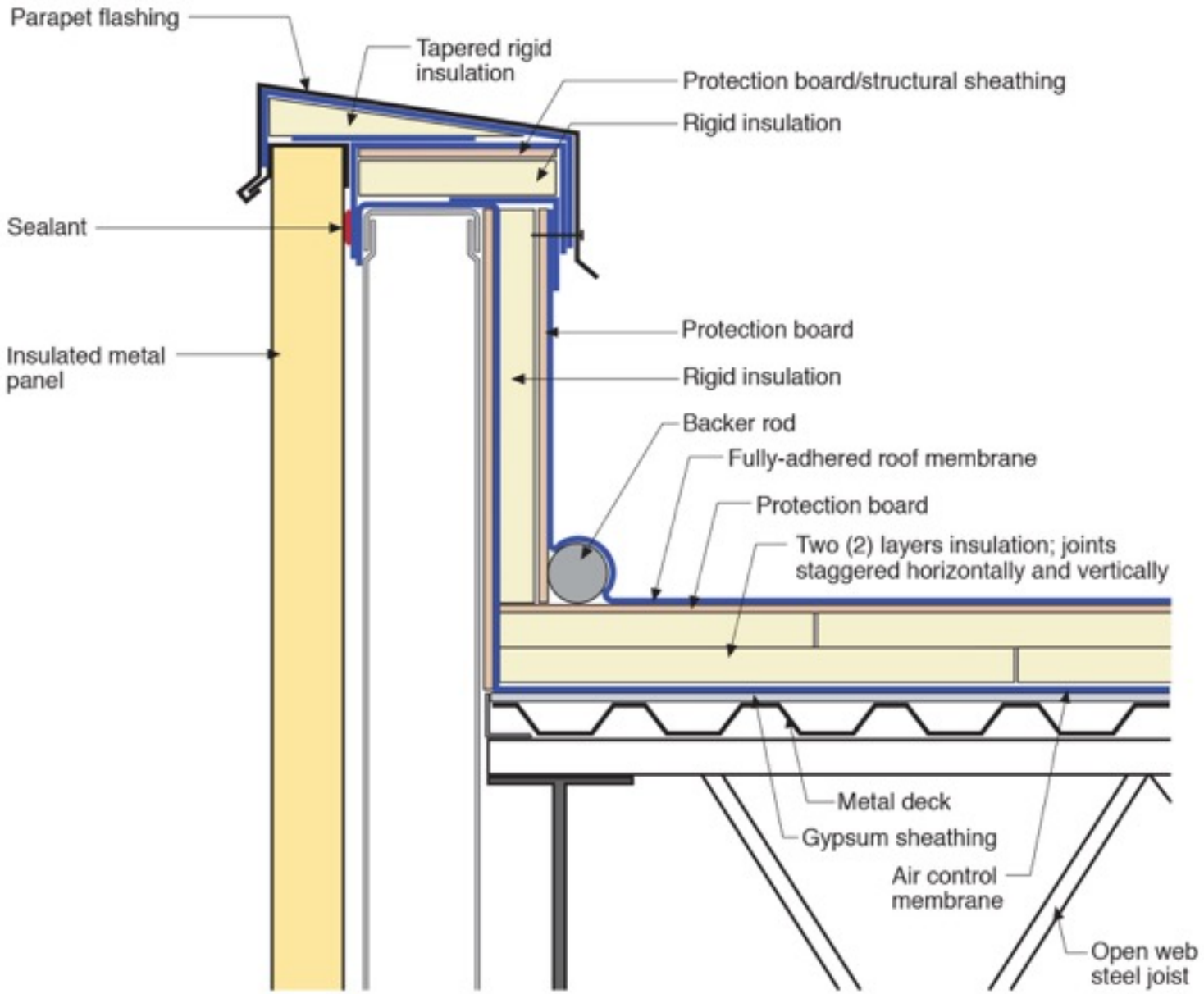

Parapet flashing
Fully-adhered water control membrane
Tapered rigid insulation
Grout and reinforce parapet CMU as per structural requirements
Backer rod
Perimeter of roof insulation wrapped in air control membrane to block airflow from roof to parapet
Fully adhered roof membrane
Two (2) layers insulation; joints staggered horizontally and vertically
Fully-adhered water, air and vapor control membrane
Peel and stick transition membrane; air and water control
Deflection space
Backer rod to fill deflection joint and debond water and air barrier

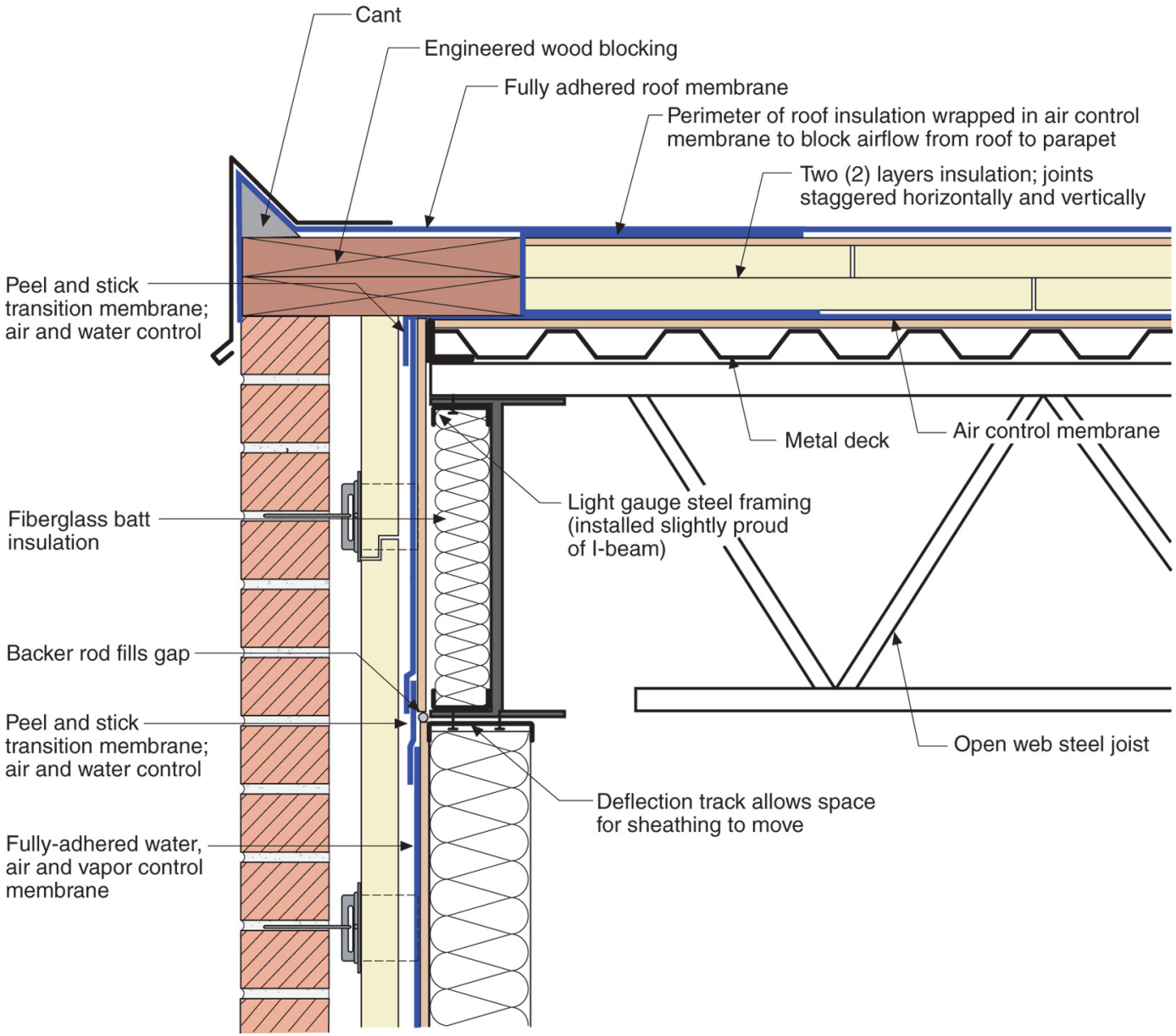

Parapet flashing
Fully-adhered water control membrane
Tapered rigid insulation
Cant
Wood blocking
Perimeter of roof insulation wrapped in air control membrane to block airflow from roof to parapet
Fully adhered roof membrane
Two (2) layers insulation; joints staggered horizontally and vertically
Air control layer transition membrane
Fiberglass batt insulation
Water, air and vapor control membrane; preferably fully-adhered
Peel and stick transition membrane; air and water control
Metal deck
Air control membrane
Light gauge steel framing (installed slightly proud of I-beam)
Fiberglass batt insulation
Backer rod fills gap
Peel and stick transition membrane; air and water control
Open web steel joist
Deflection track allows space for sheathing to move
Water, air and vapor control membrane; preferably fully-adhered

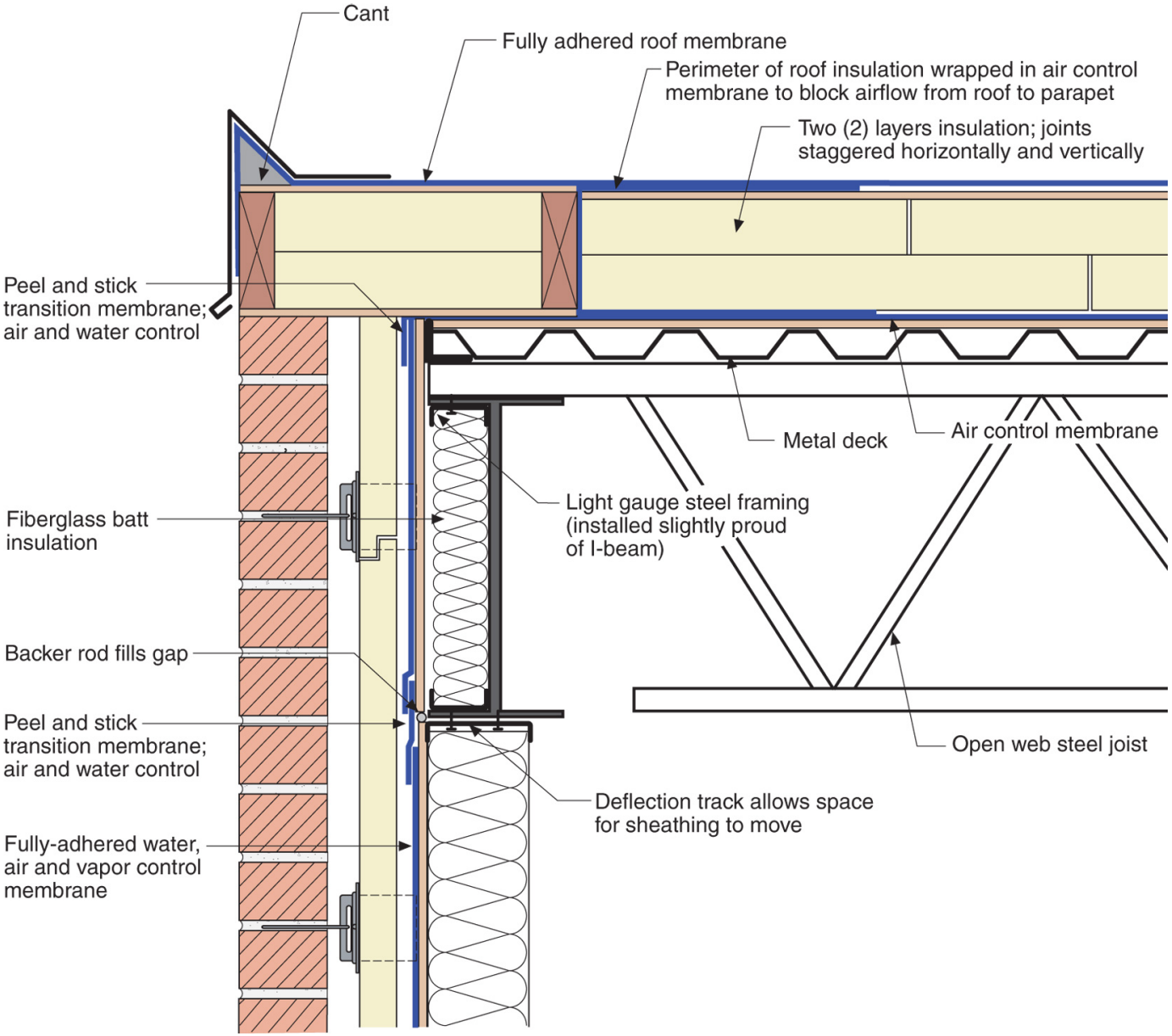

Parapet flashing
Fully-adhered water control membrane
Tapered rigid insulation
Backer rod
Air control layer transition membrane
Perimeter of roof insulation wrapped in air control membrane to block airflow from roof to parapet
Fiberglass batt insulation
Fully adhered roof membrane
Two (2) layers insulation; joints staggered horizontally and vertically
Water, air and vapor control membrane; preferably fully-adhered
Peel and stick transition membrane; air and water control
Metal deck
Air control membrane
Light gauge steel framing (installed slightly proud of I-beam)
Fiberglass batt insulation
Backer rod fills gap
Peel and stick transition membrane; air and water control
Open web steel joist
Deflection track allows space for sheathing to move
Water, air and vapor control membrane; preferably fully-adhered


Parapet flashing
Fully-adhered water control membrane
Tapered rigid insulation
Air control layer transition membrane
Vapor permeable water control and air control membrane strip
2 lb/ft³ spray polyurethane foam
Metal blocking between steel studs
Water, air and vapor control membrane; preferably fully-adhered
Backer rod
Perimeter of roof insulation wrapped in air control membrane to block airflow from roof to parapet
Fully adhered roof membrane
Two (2) layers insulation; joints staggered horizontally and vertically
Metal deck
Air control membrane
Open web steel joist


Parapet flashing
Fully-adhered water control membrane
Tapered rigid insulation
Air control layer transition membrane
Polypropylene mesh supporting flashing
Gap in membrane to allow drying by vapor diffusion
Backer rod
Perimeter of roof insulation wrapped in air control membrane to block airflow from roof to parapet
2 lb/ft³ spray polyurethane foam
Fully adhered roof membrane
Two (2) layers insulation; joints staggered horizontally and vertically
Metal blocking between steel studs
Metal deck
Air control membrane
Water, air and vapor control membrane; preferably fully-adhered
Open web steel joist


Parapet flashing
Tapered rigid insulation
Protection board/structural sheathing
Rigid insulation
Sealant
Insulated metal panel
Protection board
Rigid insulation
Backer rod
Fully-adhered roof membrane
Protection board
Two (2) layers insulation; joints staggered horizontally and vertically
Metal deck
Gypsum sheathing
Air control membrane
Open web steel joist


Cant
Engineered wood blocking
Fully adhered roof membrane
Perimeter of roof insulation wrapped in air control membrane to block airflow from roof to parapet
Two (2) layers insulation; joints staggered horizontally and vertically
Peel and stick transition membrane; air and water control
Metal deck
Air control membrane
Light gauge steel framing (installed slightly proud of I-beam)
Fiberglass batt insulation
Backer rod fills gap
Peel and stick transition membrane; air and water control
Open web steel joist
Deflection track allows space for sheathing to move
Fully-adhered water, air and vapor control membrane


Cant
Fully adhered roof membrane
Perimeter of roof insulation wrapped in air control membrane to block airflow from roof to parapet
Two (2) layers insulation; joints staggered horizontally and vertically
Peel and stick transition membrane; air and water control
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Air control membrane
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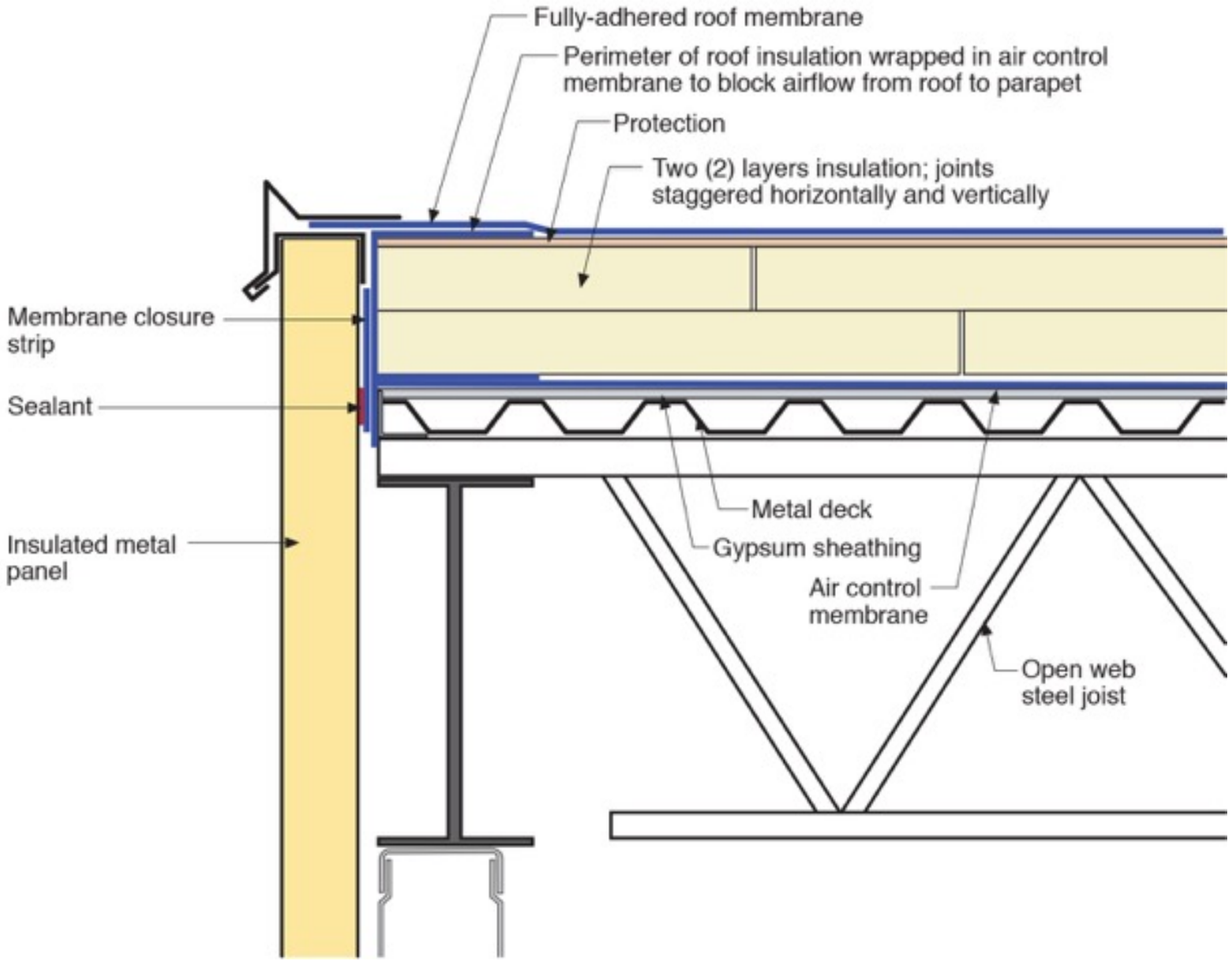
Deflection track allows space for sheathing to move
Fully-adhered water, air and vapor control membrane


Fully-adhered roof membrane
Perimeter of roof insulation wrapped in air control membrane to block airflow from roof to parapet
Protection
Two (2) layers insulation; joints staggered horizontally and vertically
Membrane closure strip
Sealant
Insulated metal panel
Metal deck
Gypsum sheathing
Air control membrane
Open web steel joist

It’s a Case of Black or White

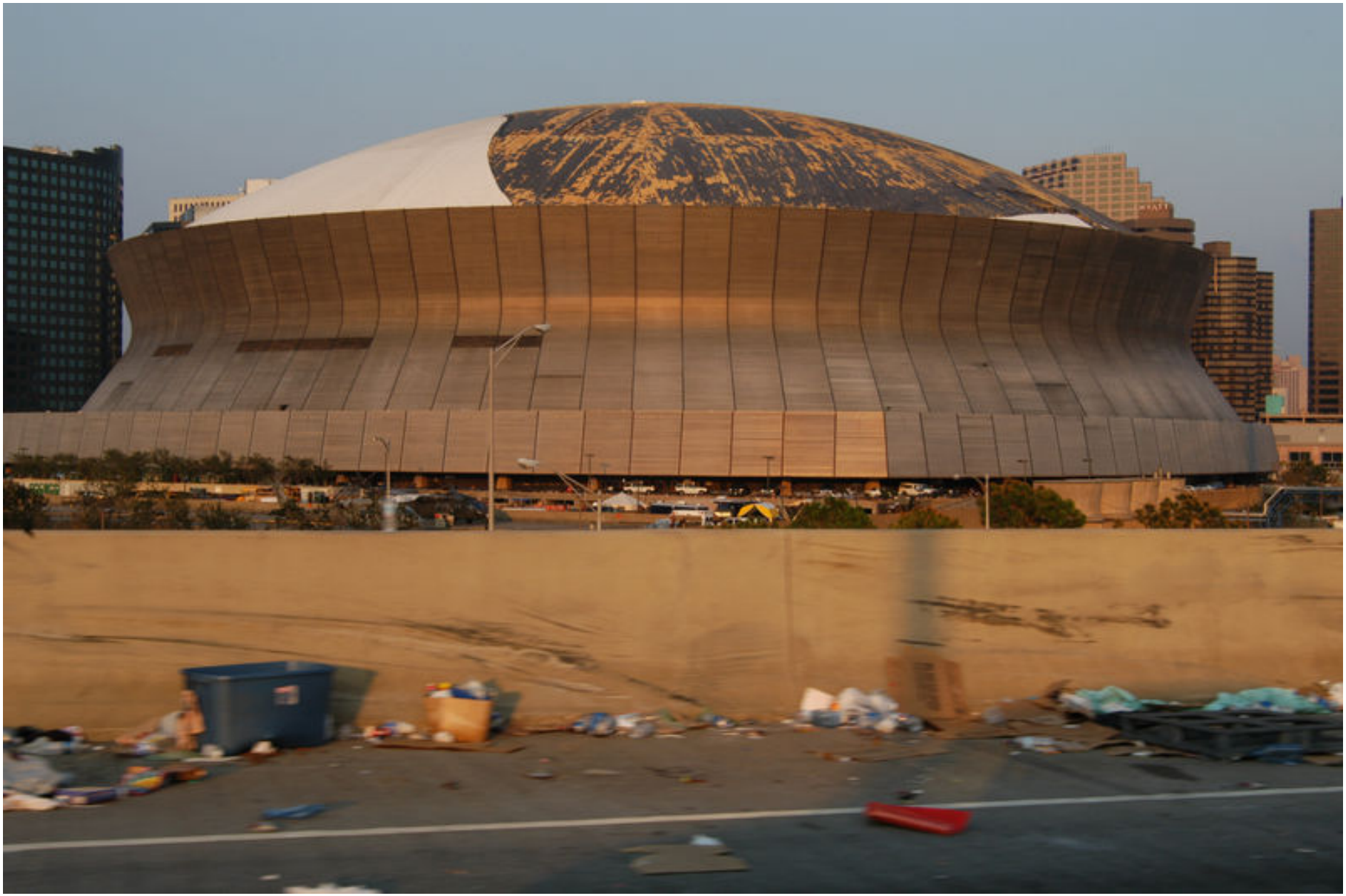
It’s a Case of Black or White

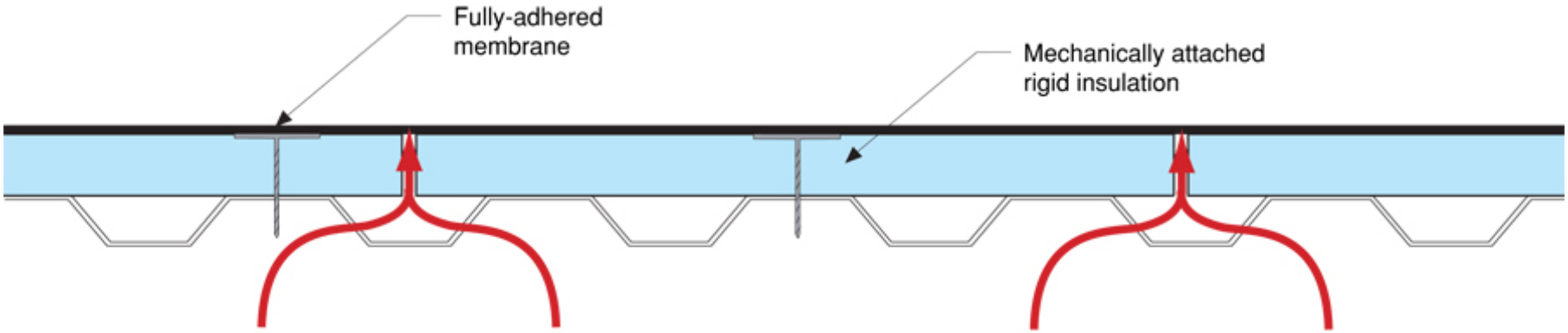
Arrhenius

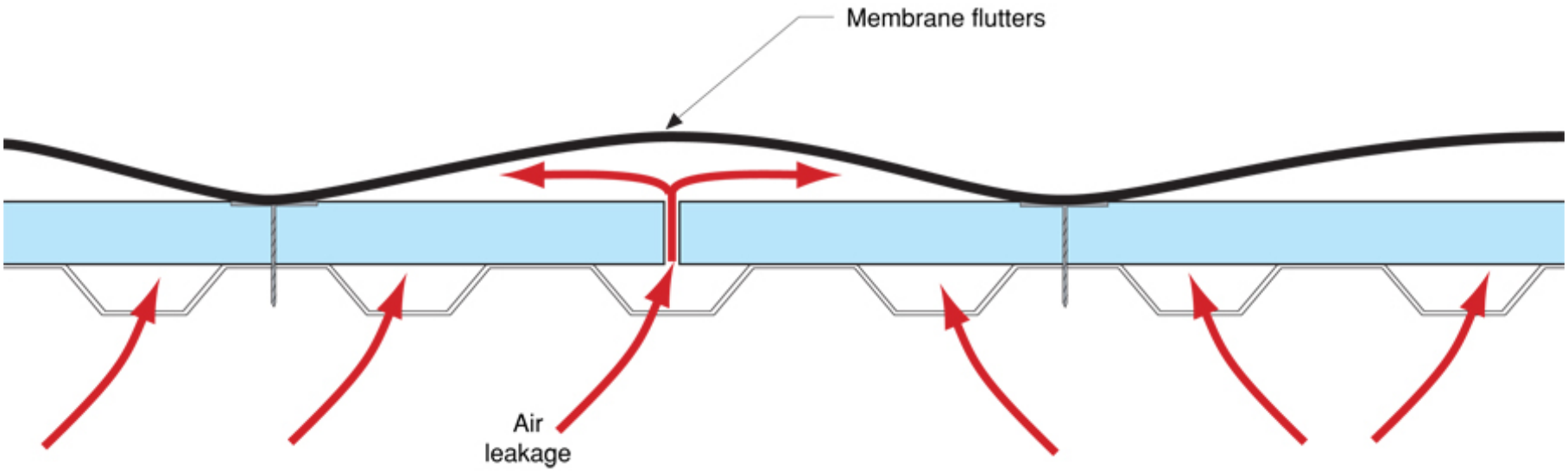
It’s a Case of Black or White

Arrhenius

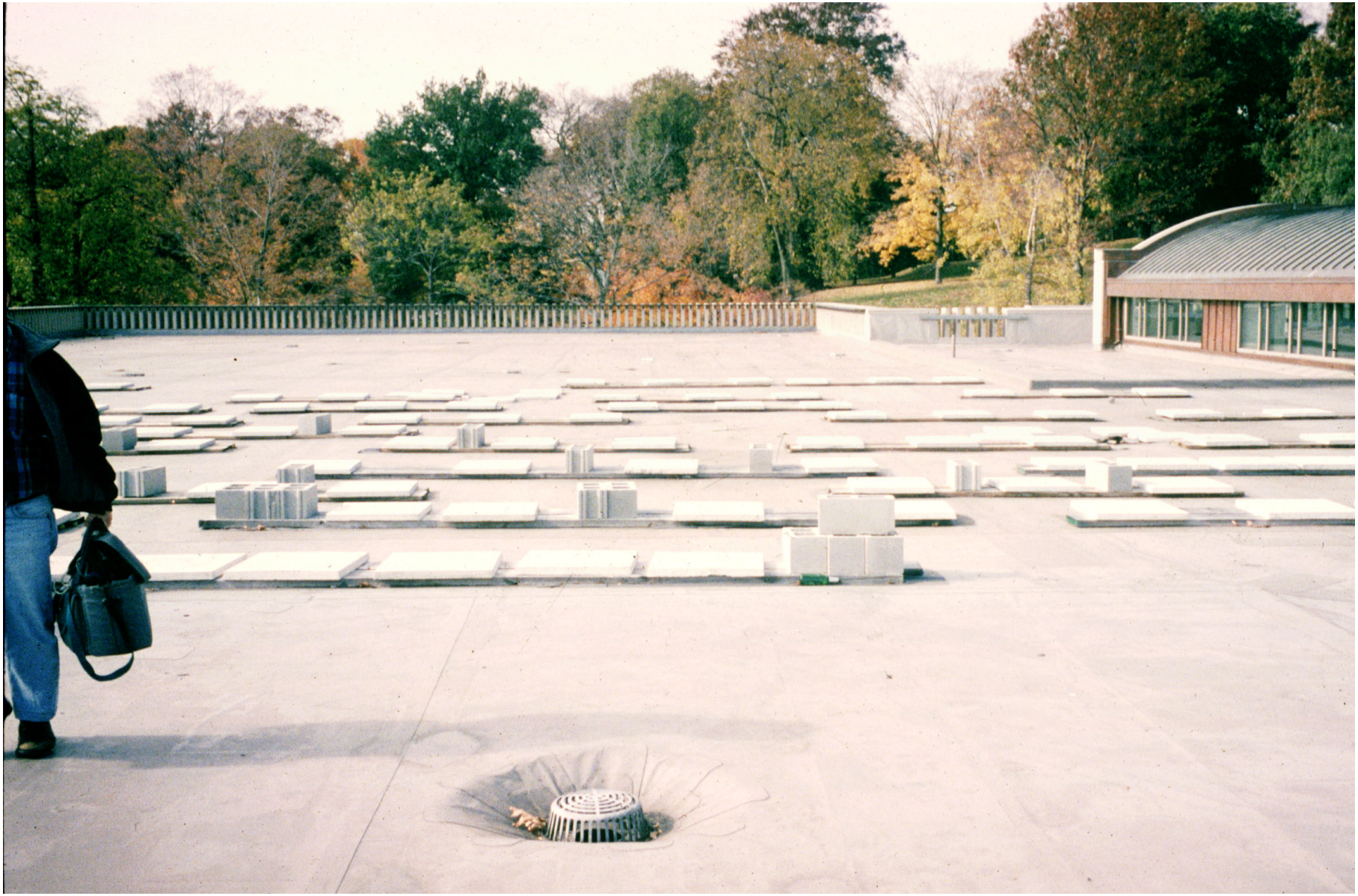
Every 10 degrees C – double the “badness”

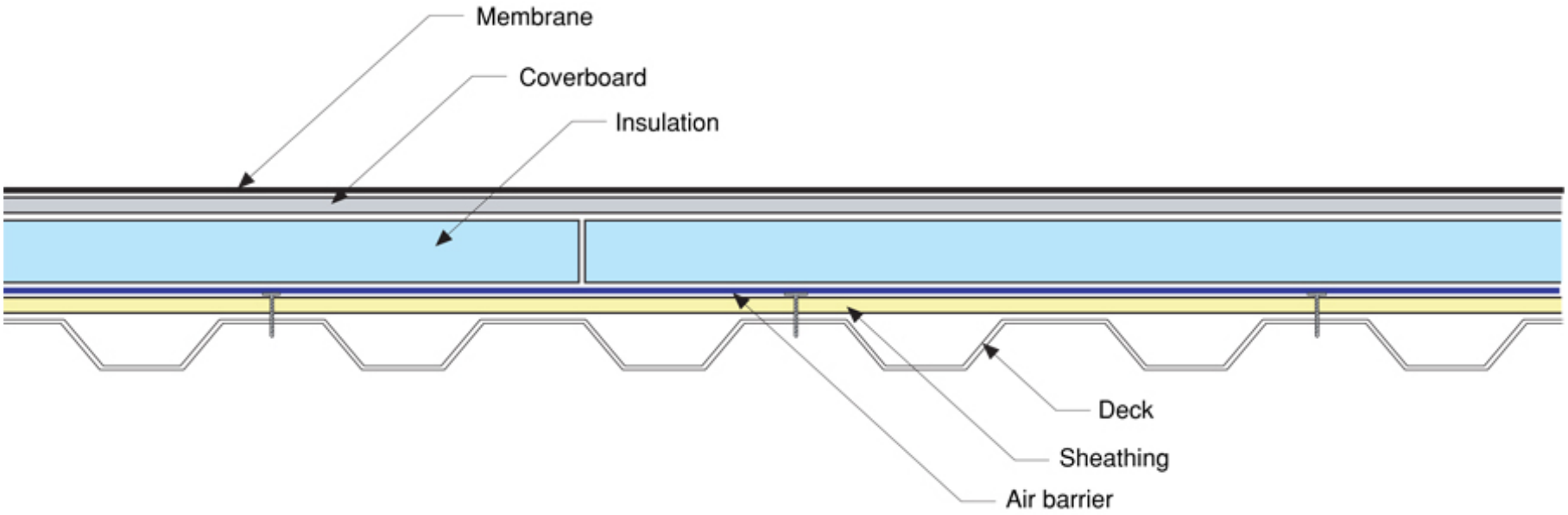


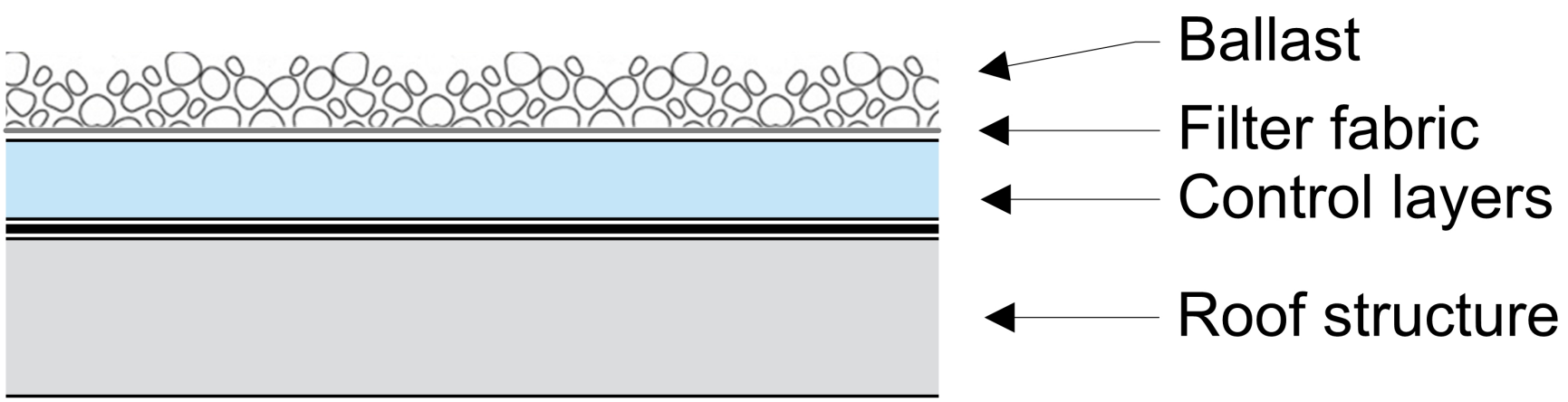

Fully-adhered
membrane
Mechanically attached
rigid insulation

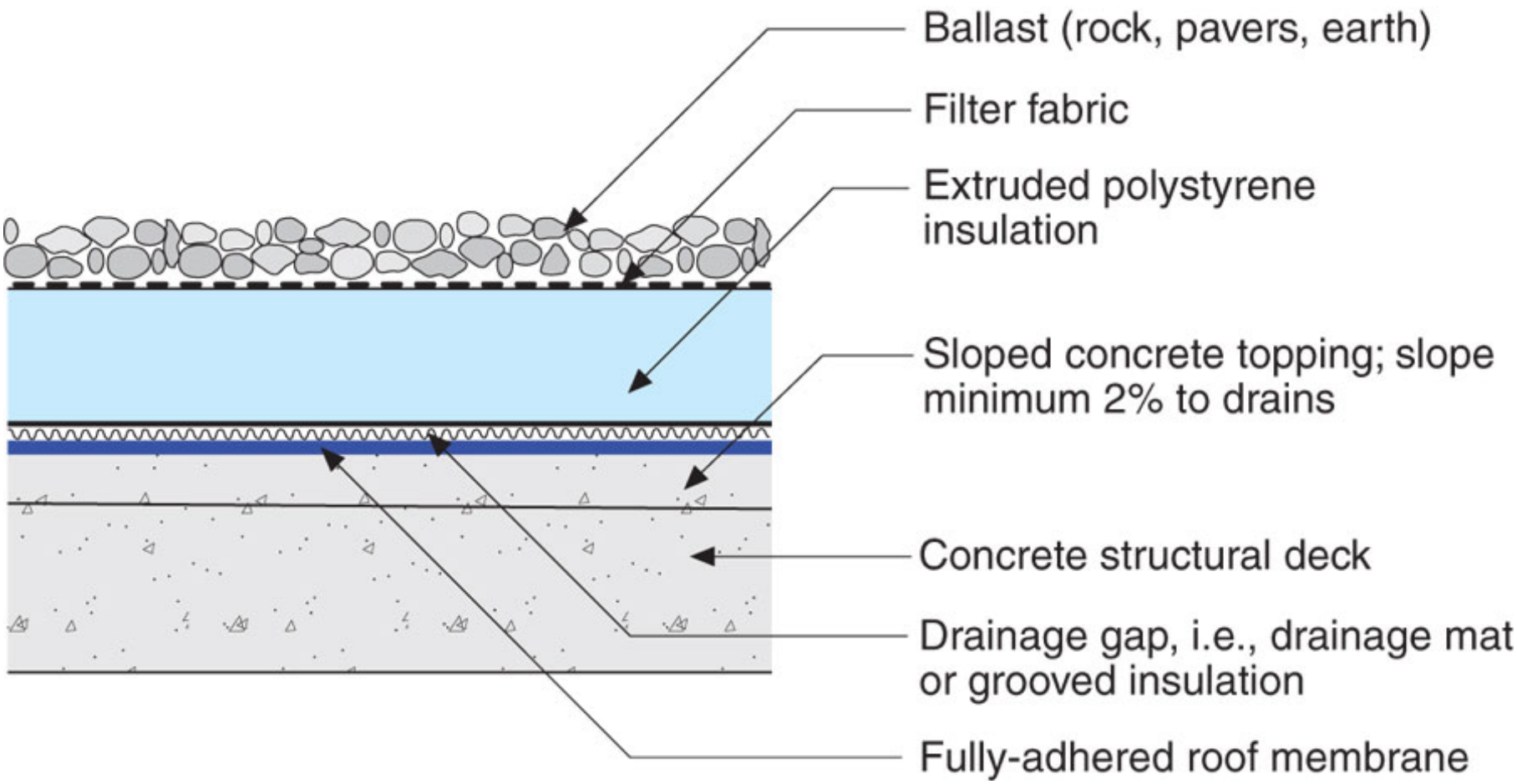

Membrane flutters
Air
leakage

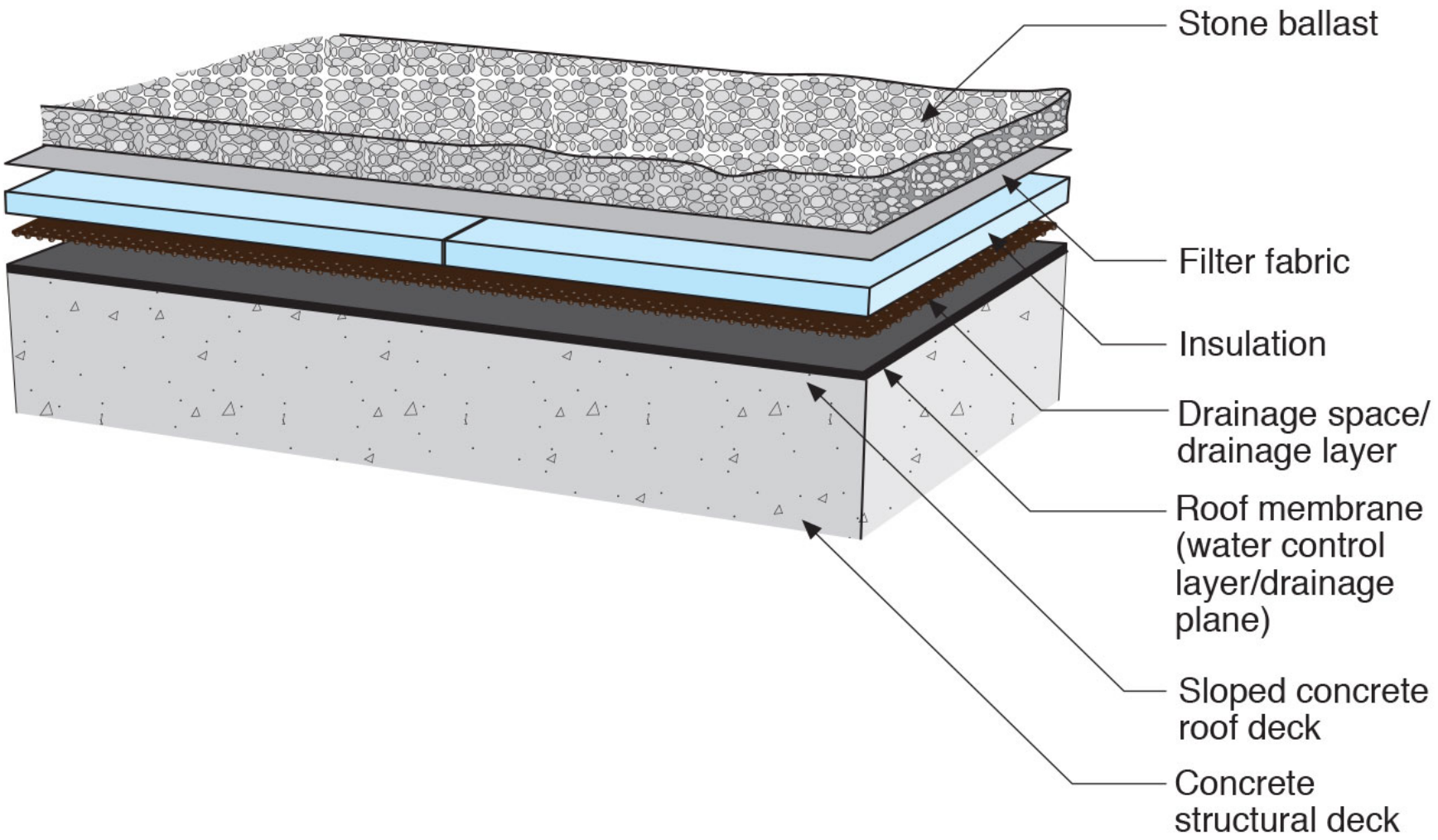

THE TISCH LIBRARY

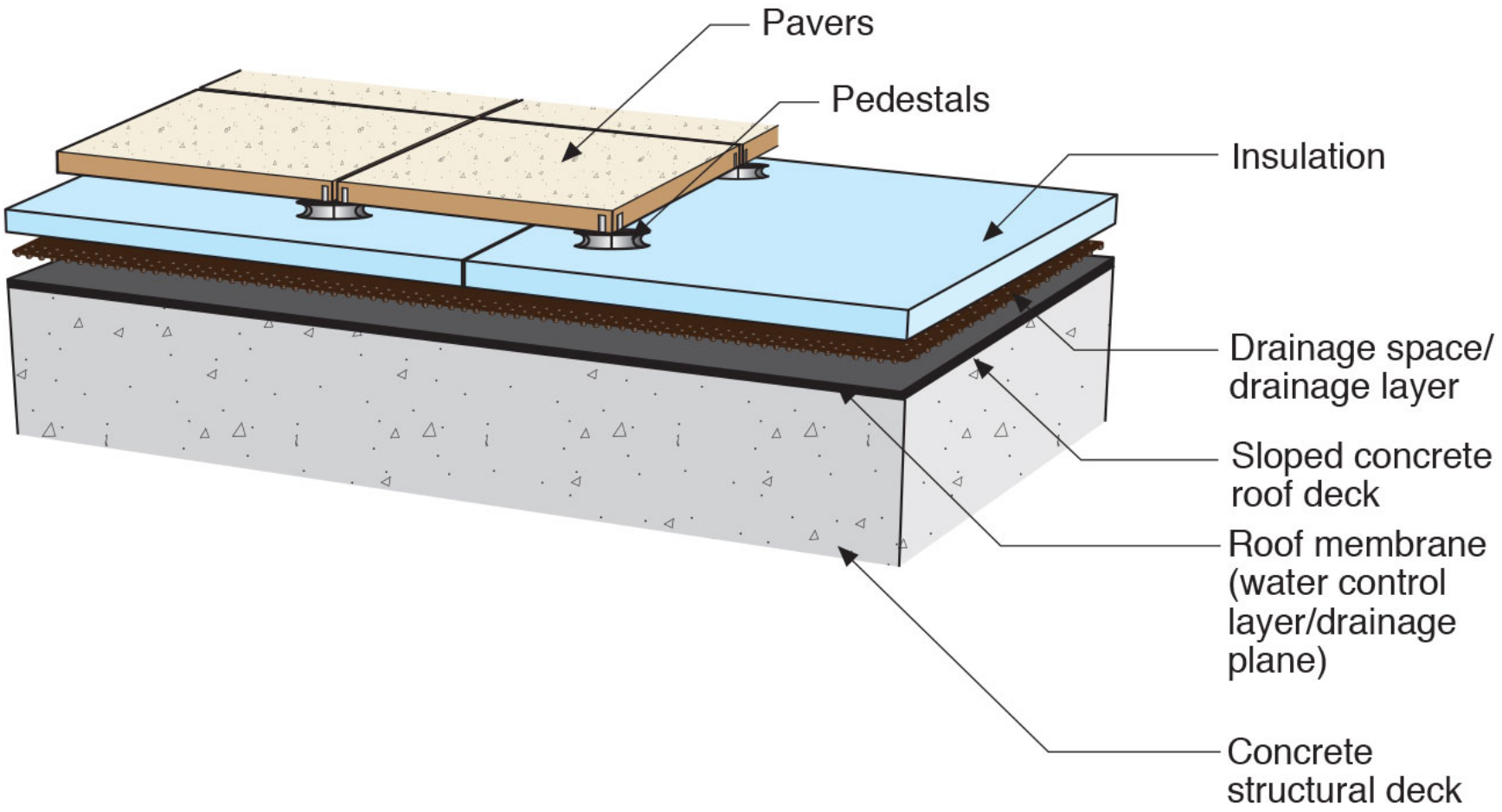


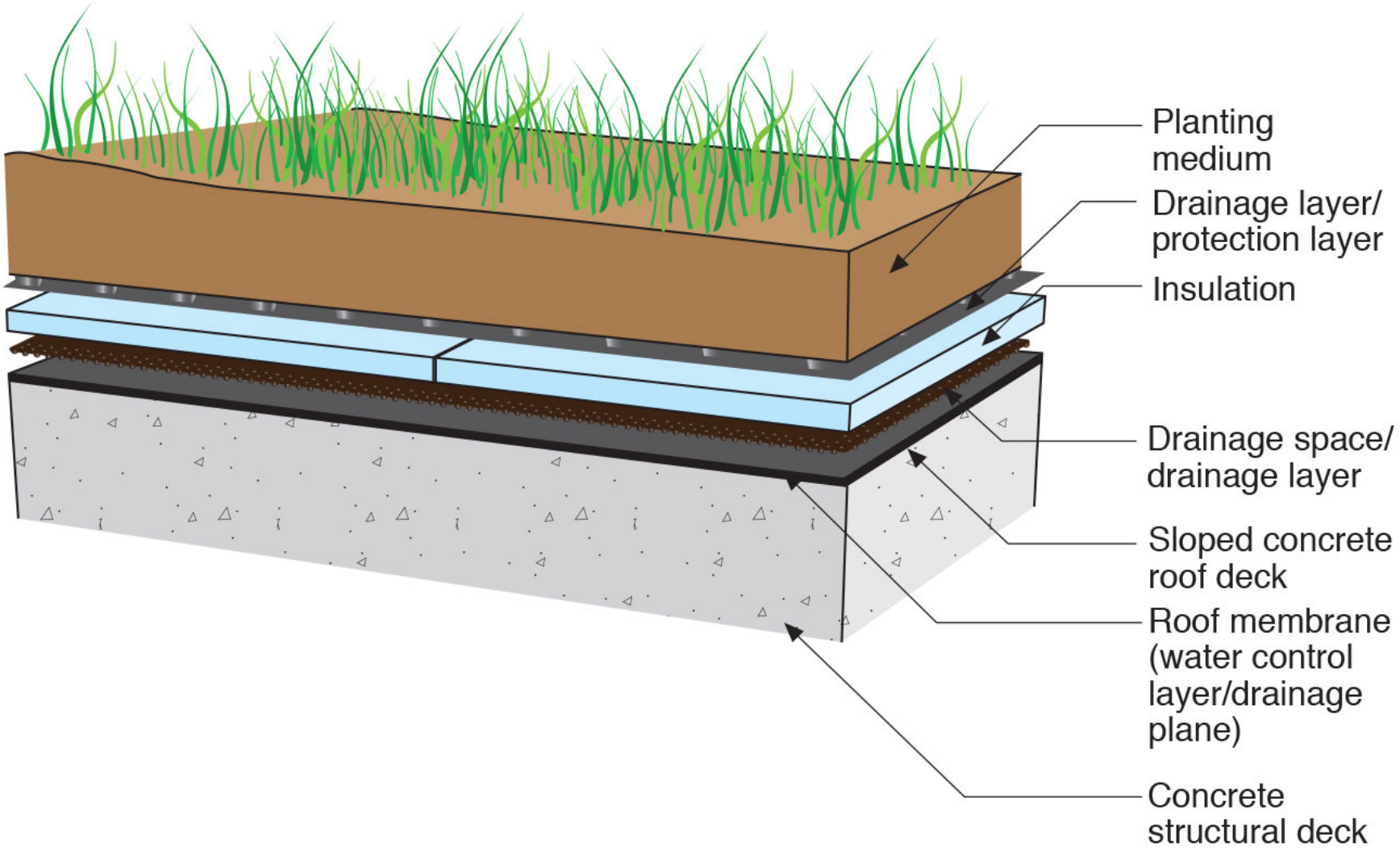

Membrane
Coverboard
Insulation
Deck
Sheathing
Air barrier

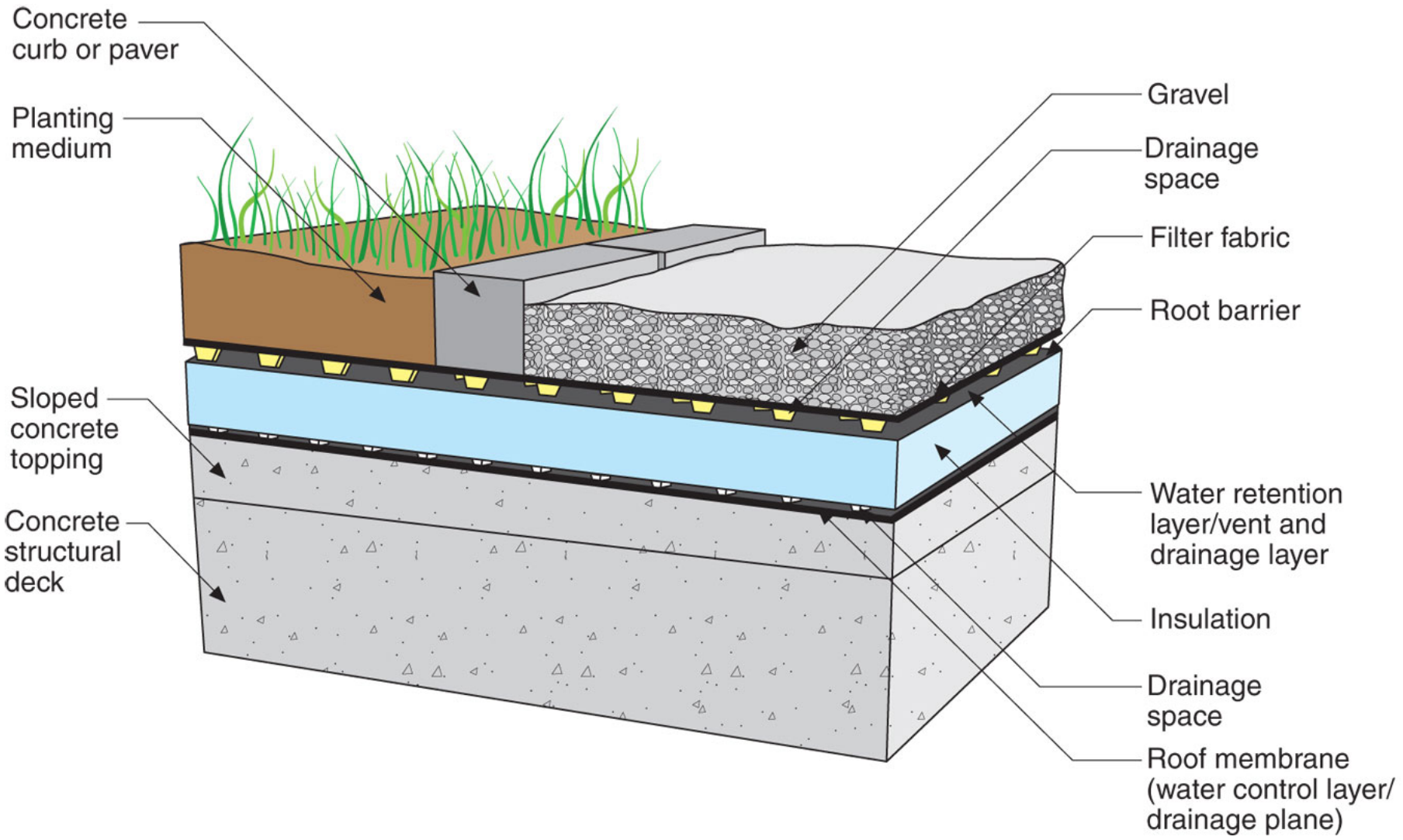

Ballast
Filter fabric
Control layers
Roof structure

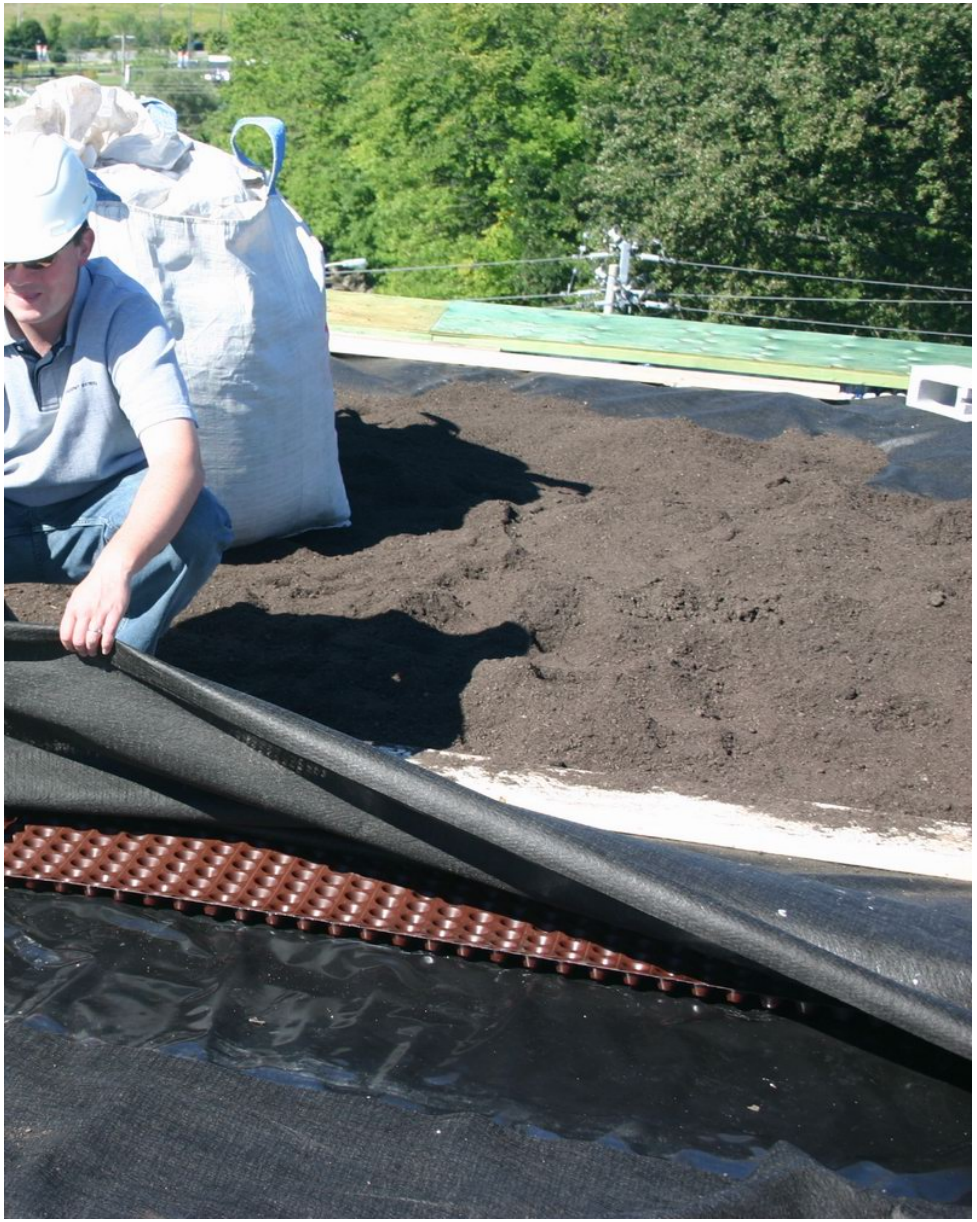

Ballast (rock, pavers, earth)
Filter fabric
Extruded polystyrene insulation
Sloped concrete topping; slope minimum 2% to drains
Concrete structural deck
Drainage gap, i.e., drainage mat or grooved insulation
Fully-adhered roof membrane


Stone ballast
Filter fabric
Insulation
Drainage space/
drainage layer
Roof membrane
(water control
layer/drainage
plane)
Sloped concrete
roof deck
Concrete
structural deck

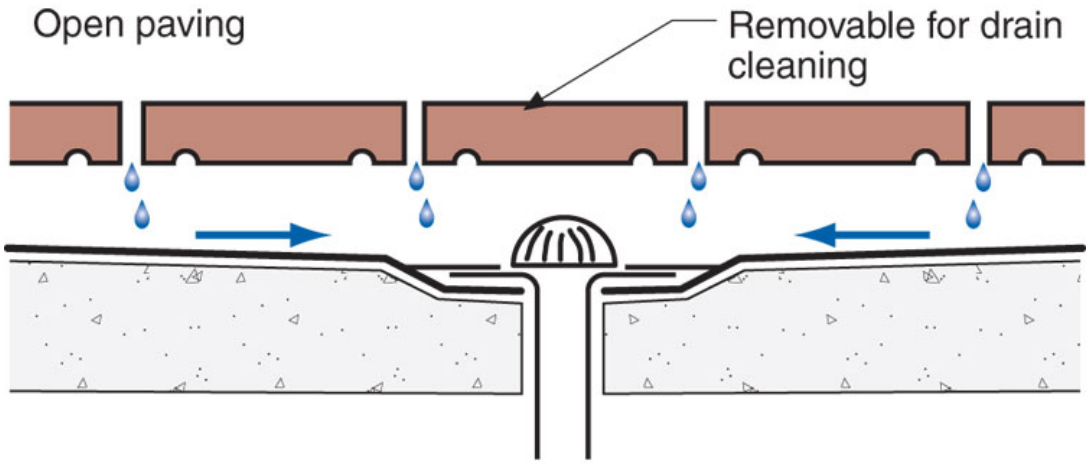

Pavers
Pedestals
Insulation
Drainage space/
drainage layer
Sloped concrete
roof deck
Roof membrane
(water control
layer/drainage
plane)
Concrete
structural deck


Planting medium
Drainage layer/ protection layer
Insulation
Drainage space/ drainage layer
Sloped concrete roof deck
Roof membrane (water control layer/drainage plane)
Concrete structural deck

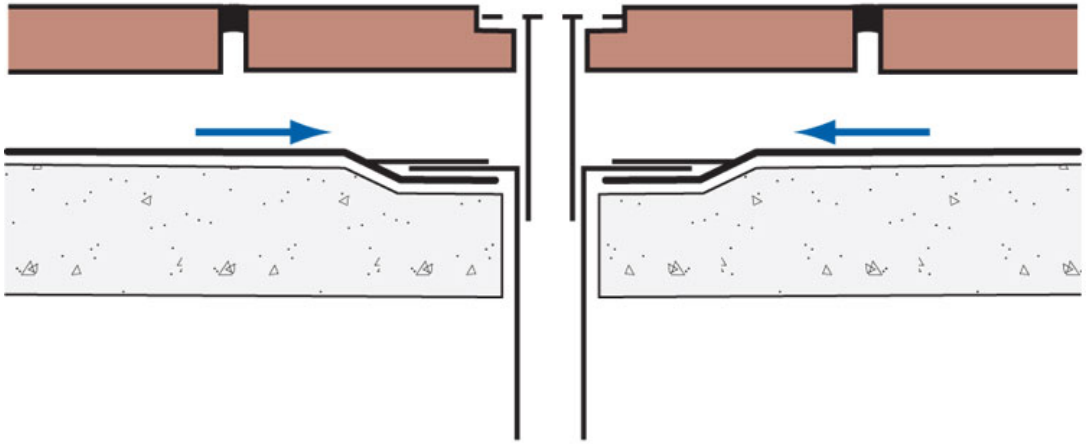

Concrete curb or paver
Planting medium
Sloped concrete topping
Concrete structural deck
Gravel
Drainage space
Filter fabric
Root barrier
Water retention layer/vent and drainage layer
Insulation
Drainage space
Roof membrane (water control layer/ drainage plane)



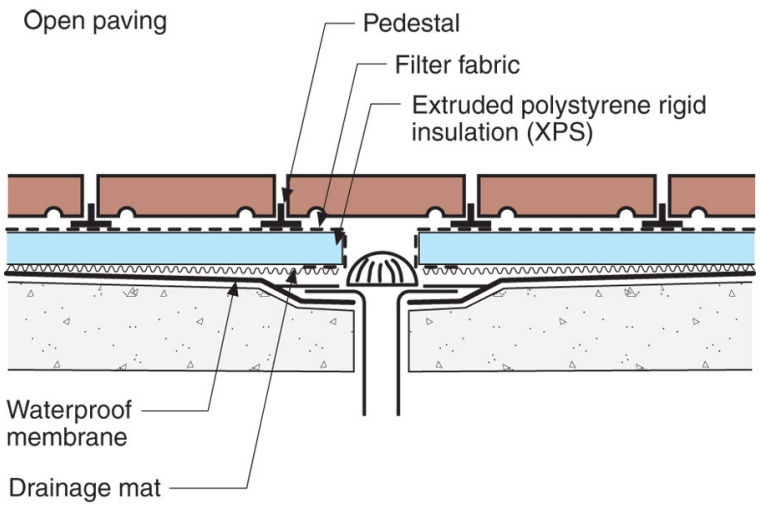
Plaza Decks

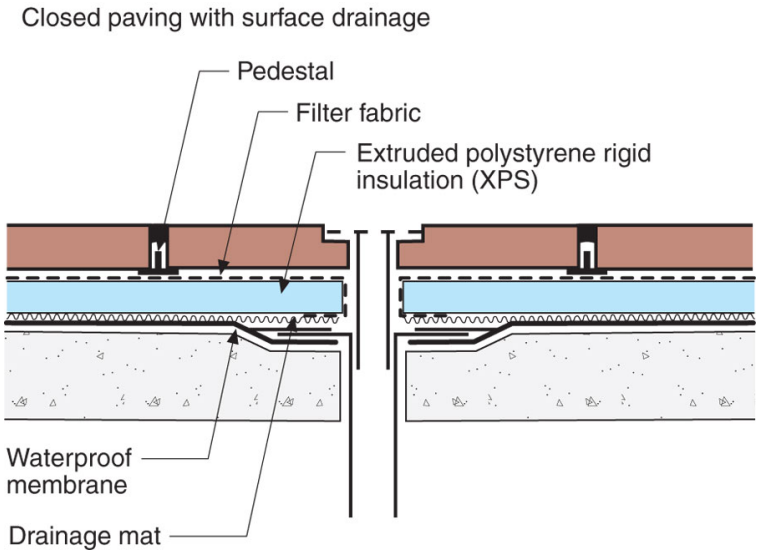


Closed paving with surface drainage

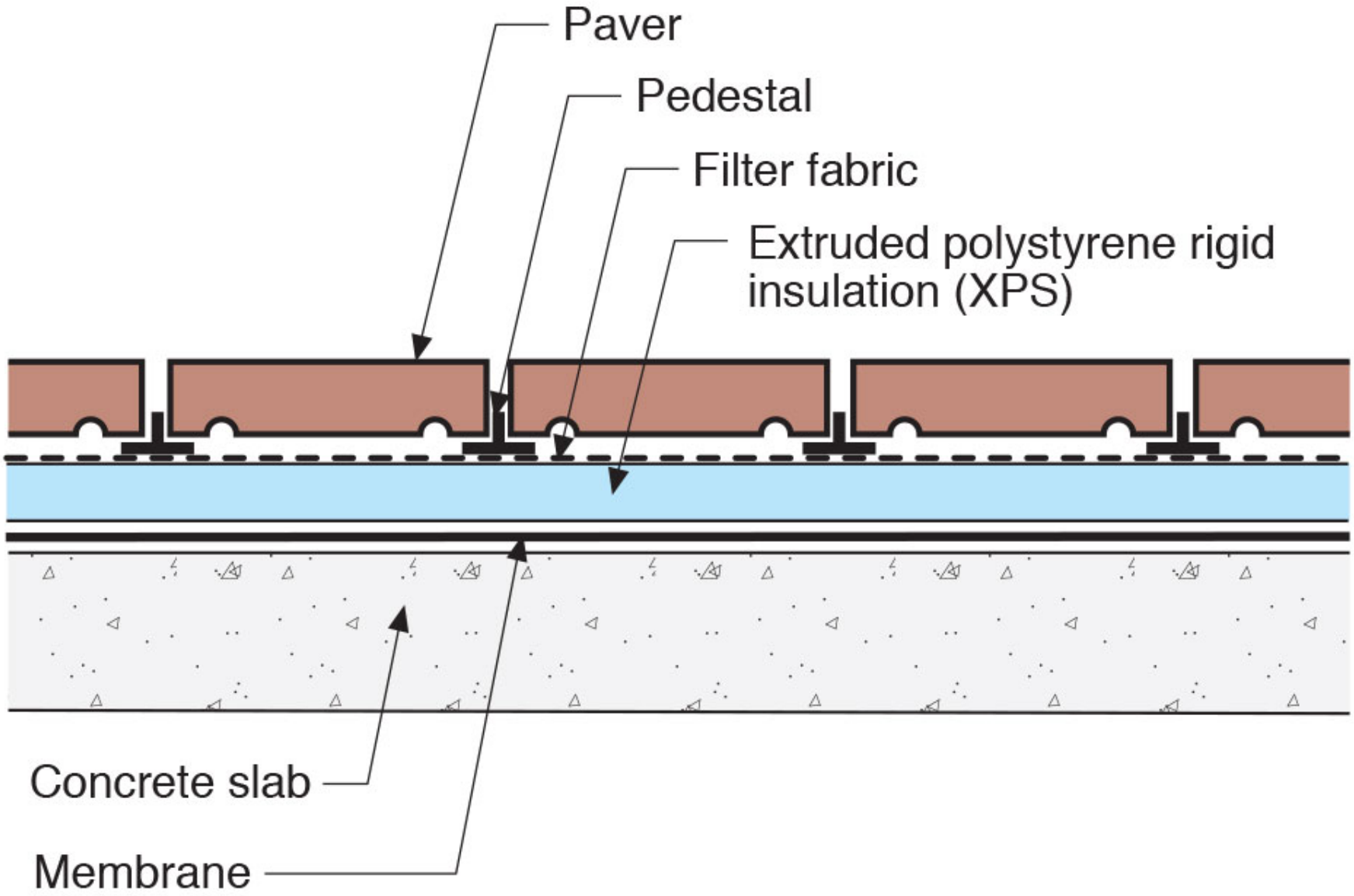


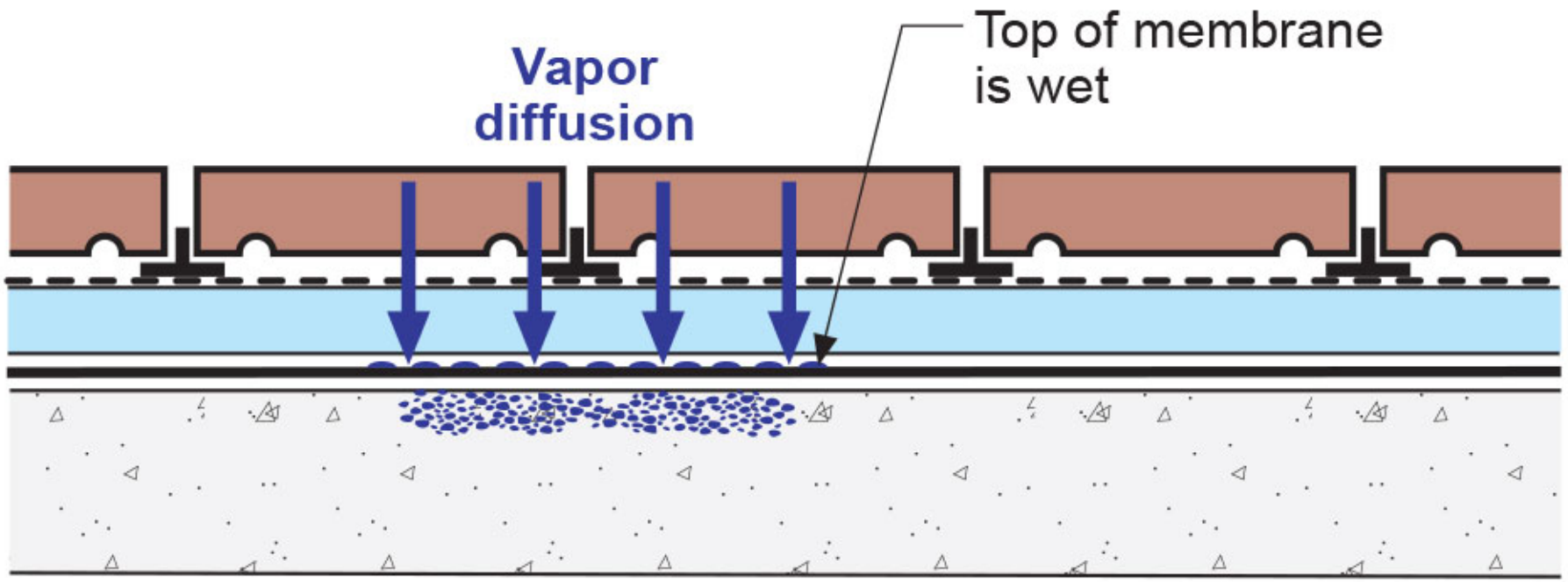
From Baker, M.; Roofs, 1980
Courtesy National Research Council of Canada

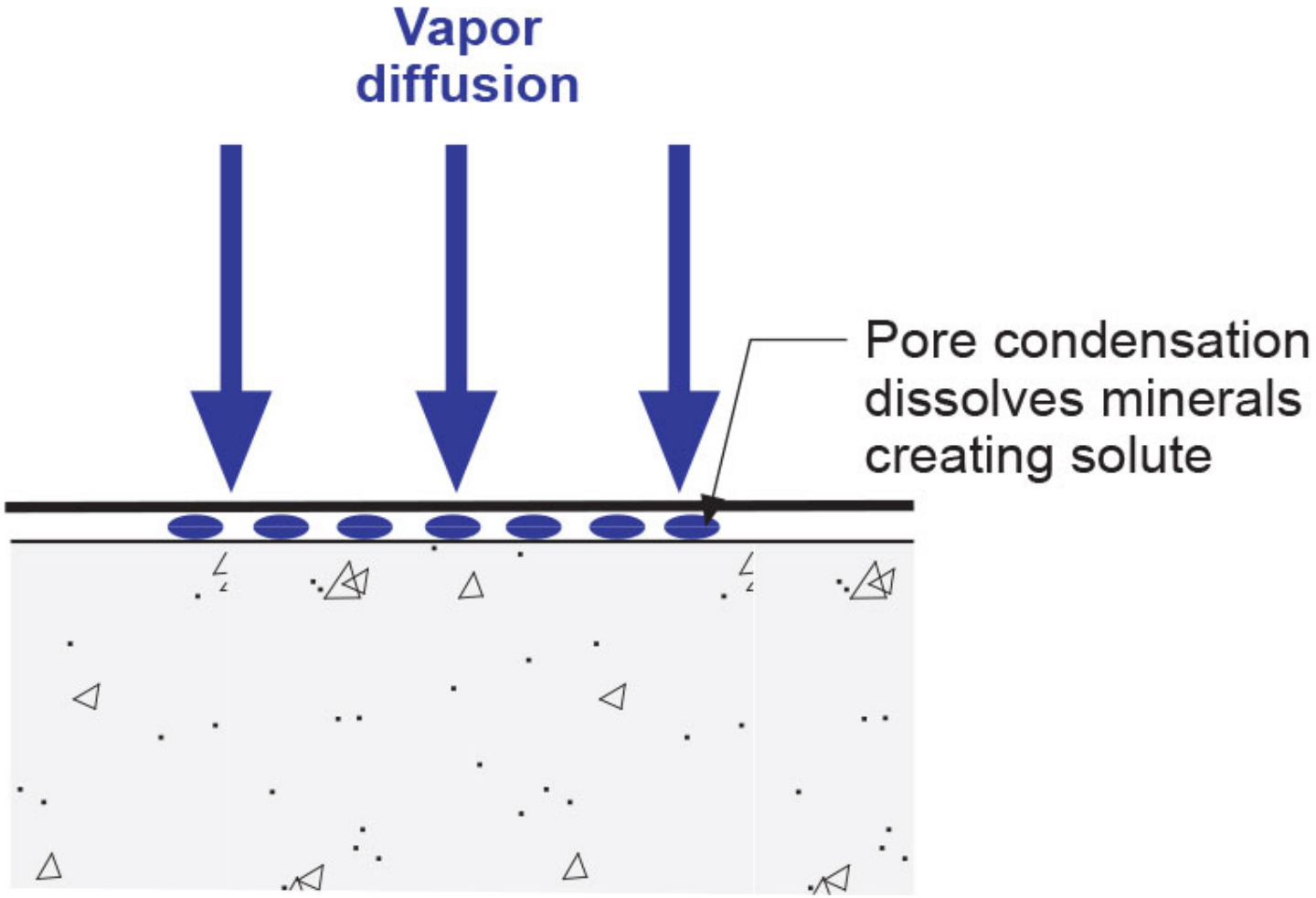

Open paving
Pedestal
Filter fabric
Extruded polystyrene rigid insulation (XPS)
Waterproof membrane
Drainage mat

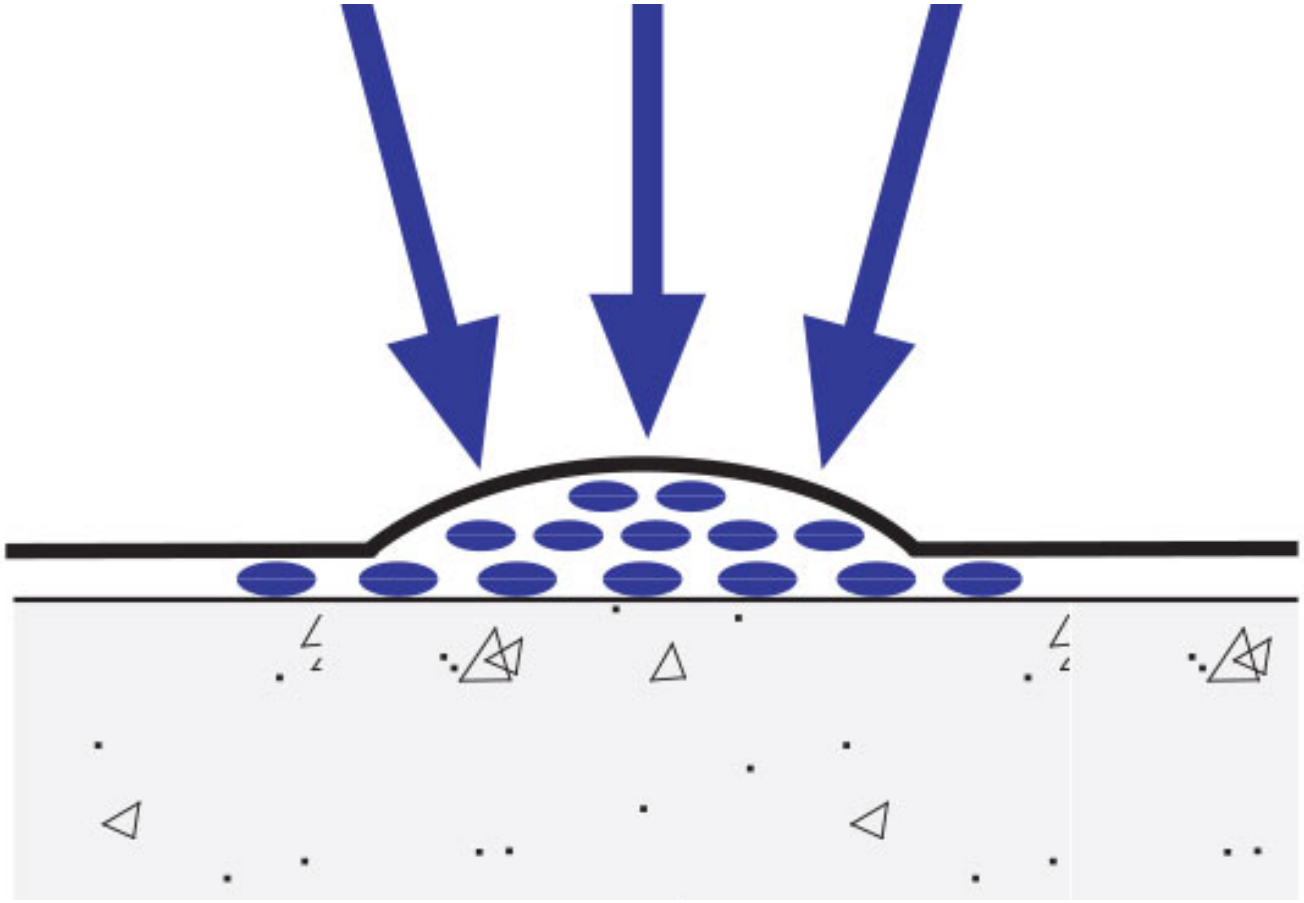

Closed paving with surface drainage
Pedestal
Filter fabric
Extruded polystyrene rigid insulation (XPS)
Waterproof membrane
Drainage mat

Osmosis

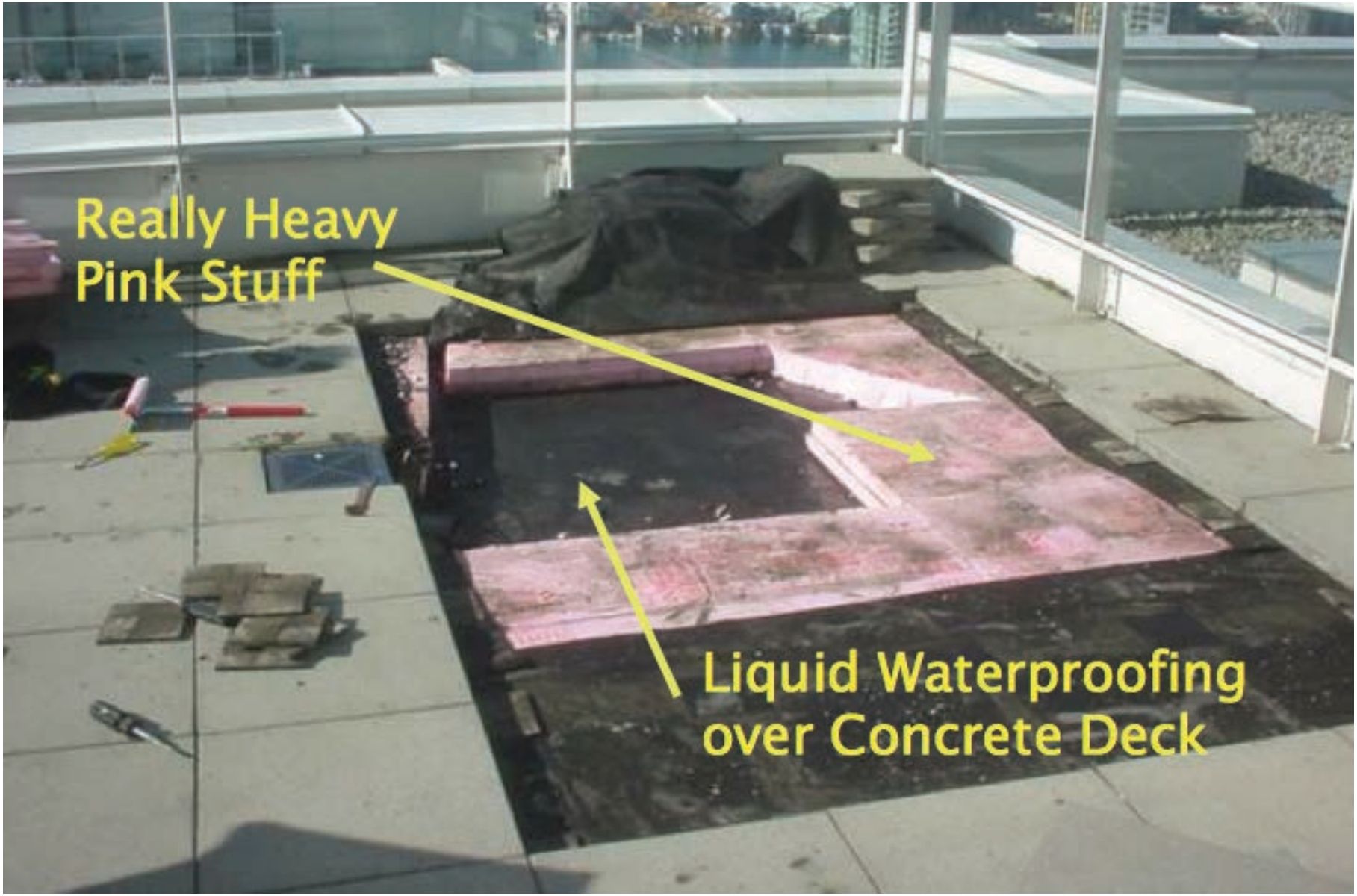

Paver
Pedestal
Filter fabric
Extruded polystyrene rigid insulation (XPS)
Concrete slab
Membrane

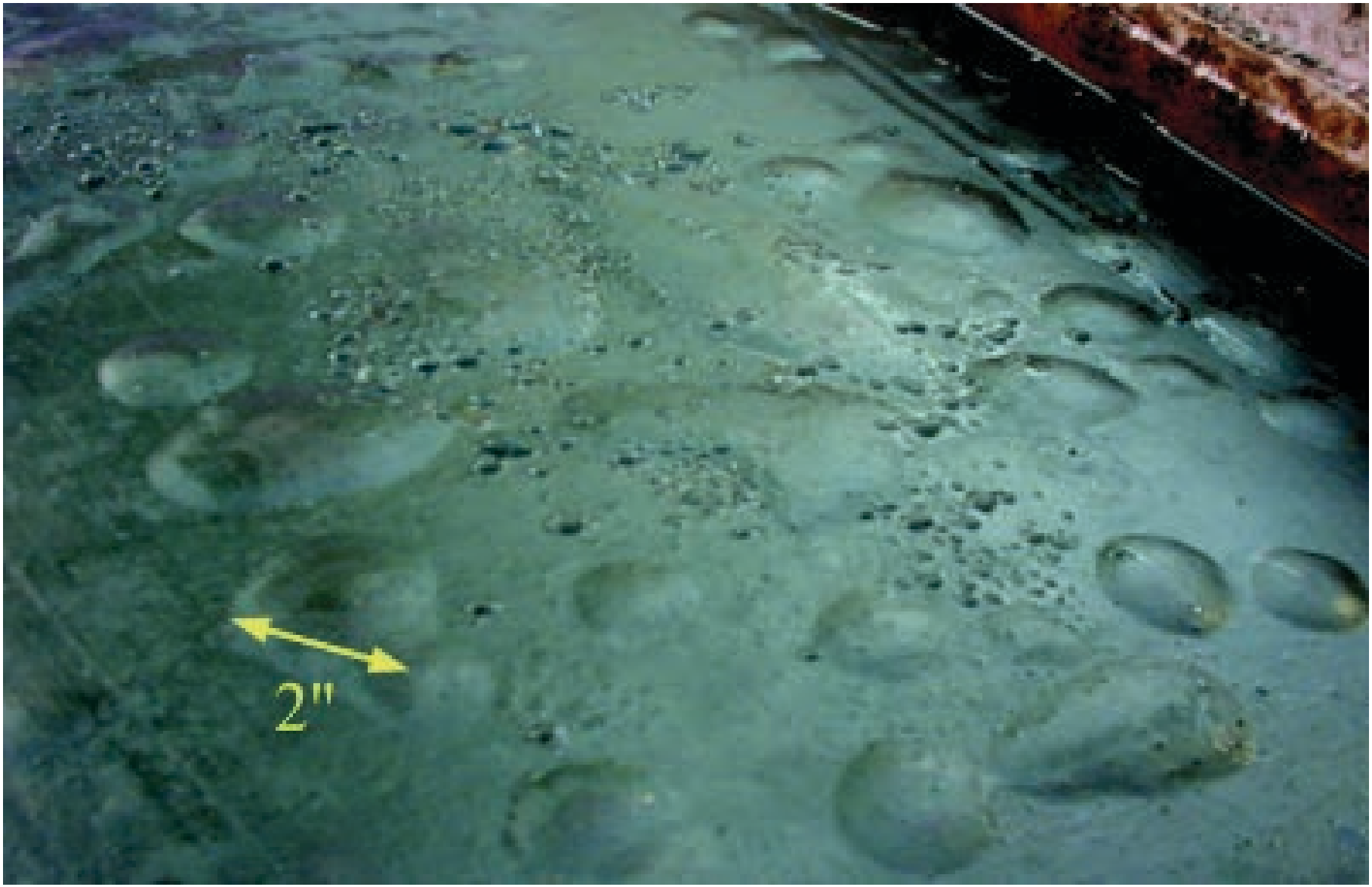

Vapor
diffusion
Top of membrane
is wet

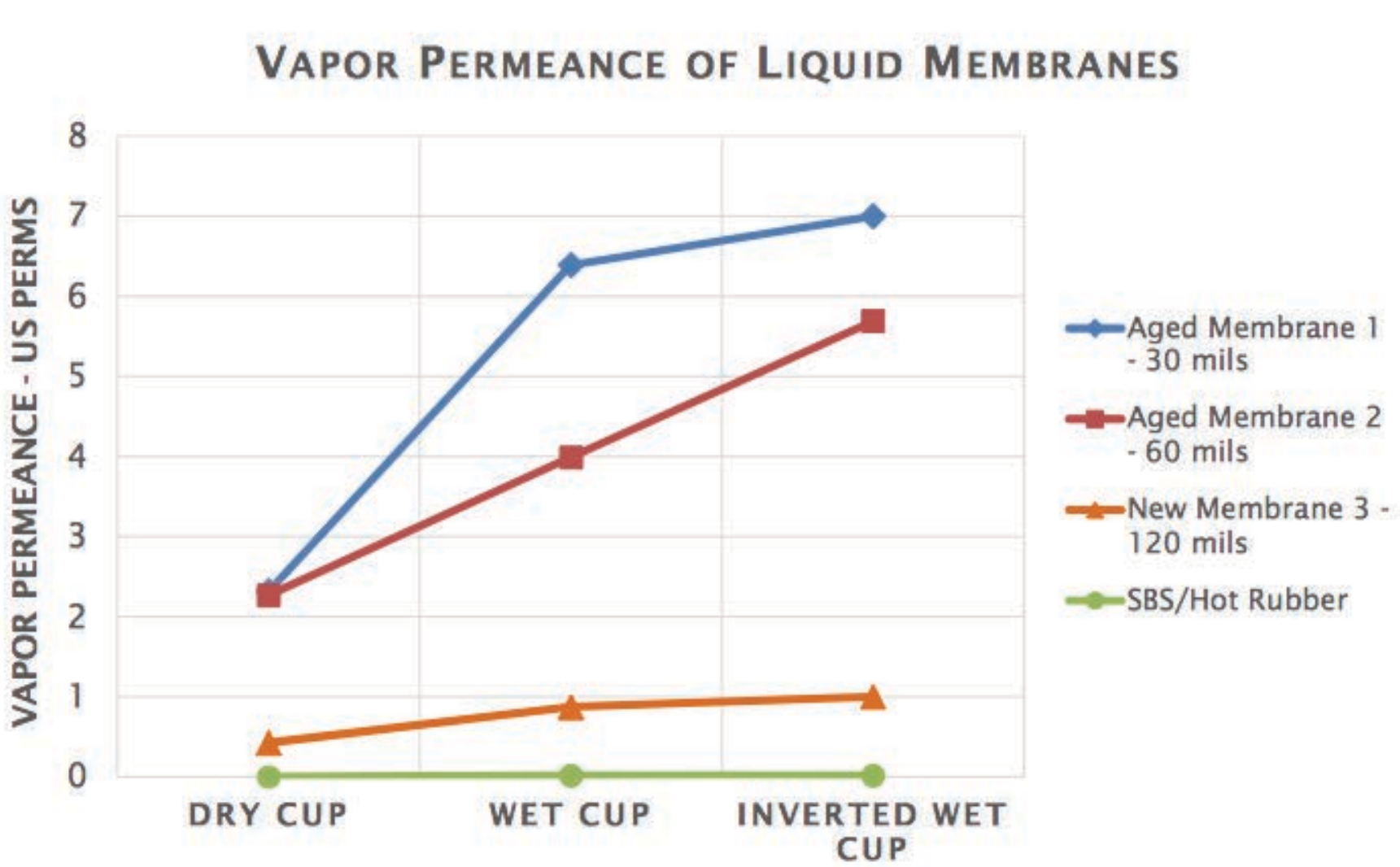

Vapor
diffusion
Pore condensation
dissolves minerals
creating solute

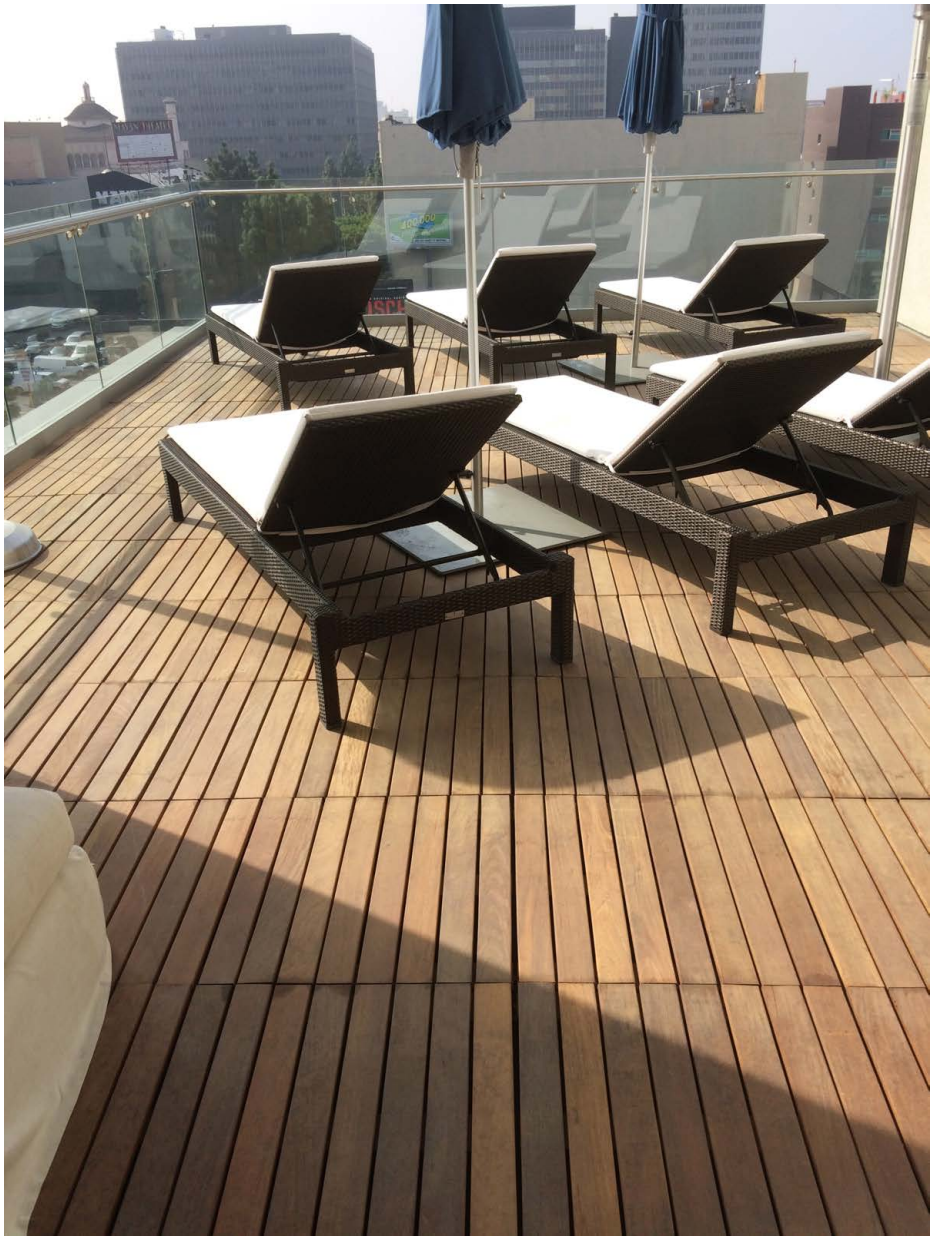


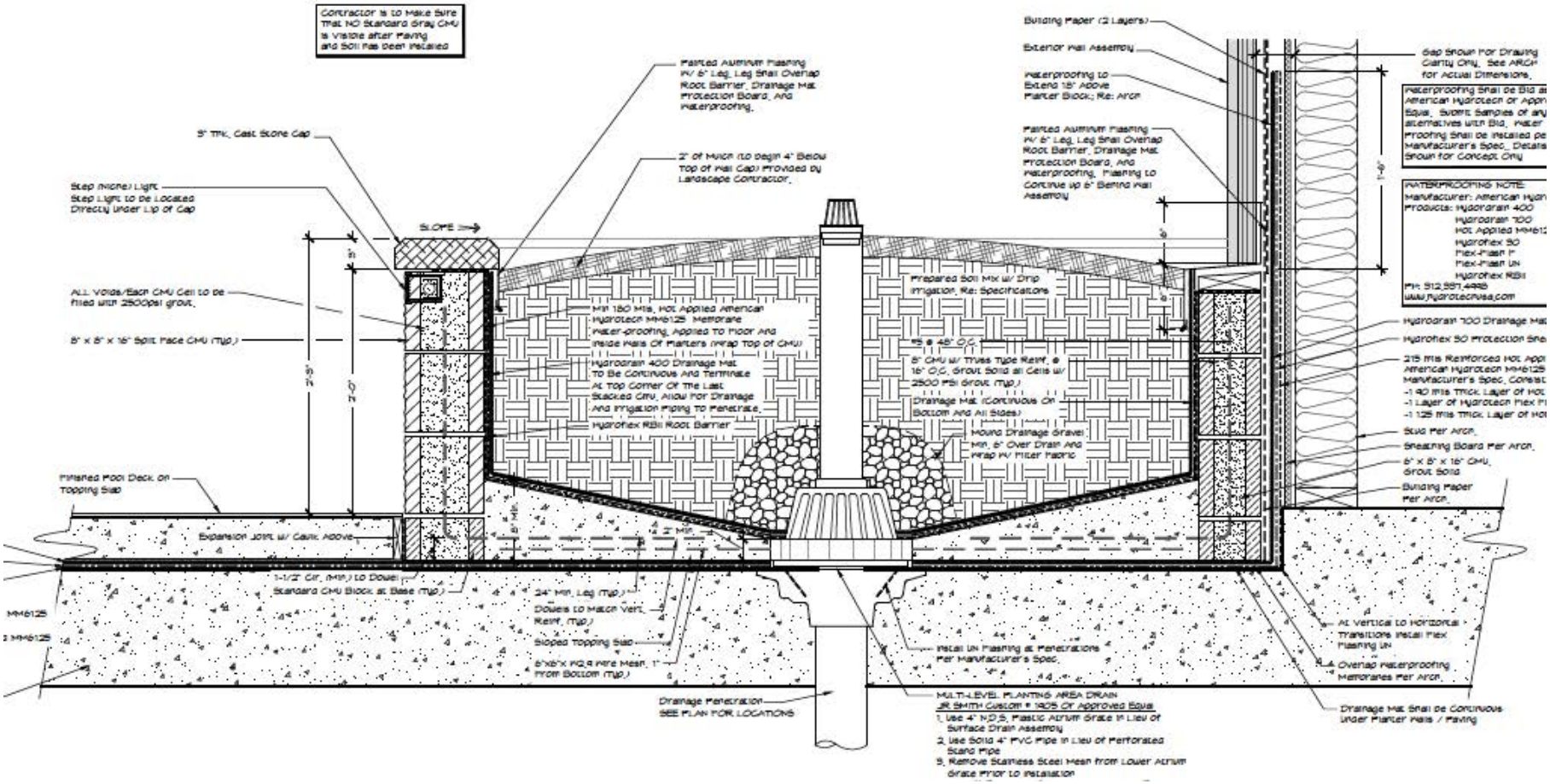
Paver Water Beds!


Really Heavy
Pink Stuff
Liquid Waterproofing
over Concrete Deck


2"


VAPOR PERMEANCE OF LIQUID MEMBRANES
VAPOR PERMEANCE - US PERMS
8
7
6
5
4
3
2
1
0
DRY CUP
WET CUP
INVERTED WET CUP
Aged Membrane 1 - 30 mils
Aged Membrane 2 - 60 mils
New Membrane 3 - 120 mils
SBS/Hot Rubber




Contractor is to Make Sure That NO Standard Gray CMU is Visible after Paving and Soil has been Installed
Painted Aluminum Flashing W/ 6" Leg, Leg Shall Overlap Root Barrier, Drainage Mat Protection Board, and Waterproofing.
2" of Mulch (To Begin 4" Below Top of Wall Cap) Provided by Landscape Contractor.
5" Thk. Cast Stone Cap
Step (Niche) Light
Step Light to be Located Directly Under Lip of Cap
SLOPE
All Voids/Each CMU Cell to be Filled with 2500psi grout.
8" x 8" x 16" Split Face CMU (Typ.)
Min 180 Mils, Hot Applied American Hydrotech MM6125 Membrane Water-proofing, Applied to Floor and Inside Walls of Planters (Wrap Top of CMU)
Hydrodrain 400 Drainage Mat To Be Continuous and Terminate At Top Corner of the Last Stacked CMU. Allow for Drainage and Irrigation Piping to Penetrate.
Hydrotex RBII Root Barrier
Prepared Soil Mix w/ Drip Irrigation, Re: Specifications
#5 @ 48" O.C.
8" CMU w/ Truss Type Reinf. @ 16" O.C. Grout Solid all Cells w/ 2500 PSI Grout (Typ.)
Drainage Mat (Continuous On Bottom and All Sides)
Mound Drainage Gravel Min. 6" Over Drain and Wrap W/ Filter Fabric
Finished Pool Deck on Topping Slab
Expansion Joint w/ Caulk Above
1-1/2" Clr. (Min.) to Dowel
Standard CMU Block at Base (Typ.)
24" Min. Leg (Typ.)
Dowels to Match Vert. Reinf. (Typ.)
Sloped Topping Slab
6"x6"x W2.9 Wire Mesh, 1" from Bottom (Typ.)
Drainage Penetration SEE PLAN FOR LOCATIONS
Building Paper (2 Layers)
Exterior Wall Assembly
Waterproofing to Extend 18" Above Planter Block; Re: Arch
Painted Aluminum Flashing W/ 6" Leg, Leg Shall Overlap Root Barrier, Drainage Mat Protection Board, and Waterproofing. Flashing to Continue up & Behind Wall Assembly
Gap Shown for Drawing Clarity Only. See Arch for Actual Dimensions.
Waterproofing Shall be Bid as American Hydrotech or Approved Equal. Submit Samples of any Alternatives with Bid. Water Proofing Shall be Installed per Manufacturer's Spec. Details Shown for Concept Only
WATERPROOFING NOTE:
Manufacturer: American Hydrotech
Products: Hydrodrain 400
Hydrodrain 700
Hot Applied MM612
Hydrotex 50
Flex-Flash II
Flex-Flash UN
Hydrotex RBII
PH: 312.337.4498
www.hydrotechusa.com
Hydrodrain 700 Drainage Mat
Hydrotex 50 Protection Sheet
215 Mils Reinforced Hot Applied American Hydrotech MM6125 Membrane Manufacturer's Spec. Consist of:
-1 90 Mils Thick Layer of Hot
-1 Layer of Hydrotech Flex Fl
-1 125 Mils Thick Layer of Hot
Stud Per Arch.
Sheating Board Per Arch.
8" x 8" x 16" CMU, Grout Solid
Building Paper Per Arch.
At Vertical to Horizontal Transitions Install Flex Flashing UN
4" Overlap Waterproofing Membranes Per Arch.
Drainage Mat Shall be Continuous Under Planter Walls / Paving
Install UN Flashing at Penetrations Per Manufacturer's Spec.
MULTI-LEVEL PLANTING AREA DRAIN
JR SMITH Custom # 1905 Or Approved Equal
1. Use 4" N.D.S. Plastic Atrium Grate in Lieu of Surface Drain Assembly
2. Use Solid 4" PVC Pipe in Lieu of Perforated Stand Pipe
3. Remove Stainless Steel Mesh from Lower Atrium Grate Prior to Installation


03/04/2013 13:08


01/25/2013 09:31


Tyvek
FlexWrap NF
03/14/2013 08:59