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

Building Science

Wood Is Good…

www.buildingscience.com

Wood is good…. it grows on trees…

Transition From A Hydrocarbon Based Economy to a Carbohydrate Based Economy

Wood Is A Battery For Energy From The Sun

Carbon + Water + Sunlight = Wood

(photosynthesis)

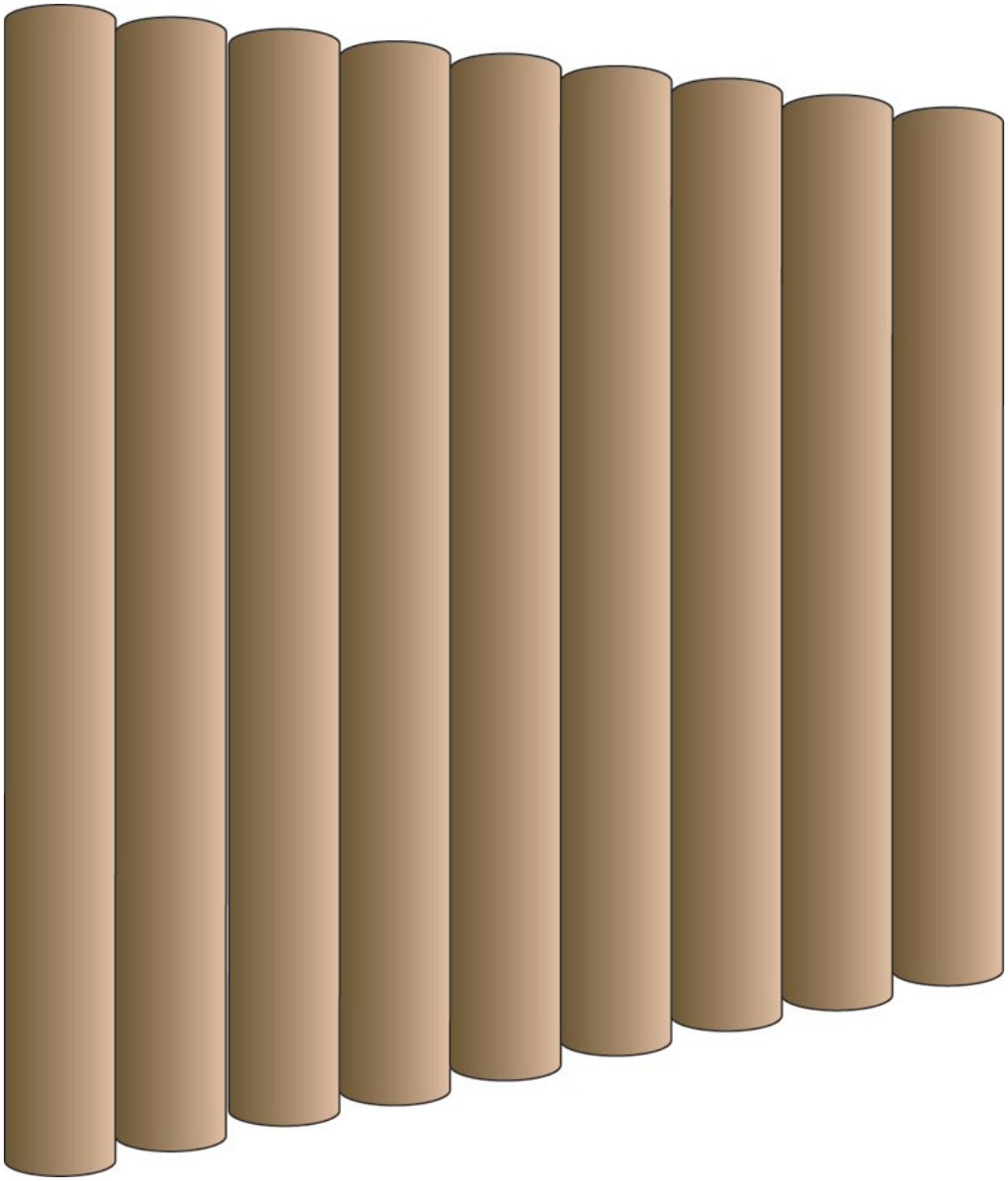
Wood Is The Ultimate Building Material

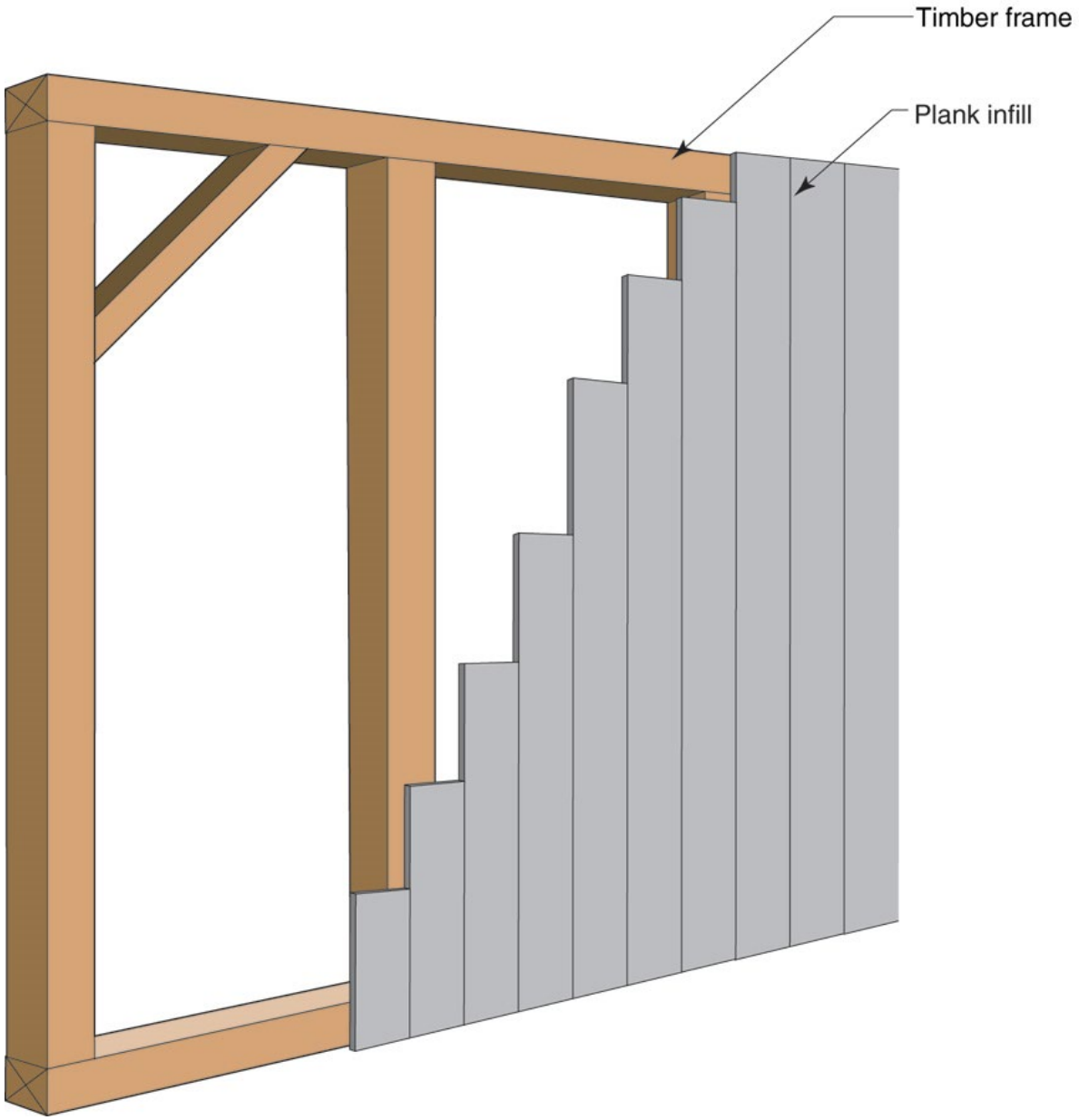
When We Are Done It Turns Back To Carbon and Water and Releases The Energy

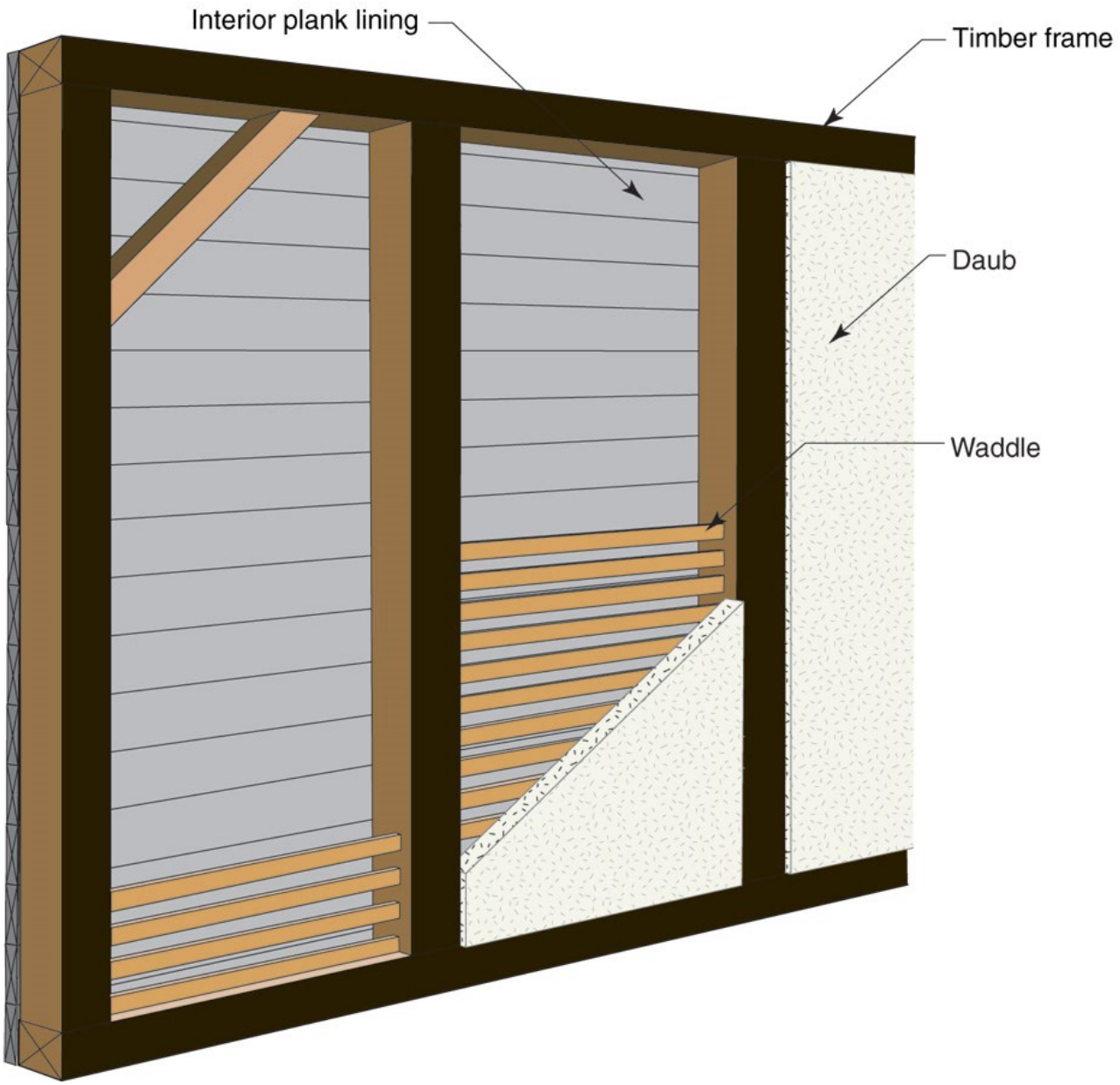
Plants Do A Better Job Of Converting Solar Energy Than Rocks

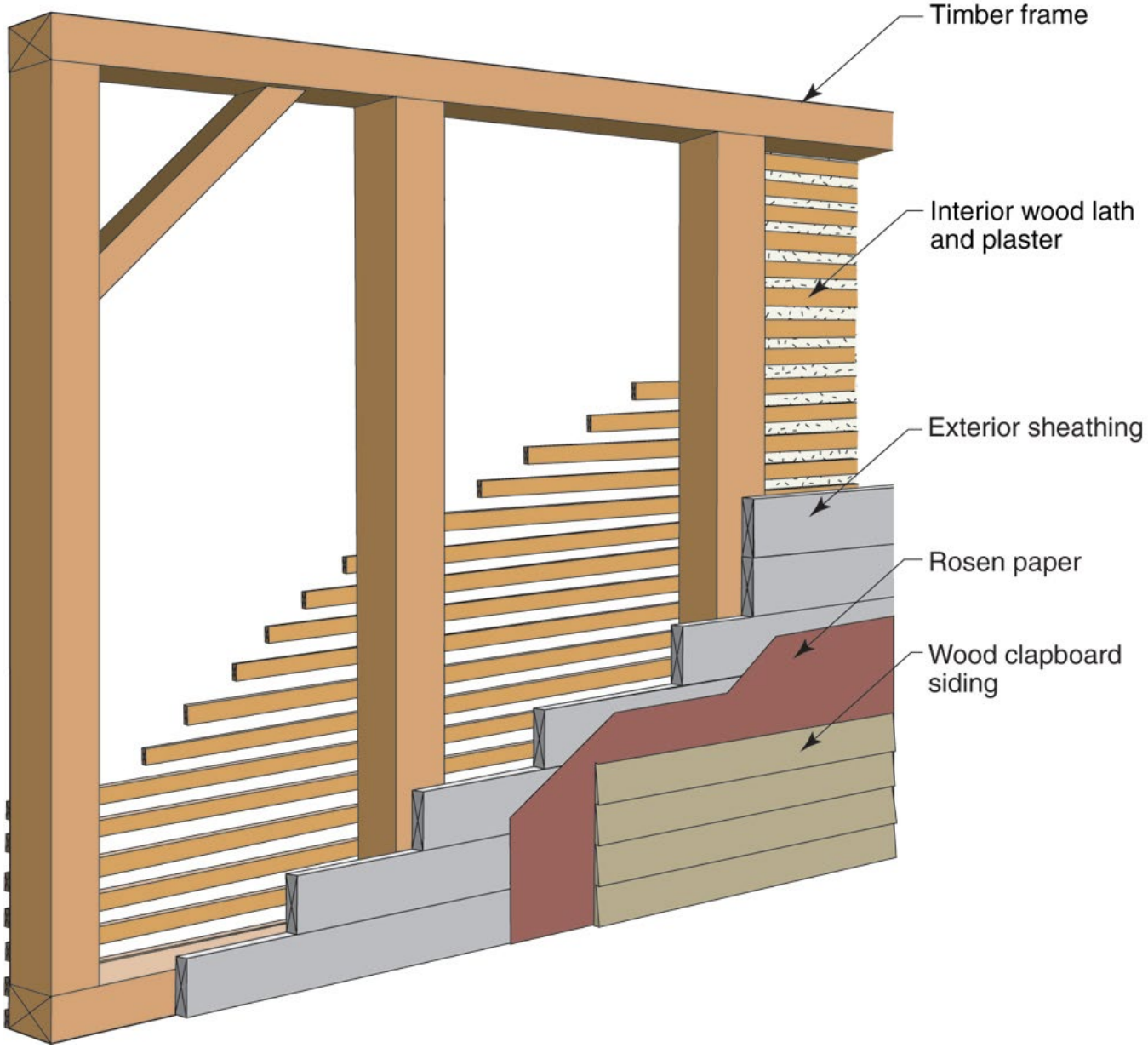
Let The Plants Do It

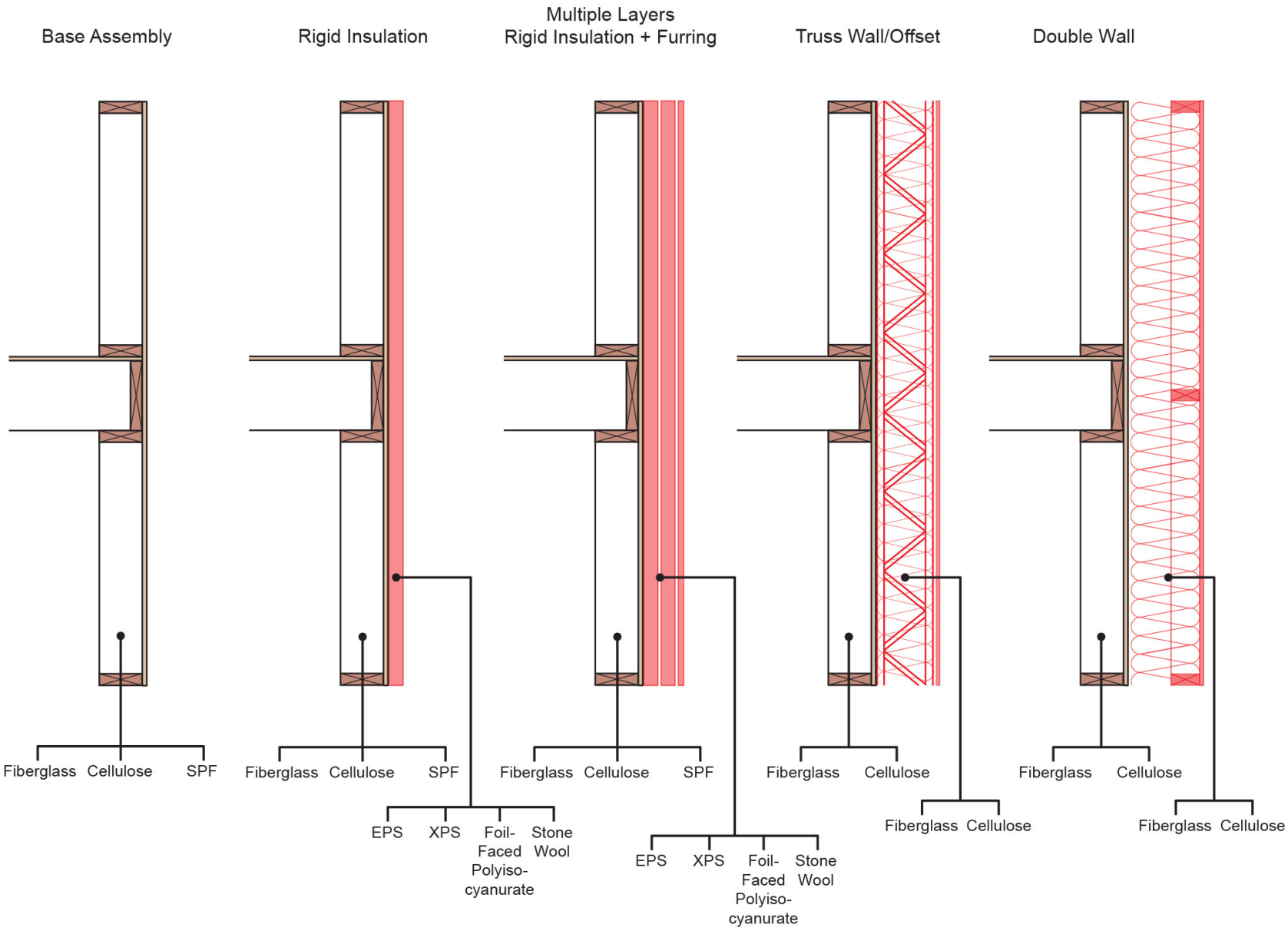
Wood Wall Evolution

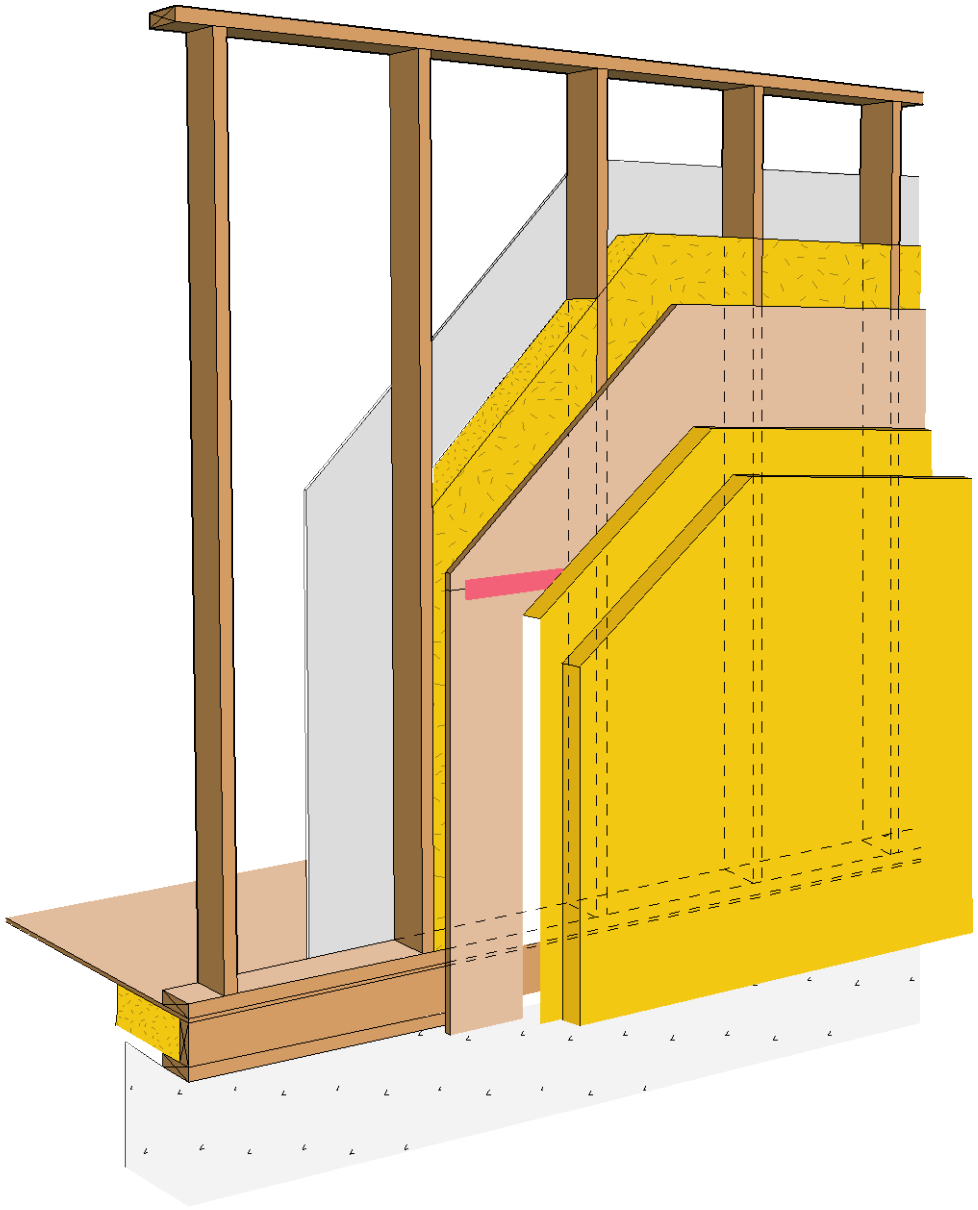


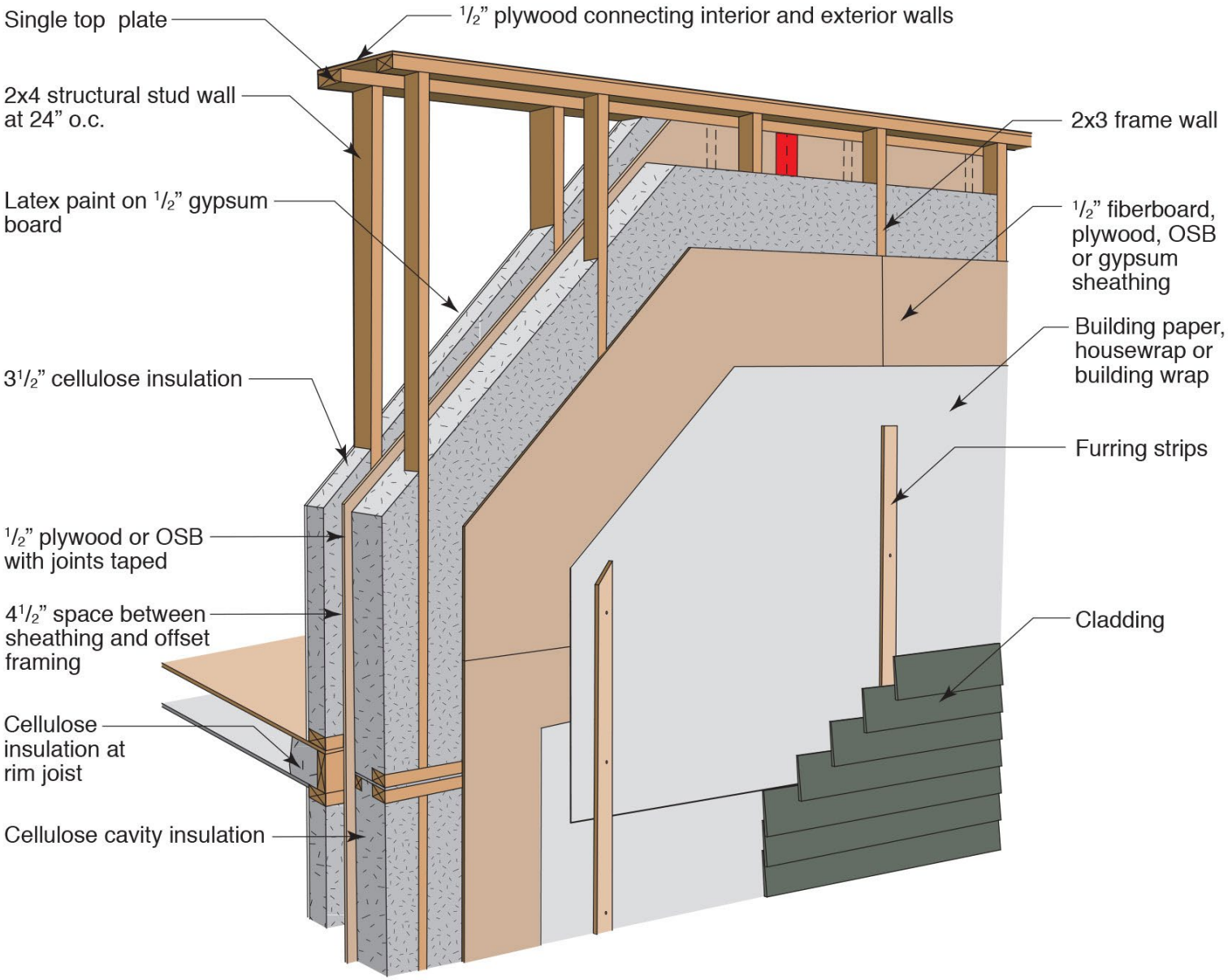

Timber frame
Plank infill

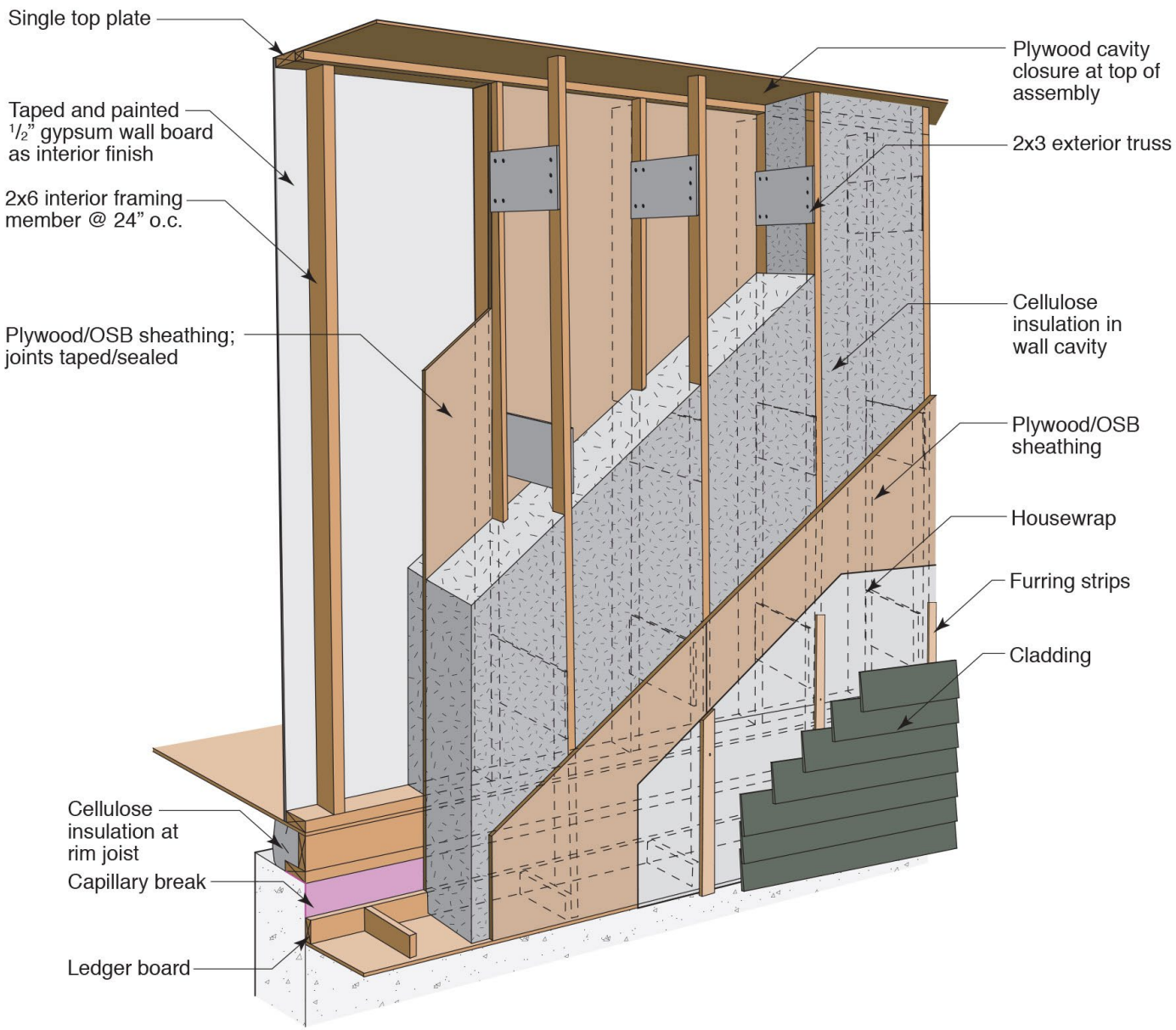

Interior plank lining
Timber frame
Daub
Waddle

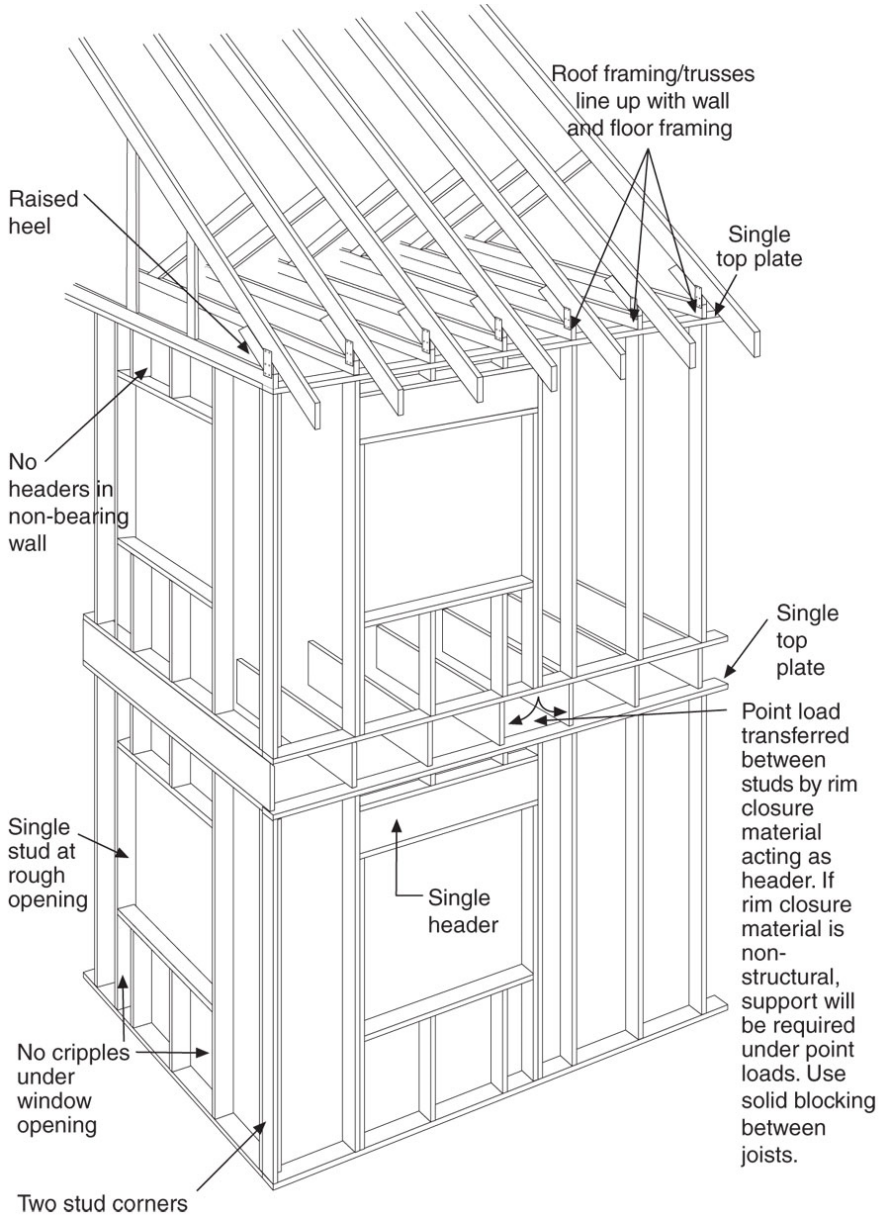

Timber frame
Interior wood lath and plaster
Exterior sheathing
Rosen paper
Wood clapboard siding


Base Assembly
Rigid Insulation
Multiple Layers
Rigid Insulation + Furring
Truss Wall/Offset
Double Wall
Fiberglass
Cellulose
SPF
EPS
XPS
Foil-Faced Polyiso-cyanurate
Stone Wool




Single top plate
½" plywood connecting interior and exterior walls
2x4 structural stud wall at 24" o.c.
2x3 frame wall
Latex paint on ½" gypsum board
½" fiberboard, plywood, OSB or gypsum sheathing
Building paper, housewrap or building wrap
3½" cellulose insulation
Furring strips
½" plywood or OSB with joints taped
4½" space between sheathing and offset framing
Cladding
Cellulose insulation at rim joist
Cellulose cavity insulation


Single top plate
Taped and painted ½" gypsum wall board as interior finish
2x6 interior framing member @ 24" o.c.
Plywood/OSB sheathing; joints taped/sealed
Cellulose insulation at rim joist
Capillary break
Ledger board
Plywood cavity closure at top of assembly
2x3 exterior truss
Cellulose insulation in wall cavity
Plywood/OSB sheathing
Housewrap
Furring strips
Cladding


Roof framing/trusses line up with wall and floor framing
Raised heel
Single top plate
No headers in non-bearing wall
Single top plate
Point load transferred between studs by rim closure material acting as header. If rim closure material is non-structural, support will be required under point loads. Use solid blocking between joists.
Single stud at rough opening
Single header
No cripples under window opening
Two stud corners


Celotex
Celotex
Celotex

Insulation and Sheathing Evolution


Celotex
INTERMEDIATE STURDY-BRACE
R-VALUE 1.2
WARNING: COMBUSTIBLE MAY SMOLDER OR BURN IF IGNITED

Wood Building Evolution


DWIGHT CRANE


STYROFOAM SM

STYROFOAM*SM
STYROFOAM*SM

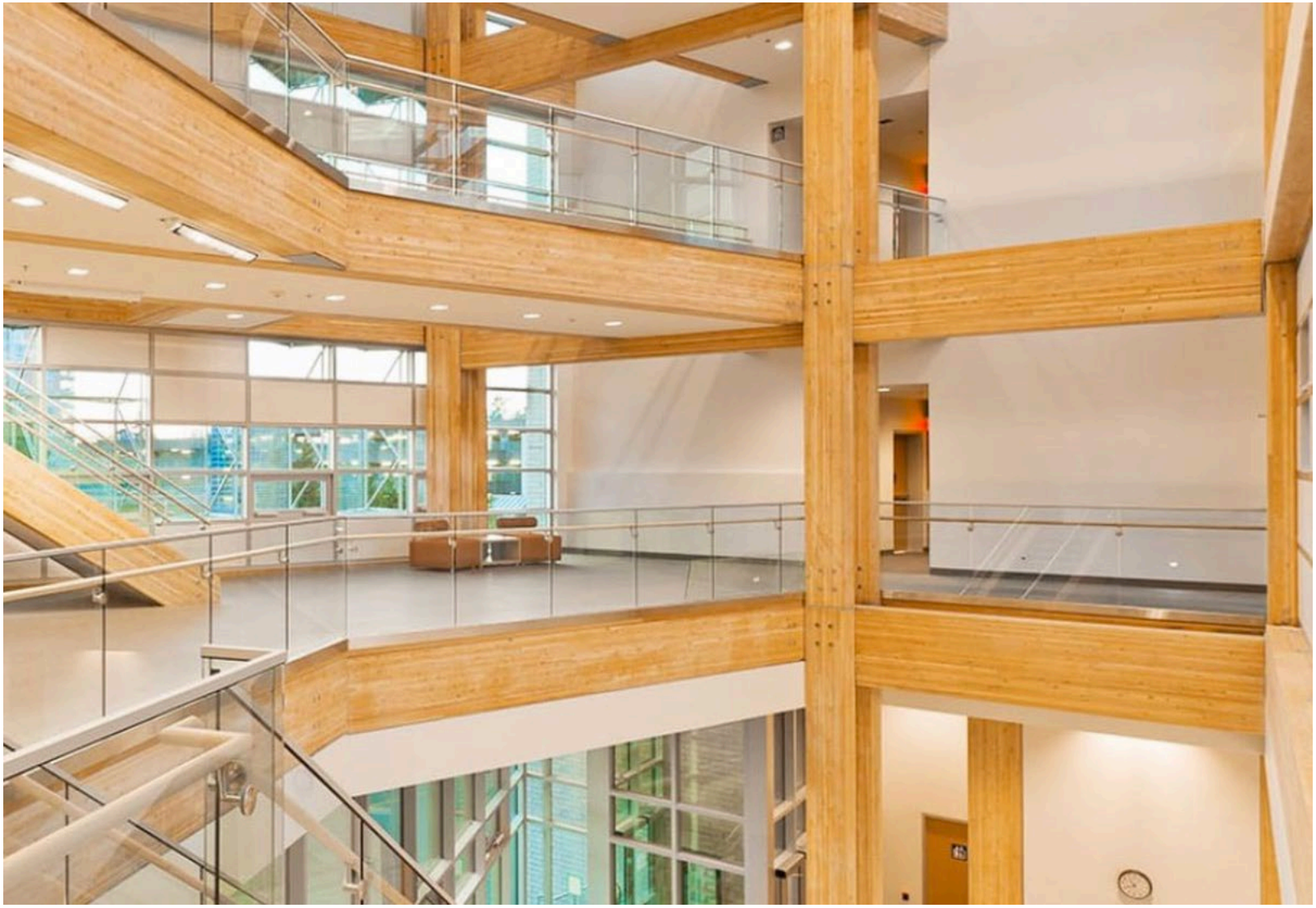

DAUGHT CRANE

Production Housing

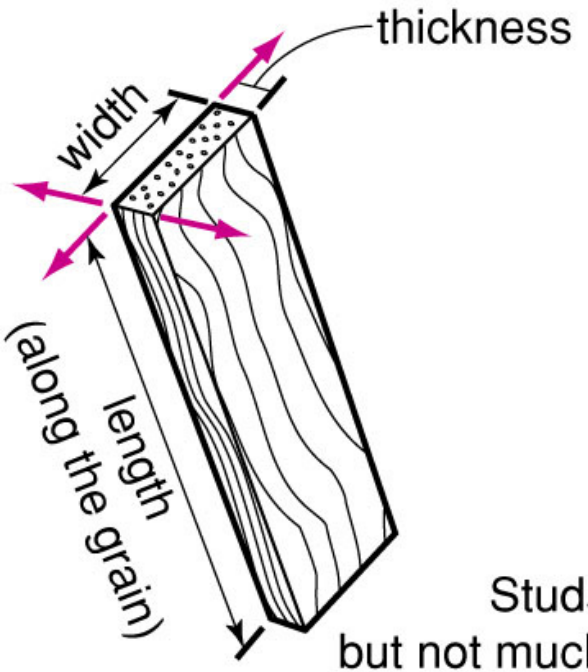

Styrofoam

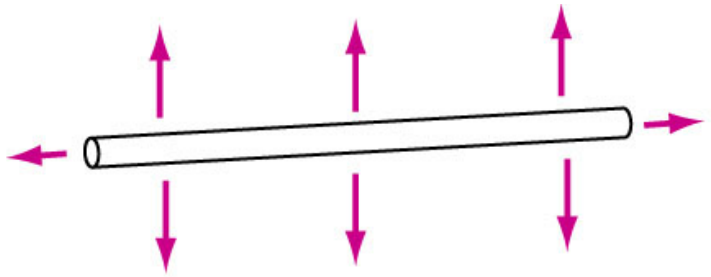

BROCKPORT
ENGINEERED
PANEL SYSTEMS

Mass Timber



Materials

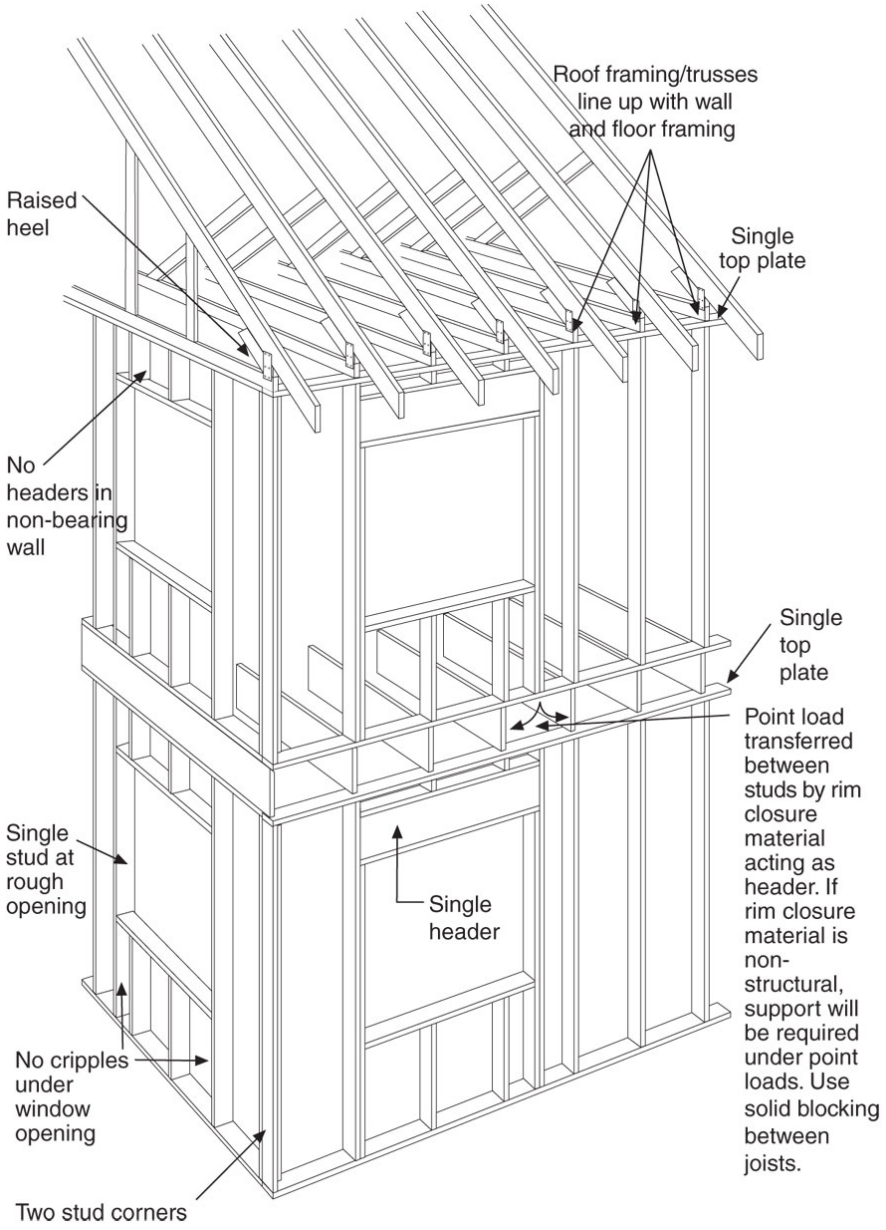


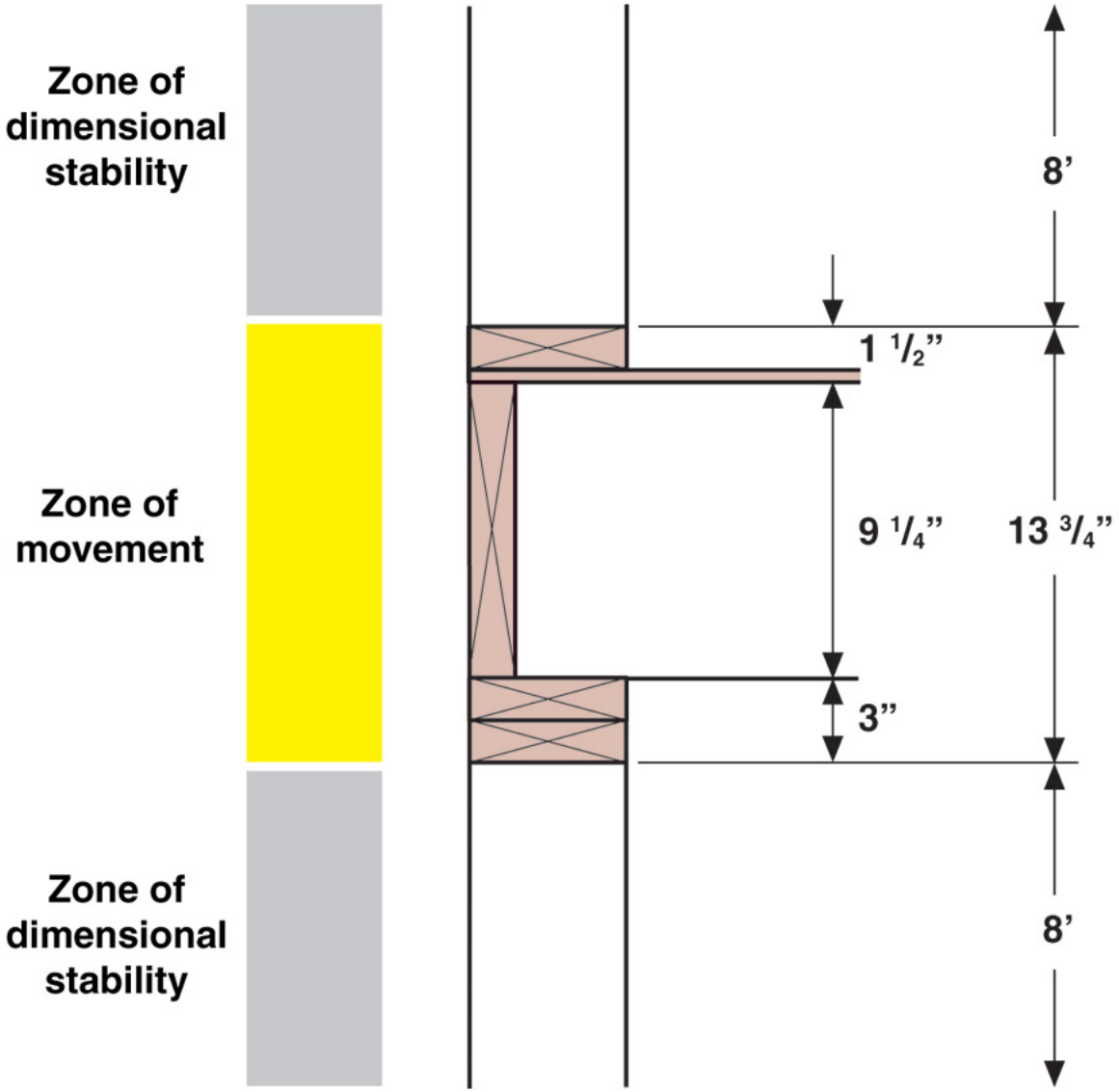


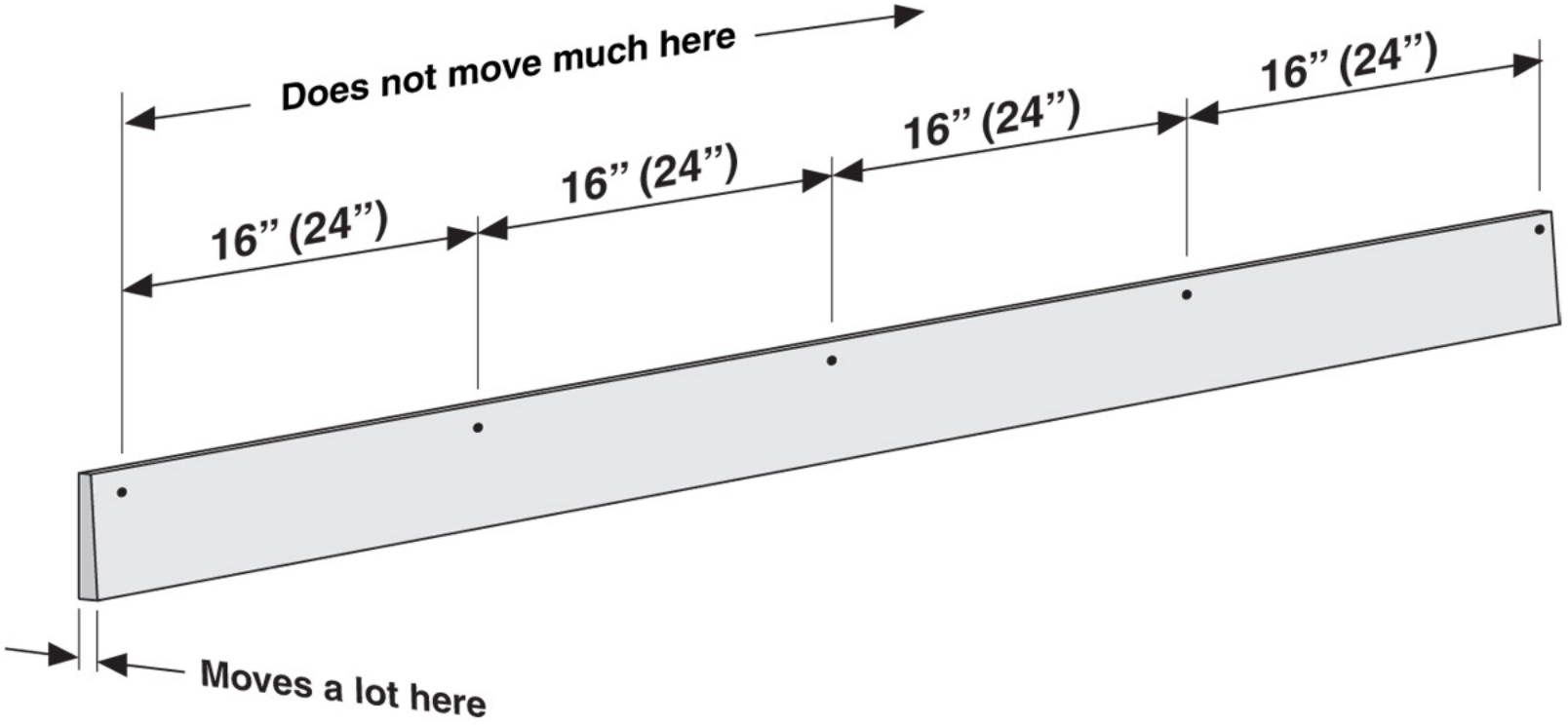
Wood Fiber

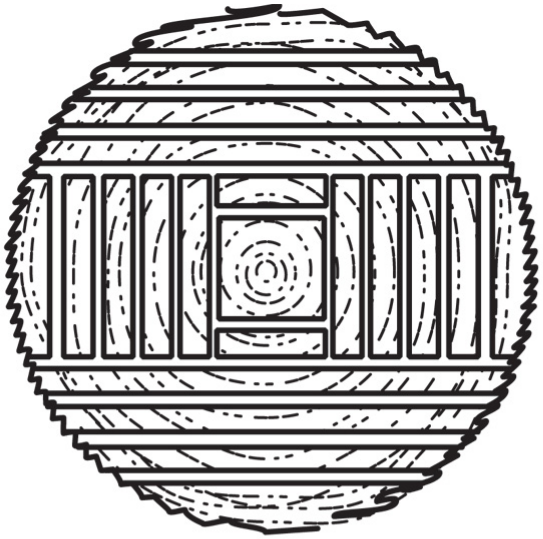
Fibers get much thicker than longer
when they pick up moisture

Studs get much wider and thicker,
but not much longer, when they pick up moisture

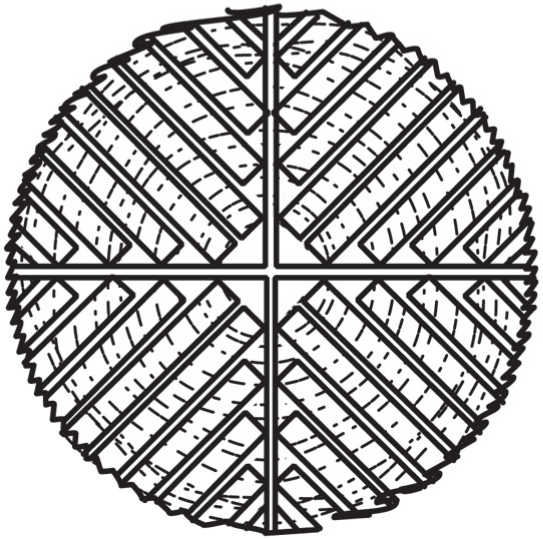

Roof framing/trusses line up with wall and floor framing
Raised heel
Single top plate
No headers in non-bearing wall
Single top plate
Point load transferred between studs by rim closure material acting as header. If rim closure material is non-structural, support will be required under point loads. Use solid blocking between joists.
Single stud at rough opening
Single header
No cripples under window opening
Two stud corners


Zone of dimensional stability
Zone of movement
Zone of dimensional stability
8’
1 1/2”
9 1/4”
13 3/4”
3”
8’

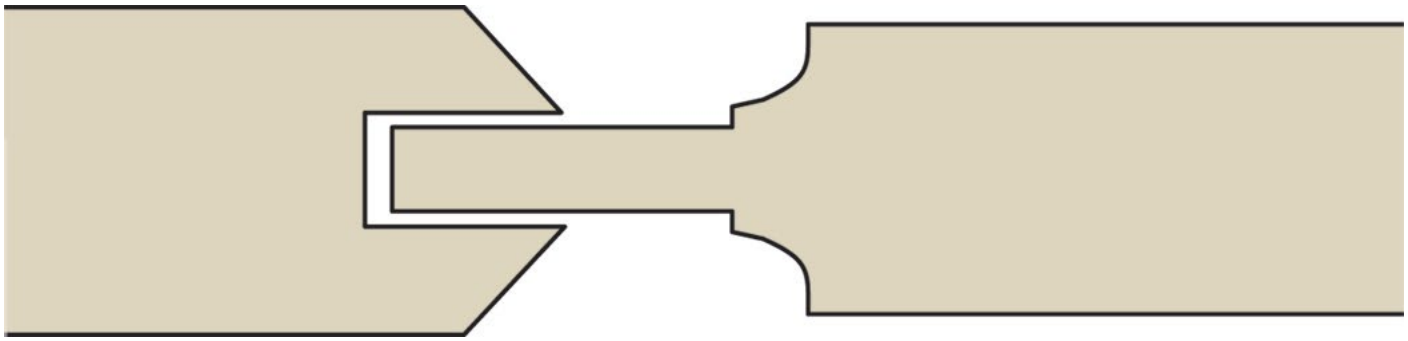

Does not move much here
16” (24”)
16” (24”)
16” (24”)
16” (24”)
Moves a lot here

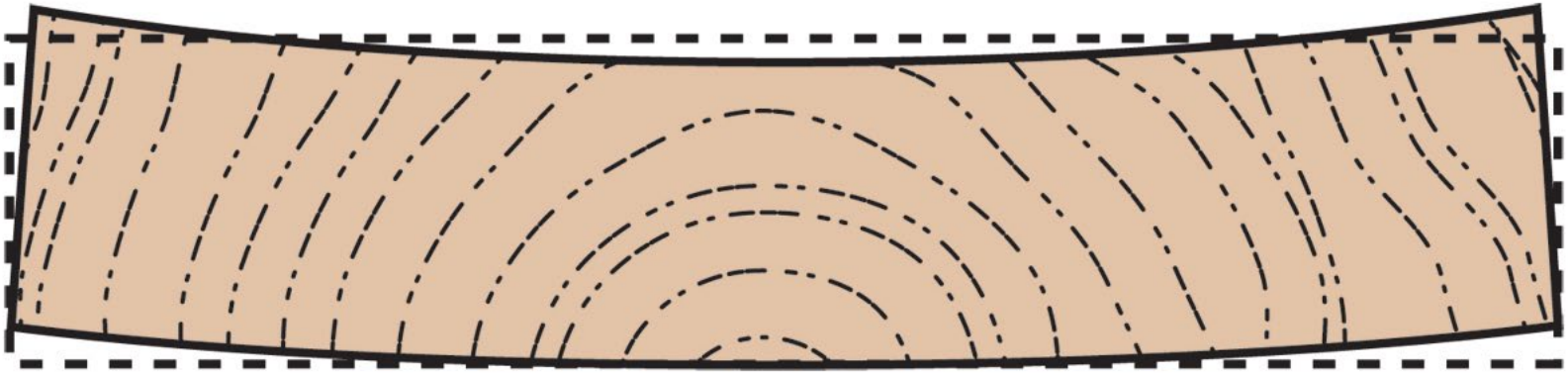


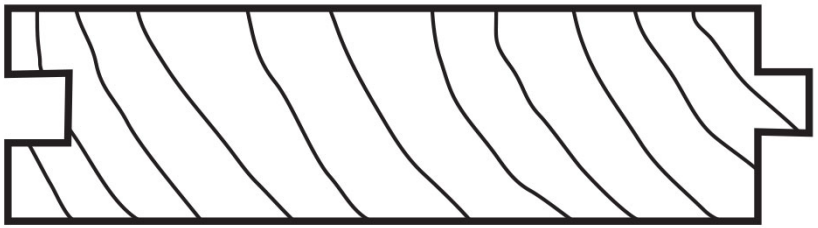
Plain sawn log



Quarter sawn log

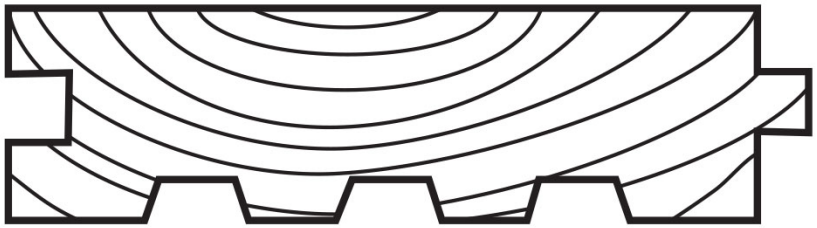






Plain

Hollow Back

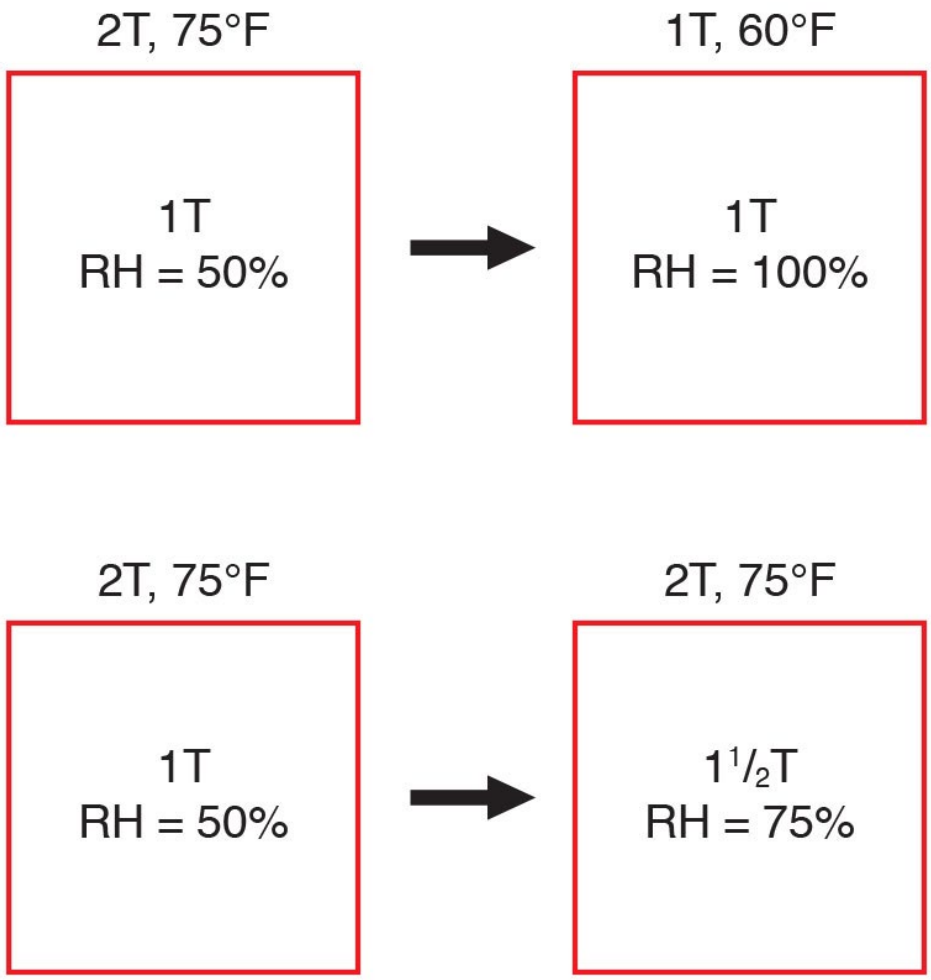


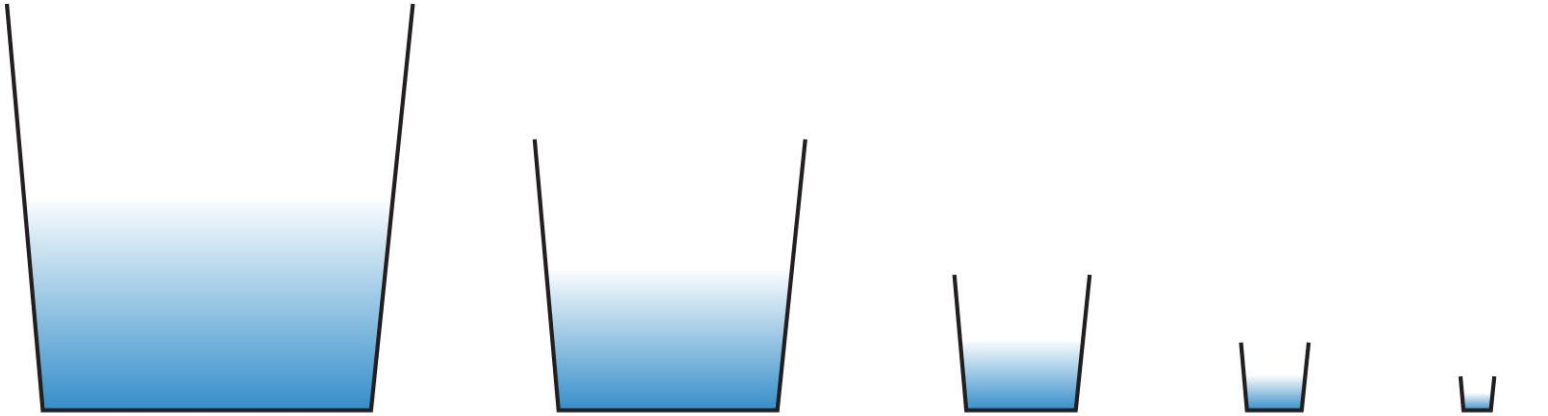
Hollow or Scratch Back

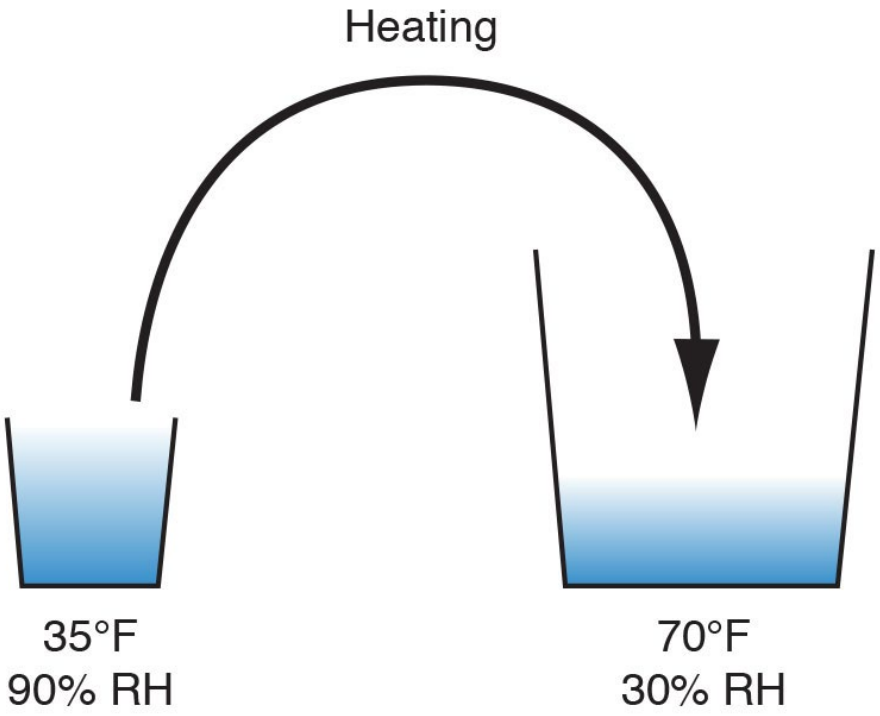
Wood ”sees” Relative Humidity

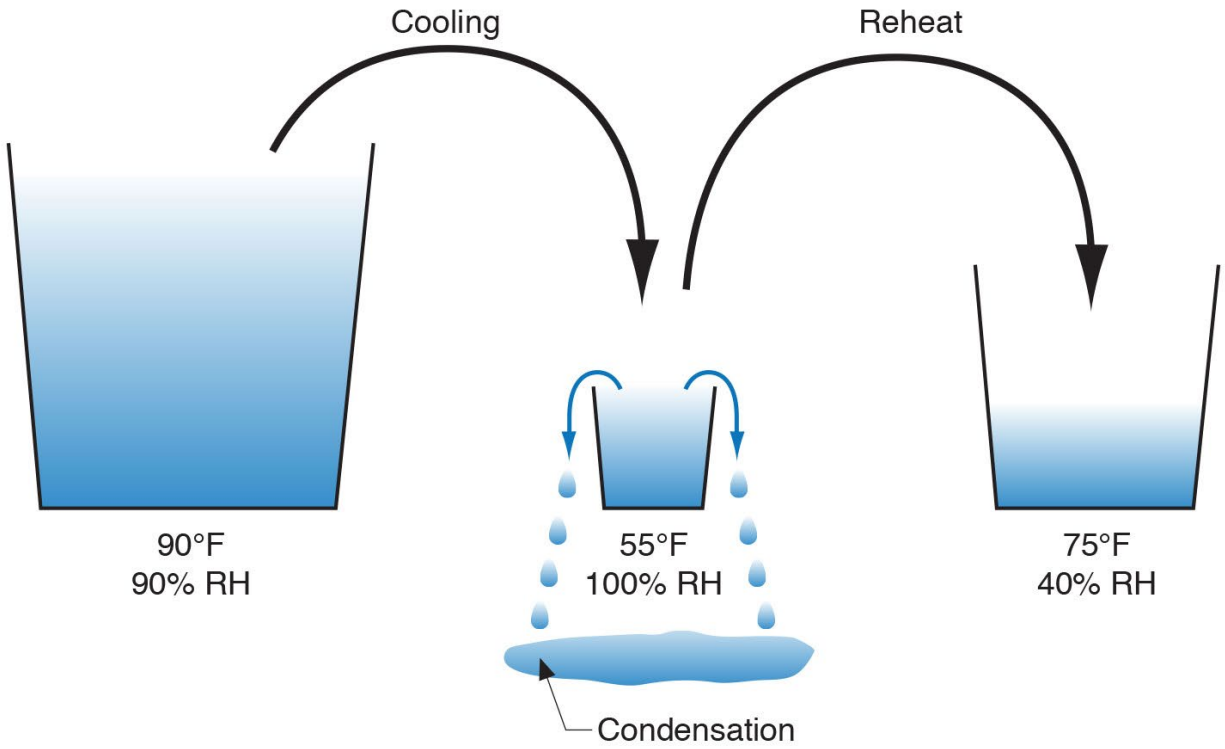
Relative Humidity

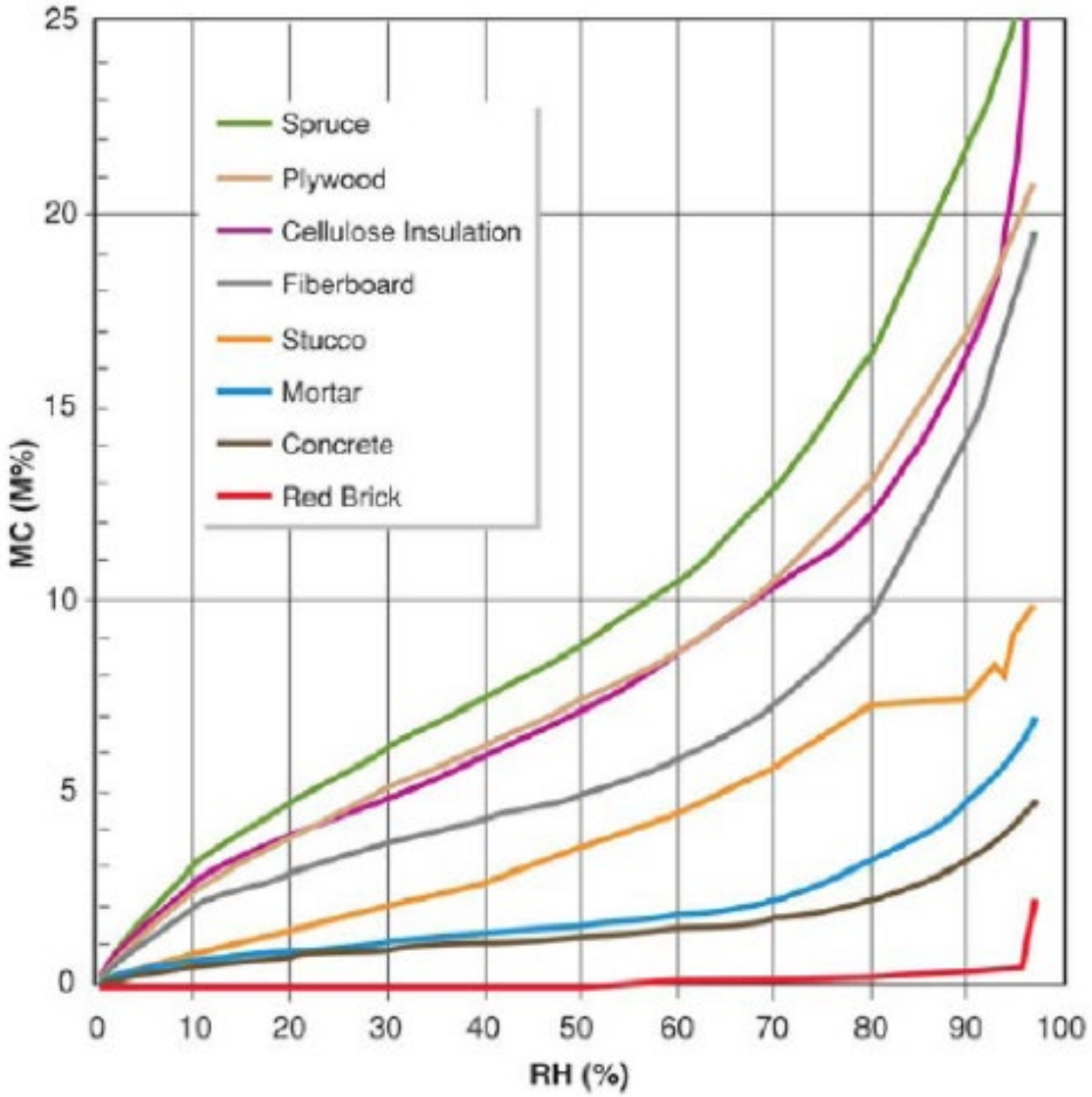
Vapor Pressure

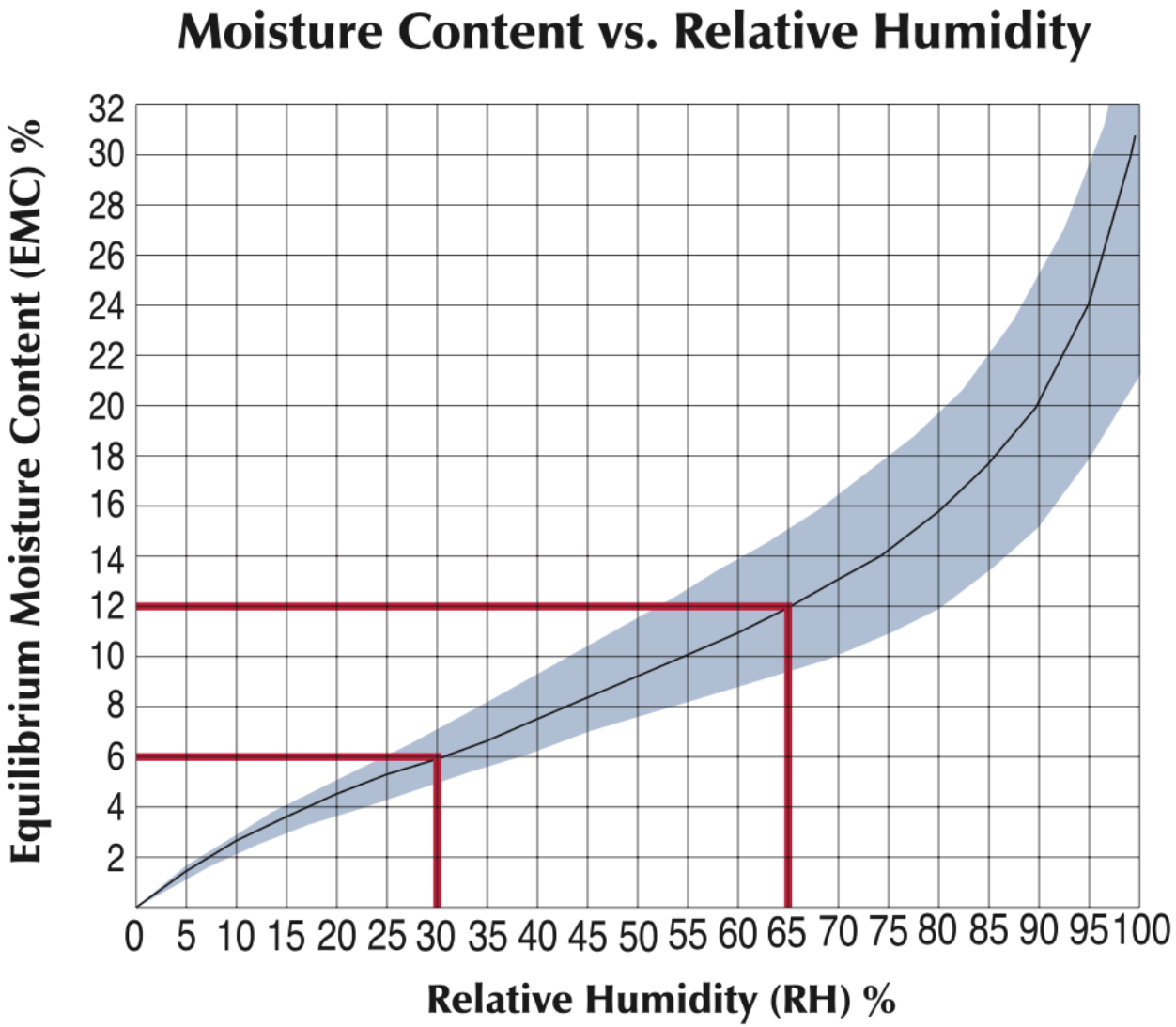

2T, 75°F
1T
RH = 50%
1T, 60°F
1T
RH = 100%
2T, 75°F
1T
RH = 50%
2T, 75°F
1 1/2T
RH = 75%

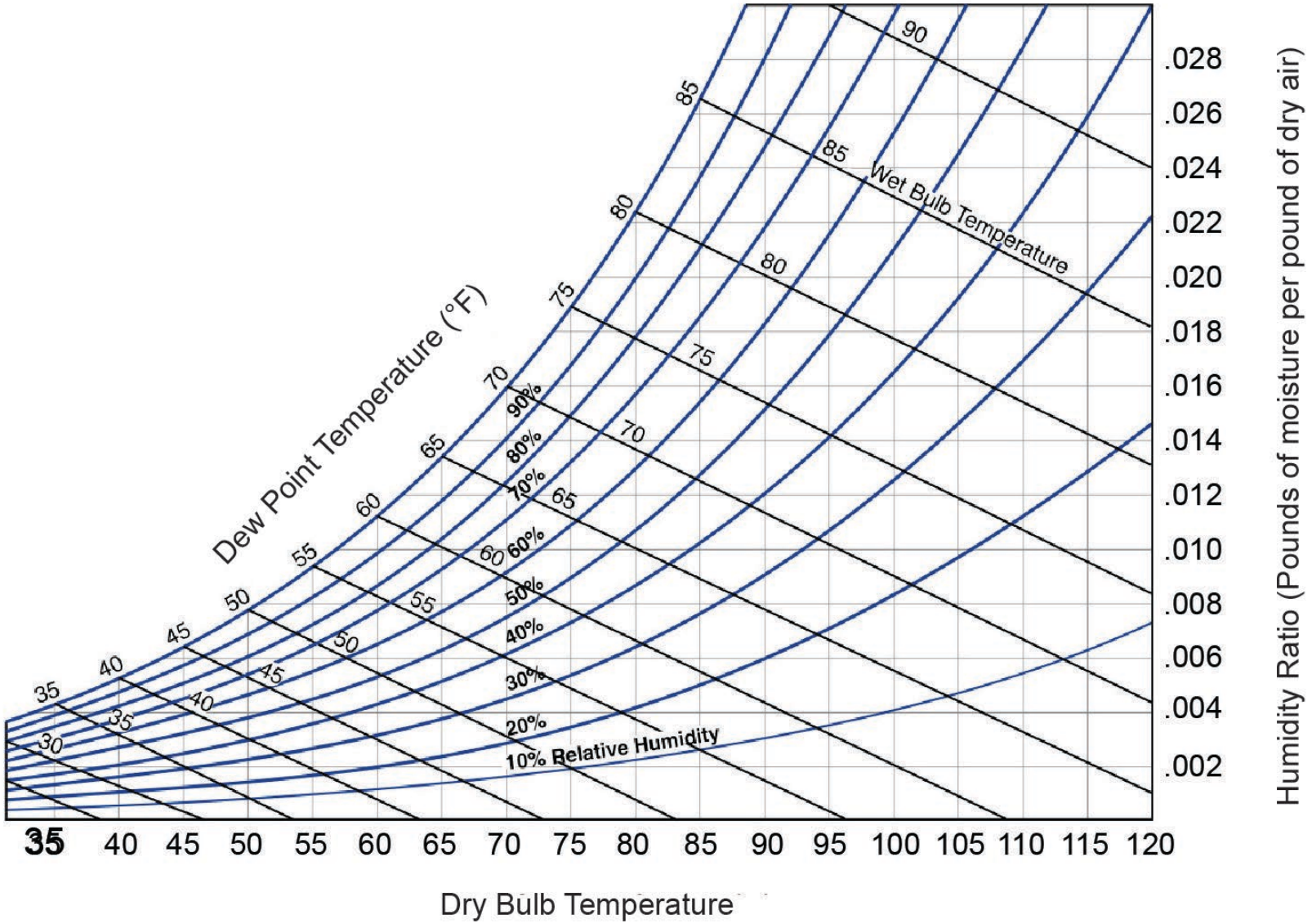

90°F
50% RH
75°F
50% RH
60°F
50% RH
45°F
50% RH
30°F
50% RH


Heating
35°F
90% RH
70°F
30% RH

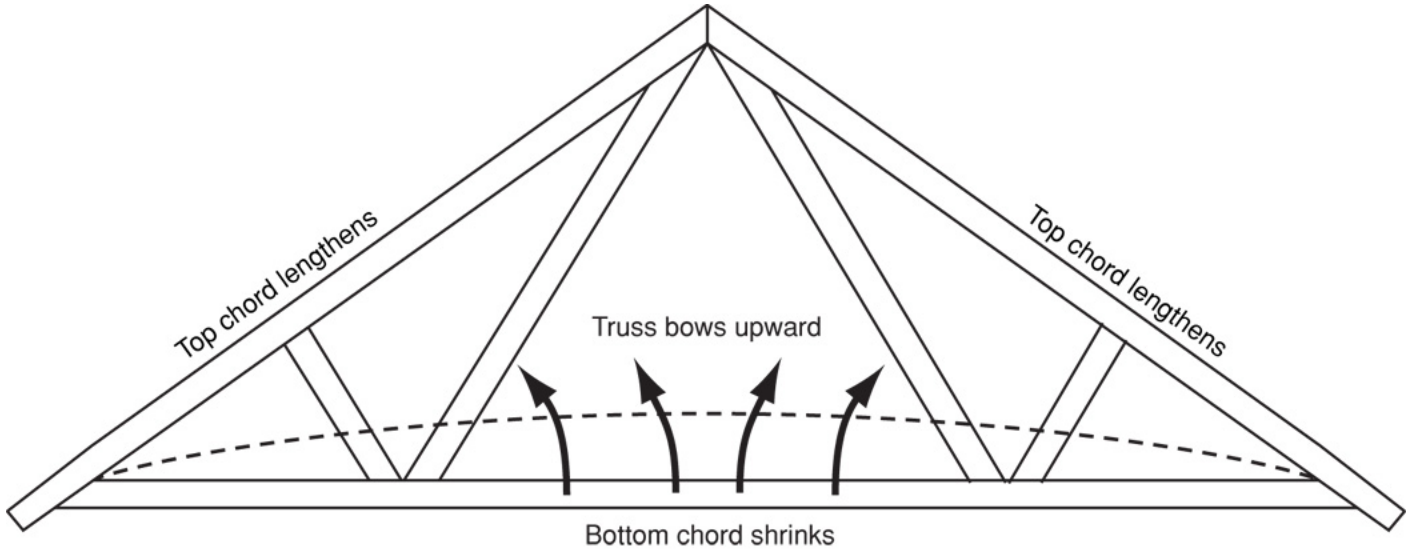

Cooling
Reheat
90°F
90% RH
55°F
100% RH
75°F
40% RH
Condensation

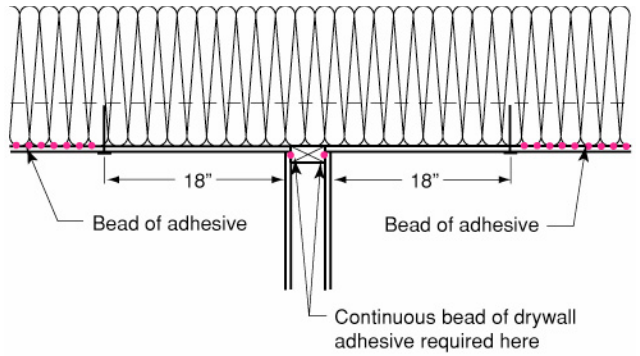

Spruce
Plywood
Cellulose Insulation
Fiberboard
Stucco
Mortar
Concrete
Red Brick
MC (M%)
RH (%)
0
5
10
15
20
25
0
10
20
30
40
50
60
70
80
90
100

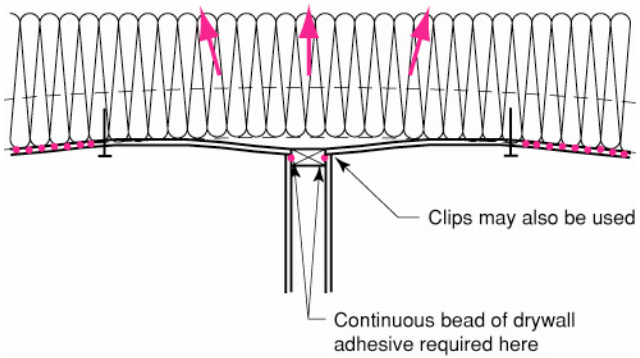

Moisture Content vs. Relative Humidity
Equilibrium Moisture Content (EMC) %
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Relative Humidity (RH) %

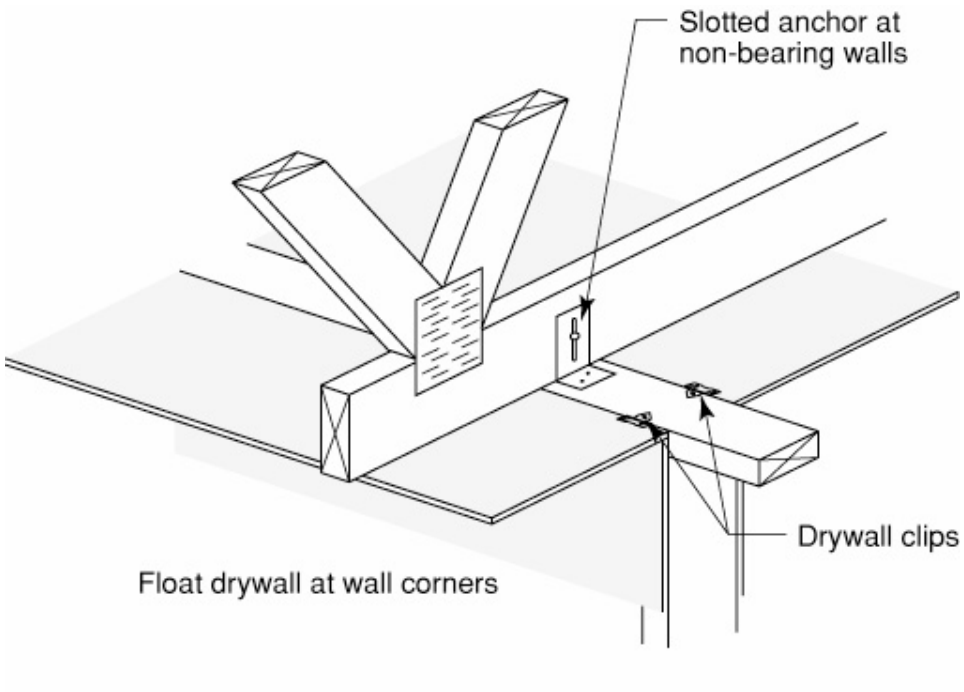

Dew Point Temperature (°F)
Wet Bulb Temperature
90%
80%
70%
60%
50%
40%
30%
20%
10% Relative Humidity
Dry Bulb Temperature
Humidity Ratio (Pounds of moisture per pound of dry air)
.028
.026
.024
.022
.020
.018
.016
.014
.012
.010
.008
.006
.004
.002
35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120


6537


Top chord lengthens
Truss bows upward
Top chord lengthens
Bottom chord shrinks


18"
18"
Bead of adhesive
Bead of adhesive
Continuous bead of drywall
adhesive required here


Clips may also be used
Continuous bead of drywall
adhesive required here


Slotted anchor at
non-bearing walls
Drywall clips
Float drywall at wall corners


10-4-8
STRUCTURAL GRADE
INSULATIVE SHEATHING
FOR ADDED ENERGY
PERFORMANCE

Tall 2x6 walls bow outwards during the winter…due to the temperature difference leading to a relative humidity difference…

Exterior wood fibers expand…interior wood fibers contract…

Continuous exterior insulation…

Wood decay vs. mold…

Decay fungi and mold fungi…

Wood decay needs 28 percent m/c to start..

Wood decay needs 20 percent m/c to stop…

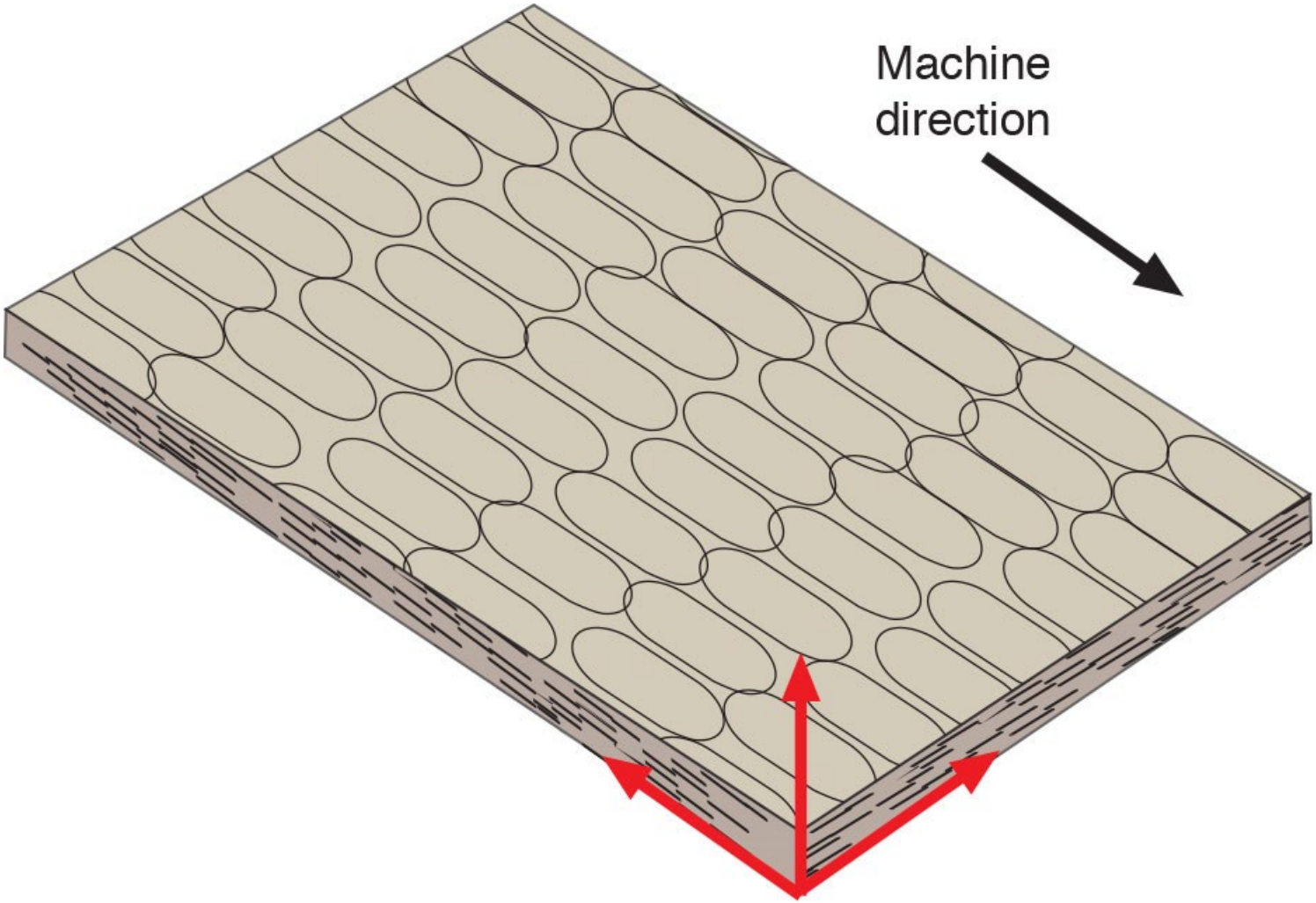
Kiln dried lumber was set at 19 percent m/c

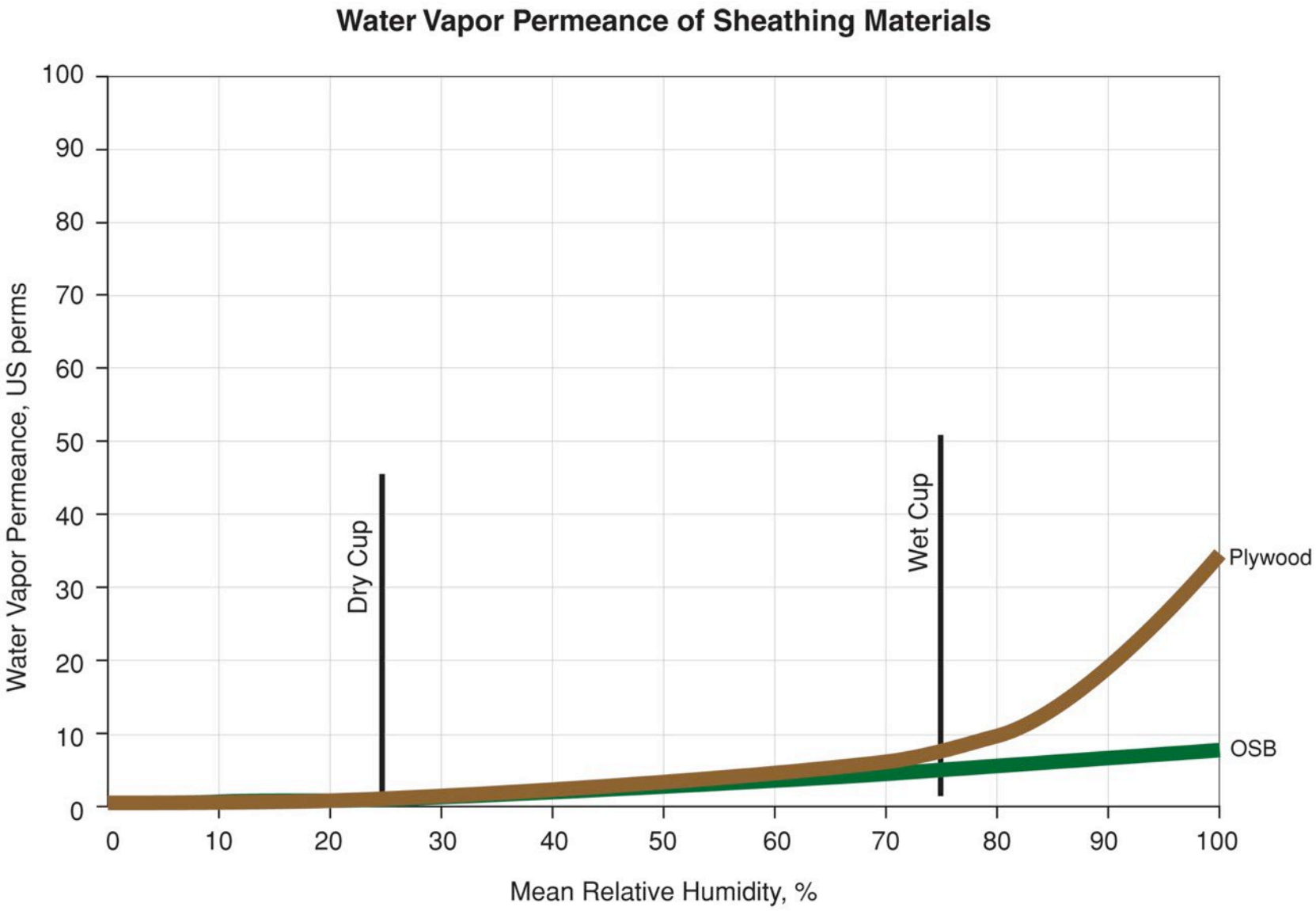
Surface mold requires 16 percent m/c (80 percent relative humidity)

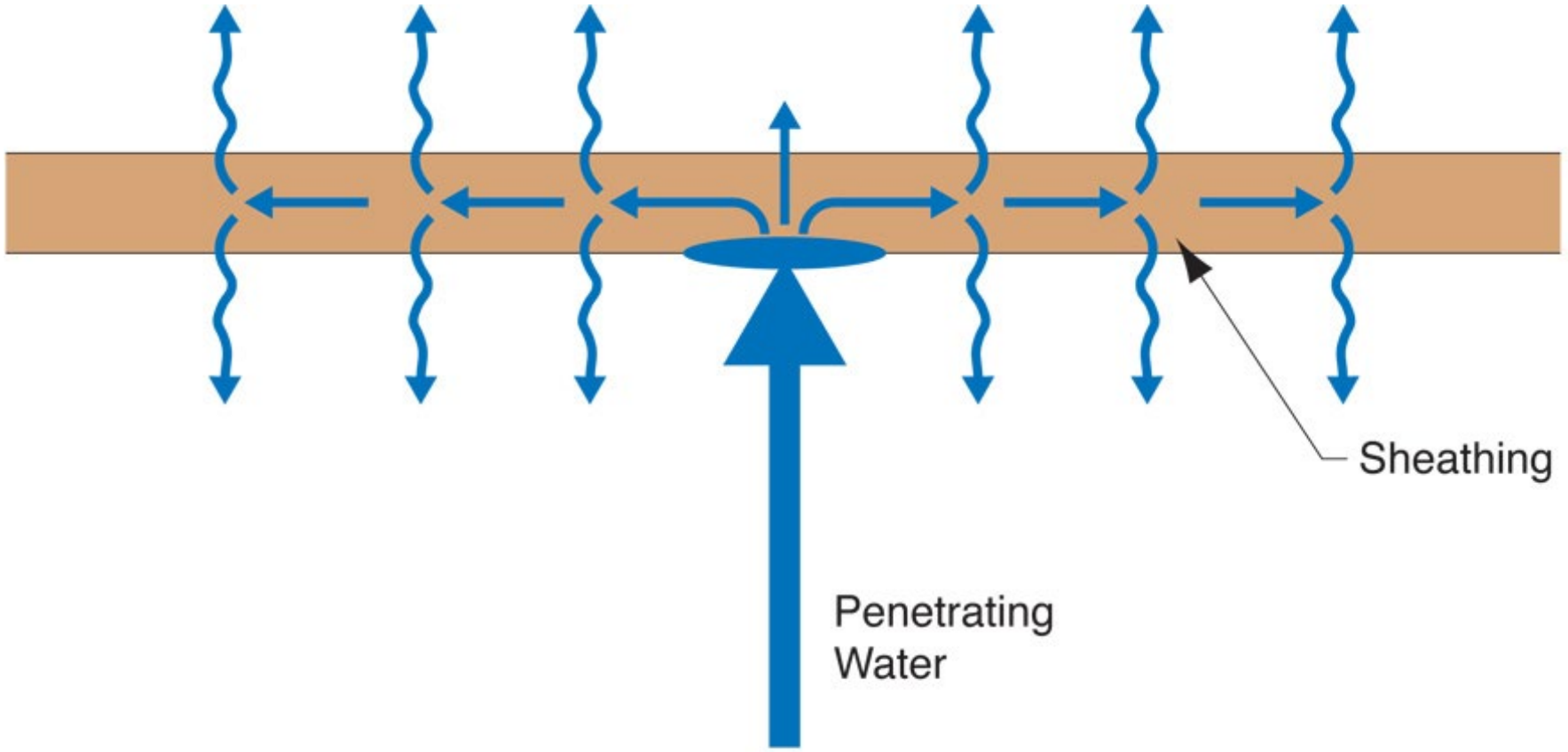
Wood decay…keep wood below 20 percent

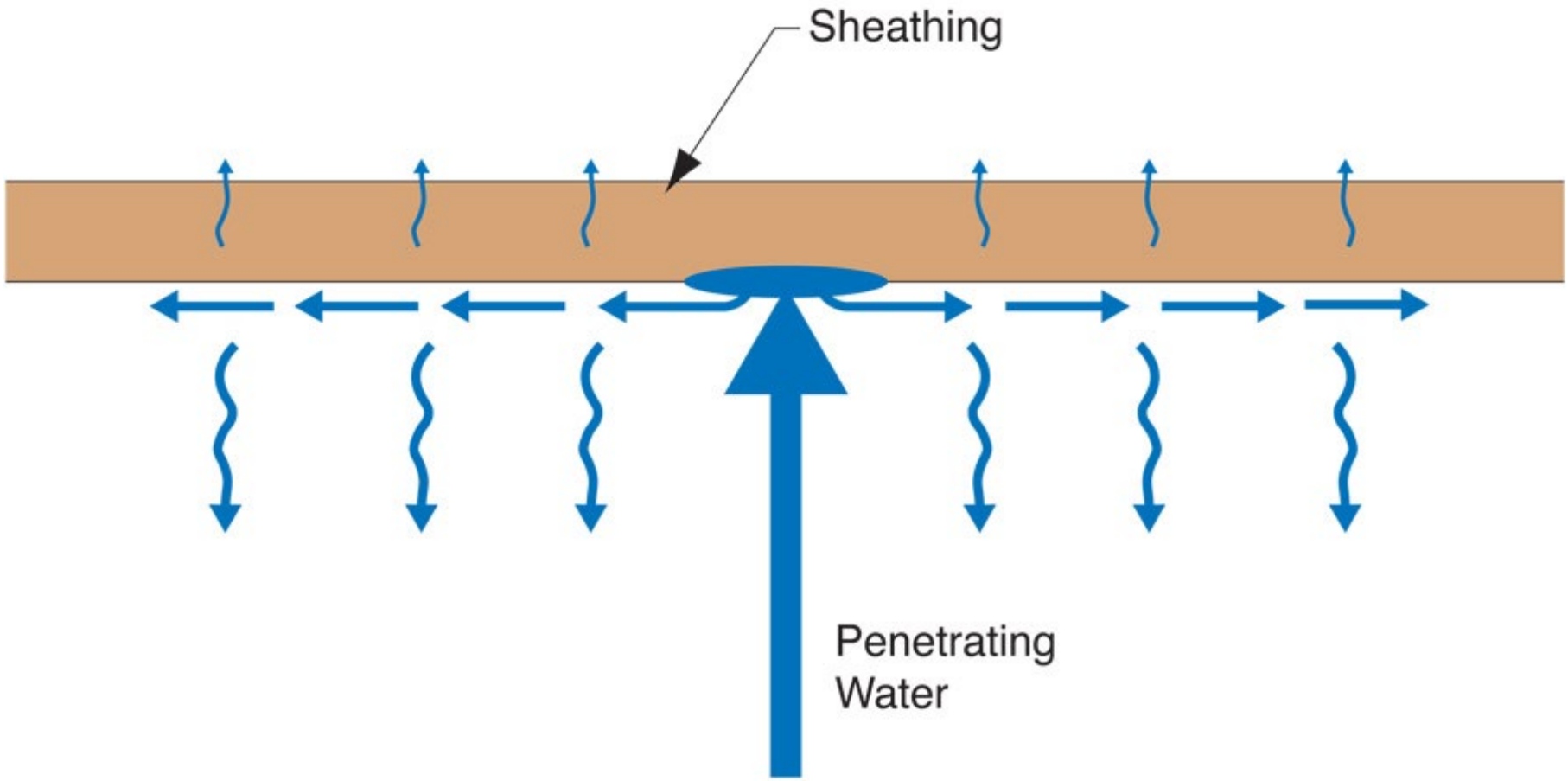
Mold…keep wood below 16 percent (note that you can clean mold…you can't clean rot…)

Engineered wood…


Machine
direction


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


Sheathing
Penetrating
Water


Sheathing
Penetrating
Water

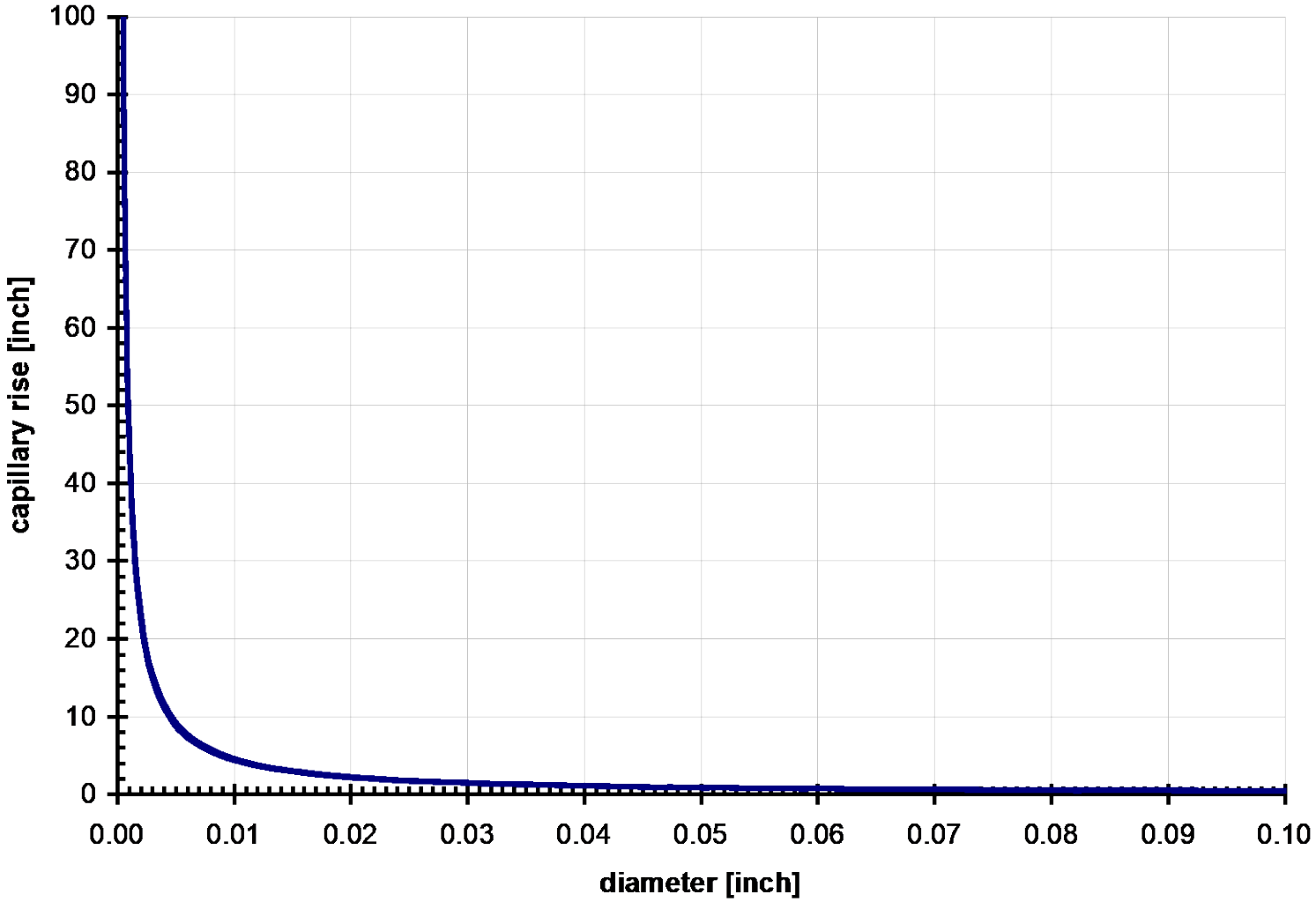
Not all OSB is the same…

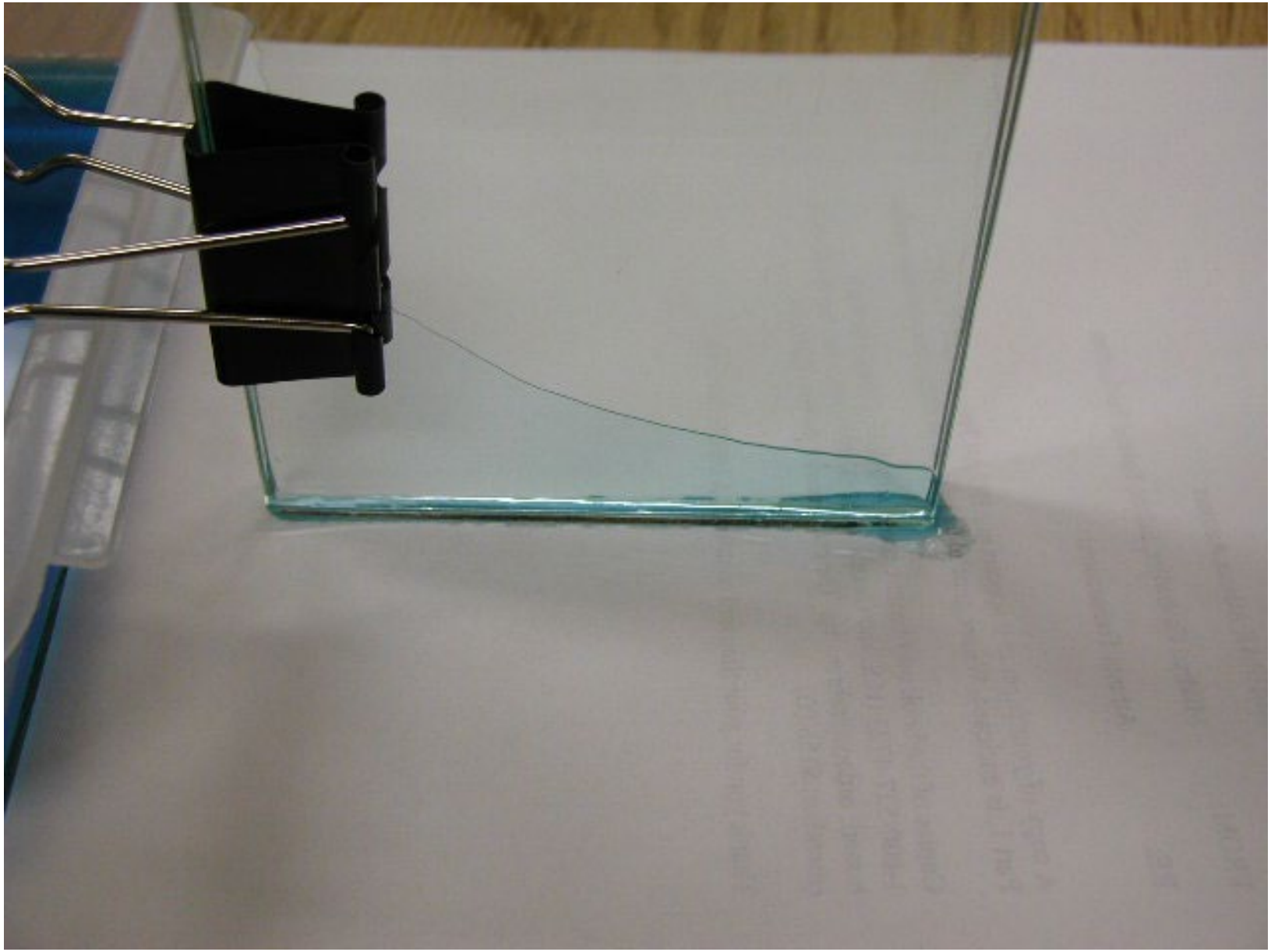
Northern OSB much better than southern OSB…”southern yellow pine” is more dimensionally unstable than northern species…

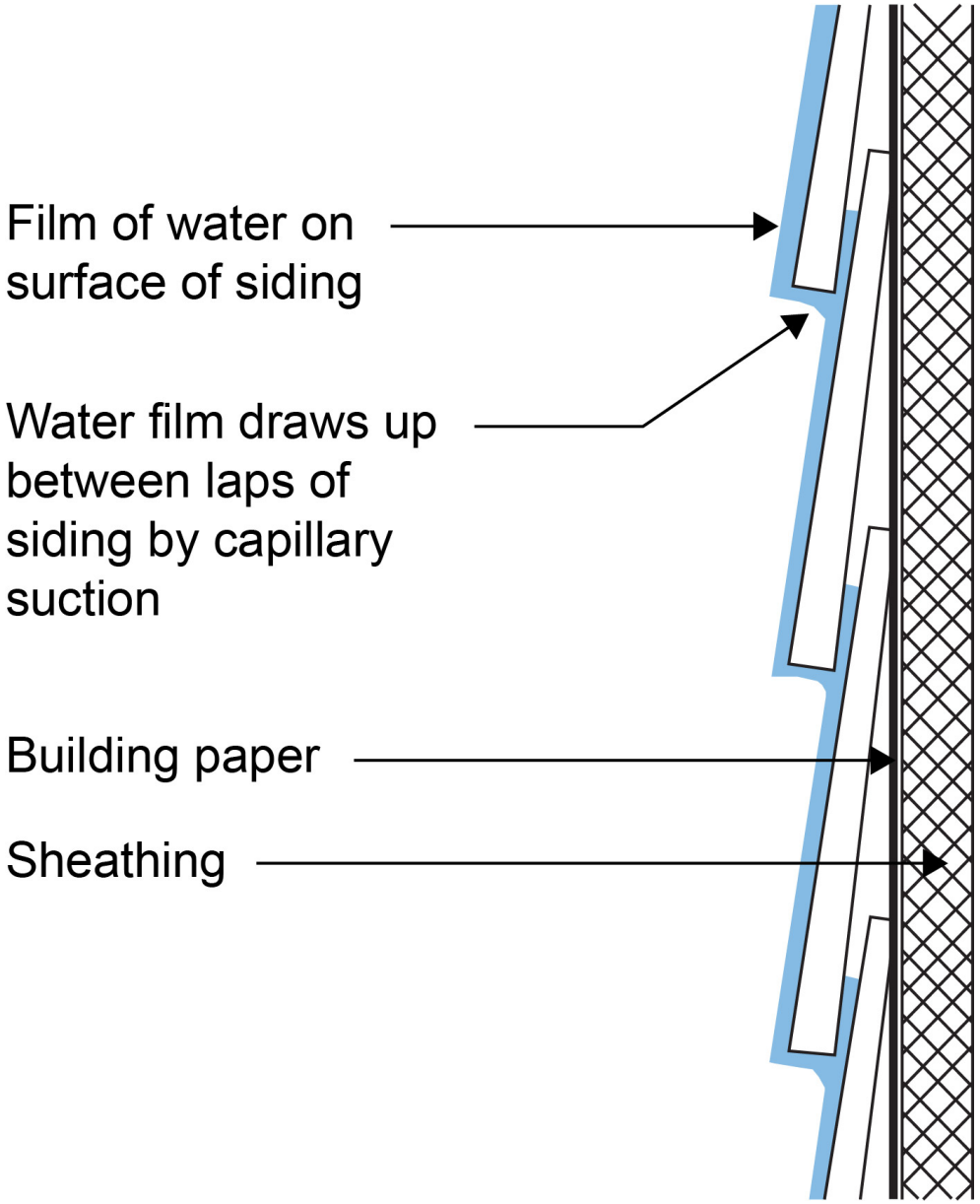
OSB siding and OSB trim…

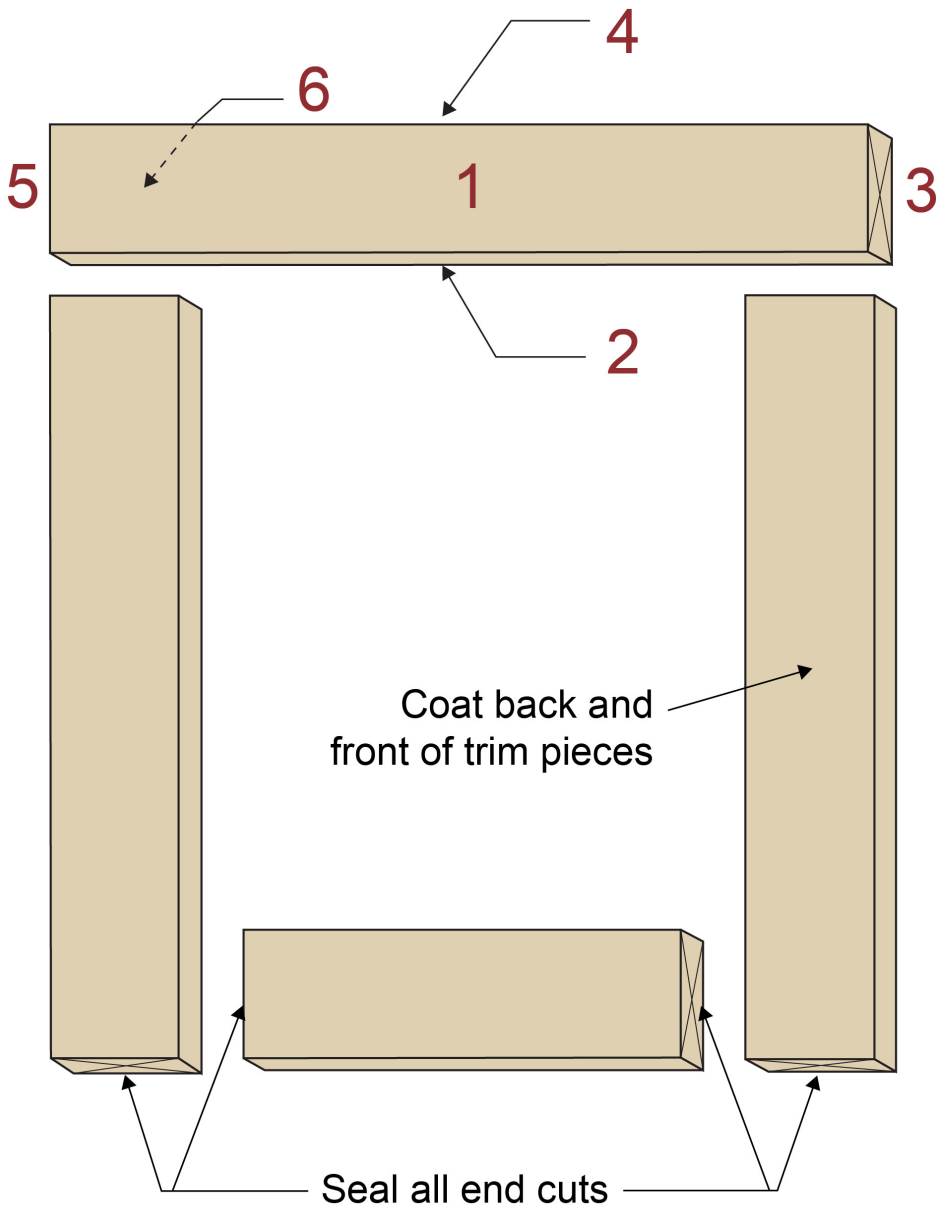
Capillarity

Capillary rise versus diameter

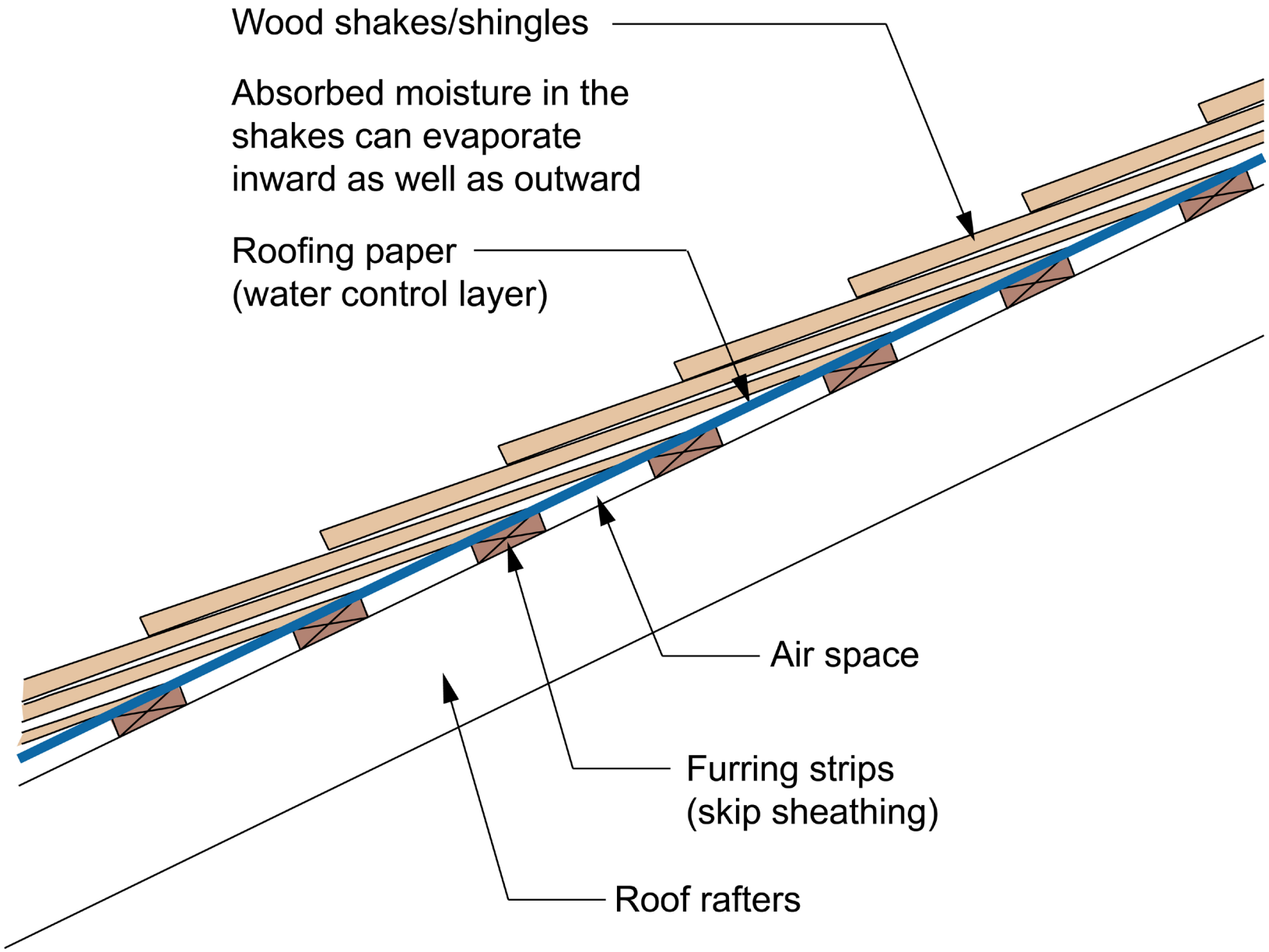


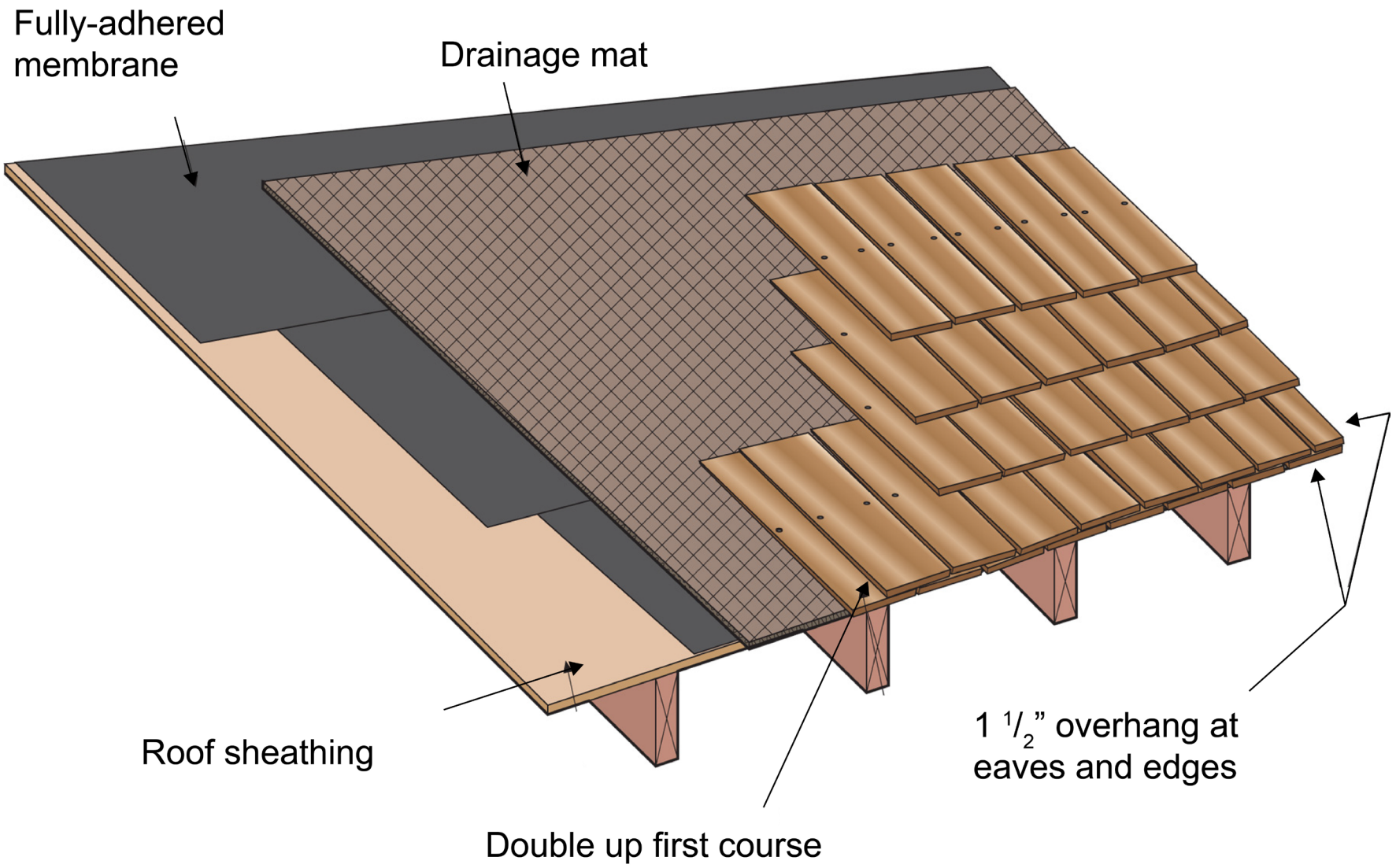


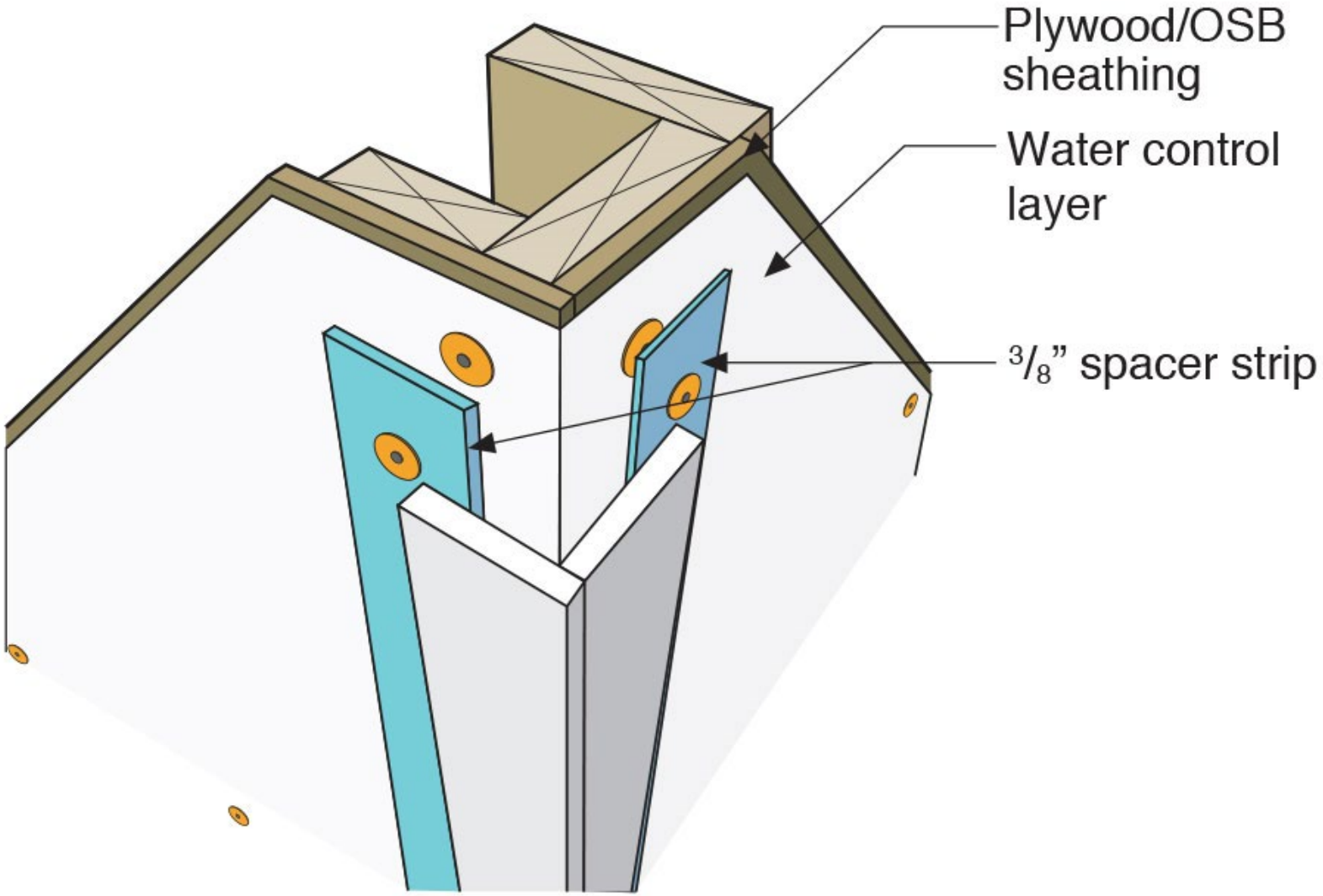

Film of water on surface of siding
Water film draws up between laps of siding by capillary suction
Building paper
Sheathing

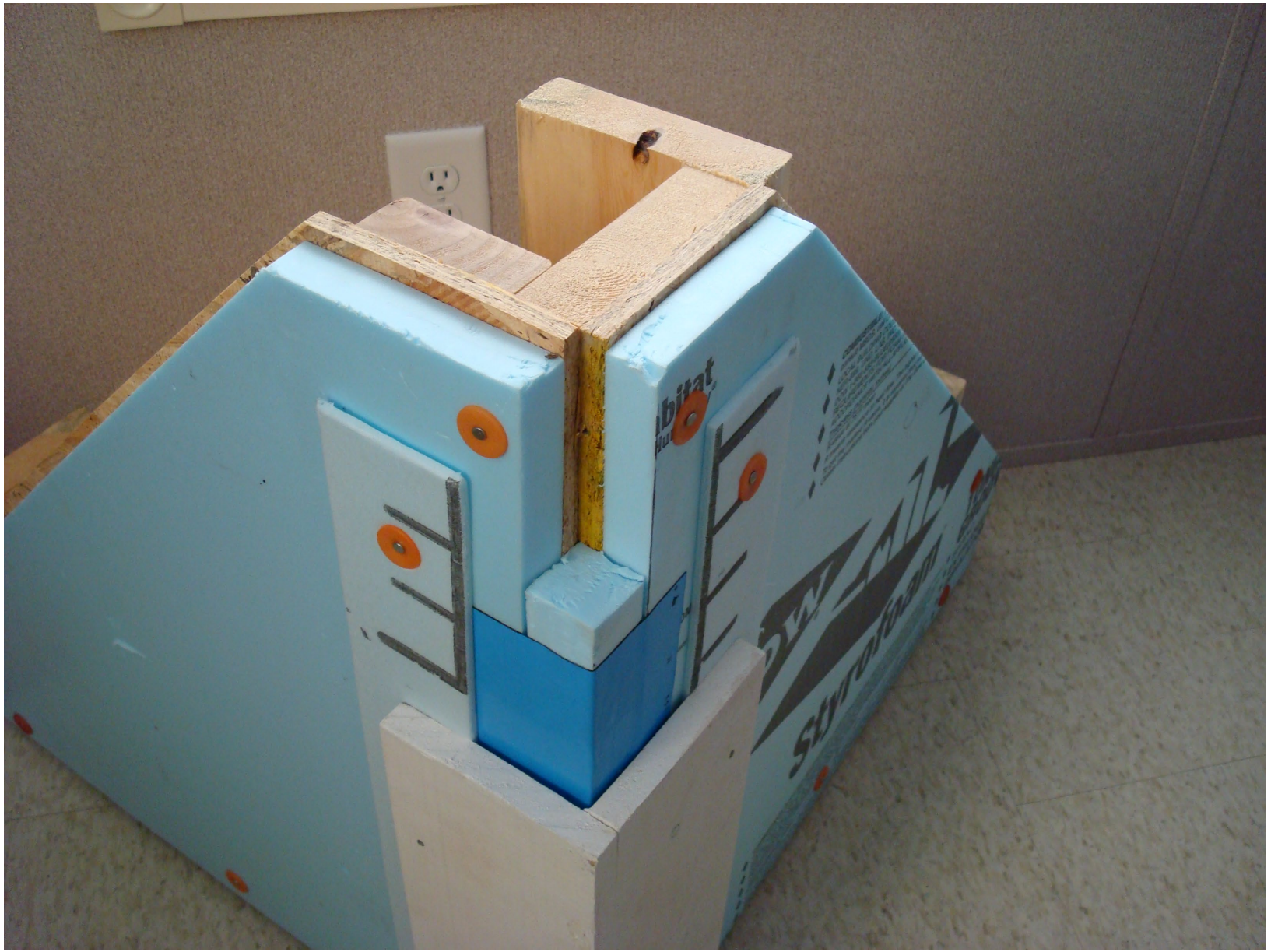

4
6
5
1
3
2
Coat back and
front of trim pieces
Seal all end cuts


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


Wood shakes/shingles
Absorbed moisture in the shakes can evaporate inward as well as outward
Roofing paper (water control layer)
Air space
Furring strips (skip sheathing)
Roof rafters

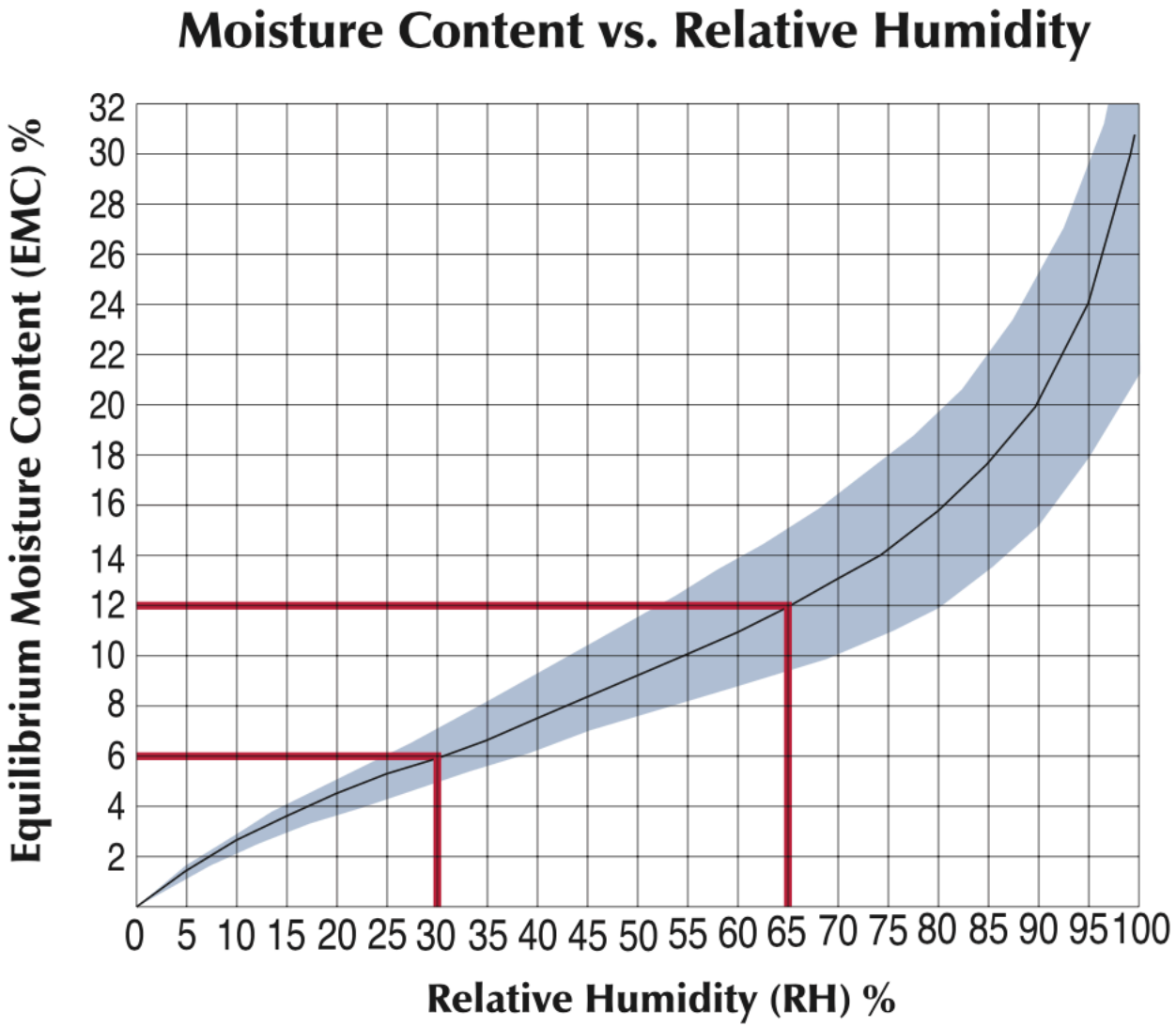

Fully-adhered membrane
Drainage mat
Roof sheathing
Double up first course
1 1/2" overhang at eaves and edges


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

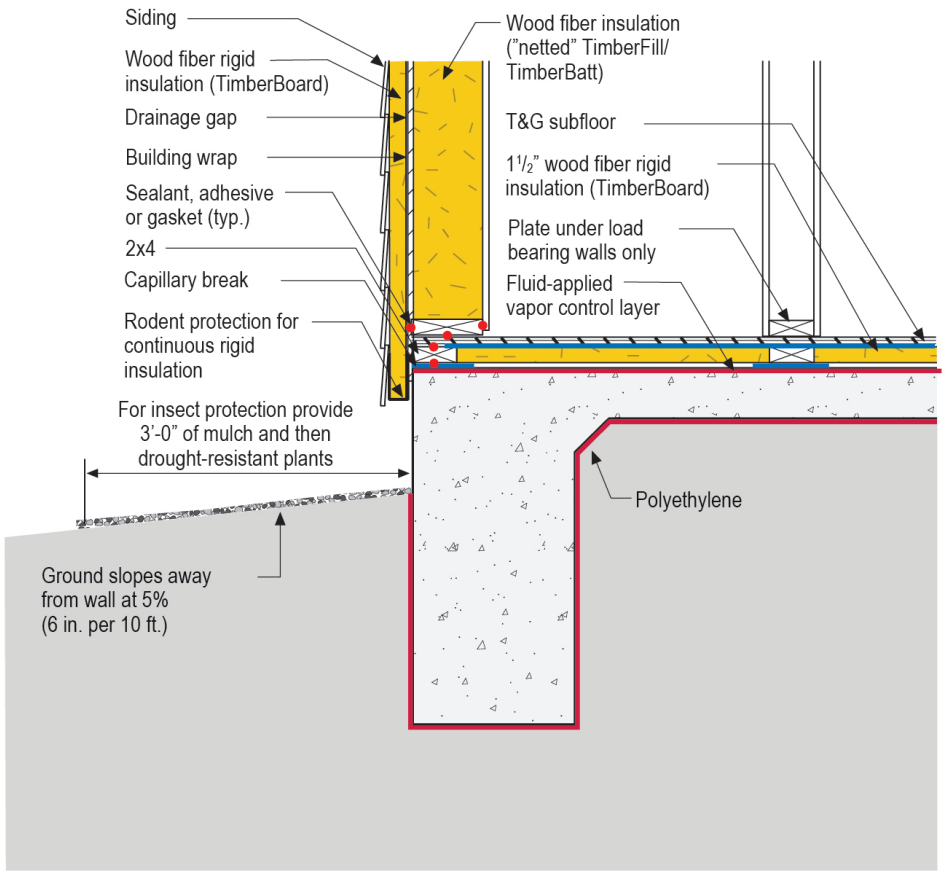

Styrofoam

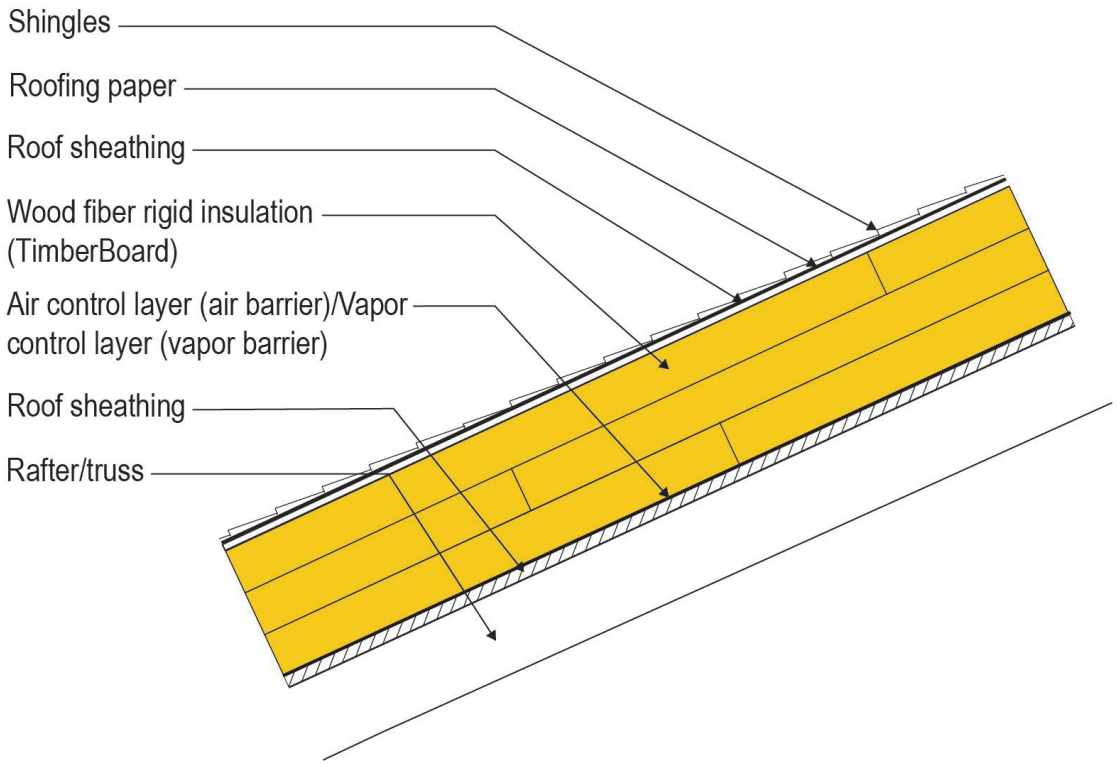
Wood floors…seasonally move between 6 percent and 12 percent m/c…

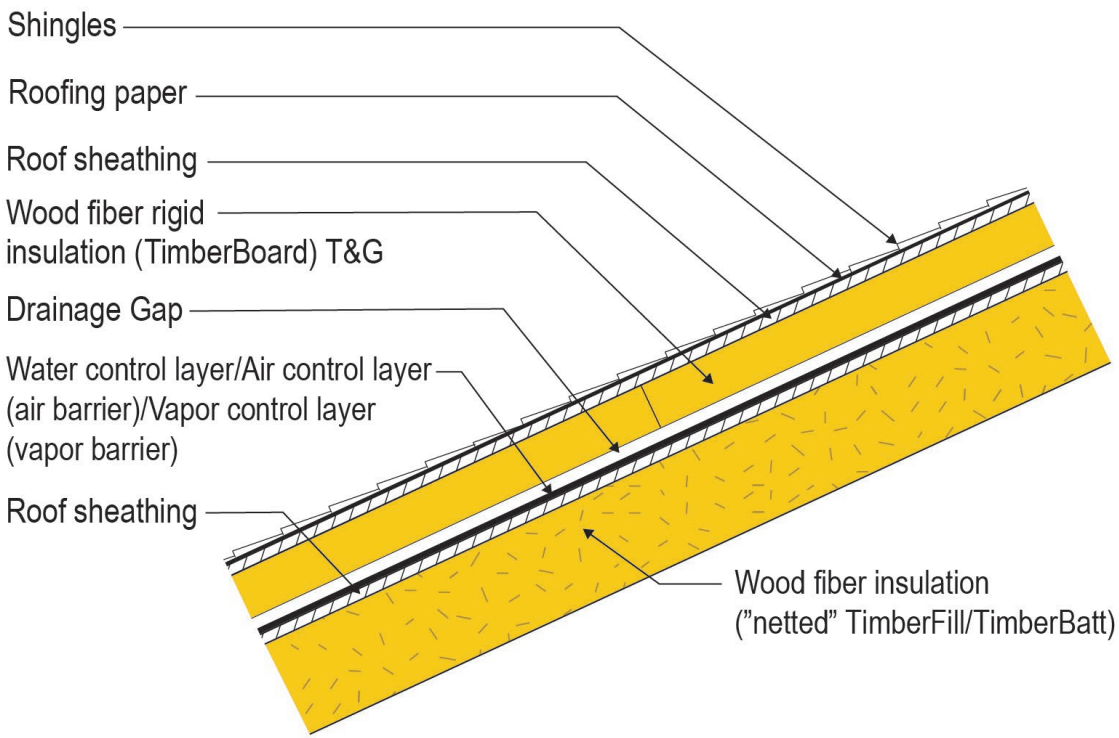
What is halfway? Duh?

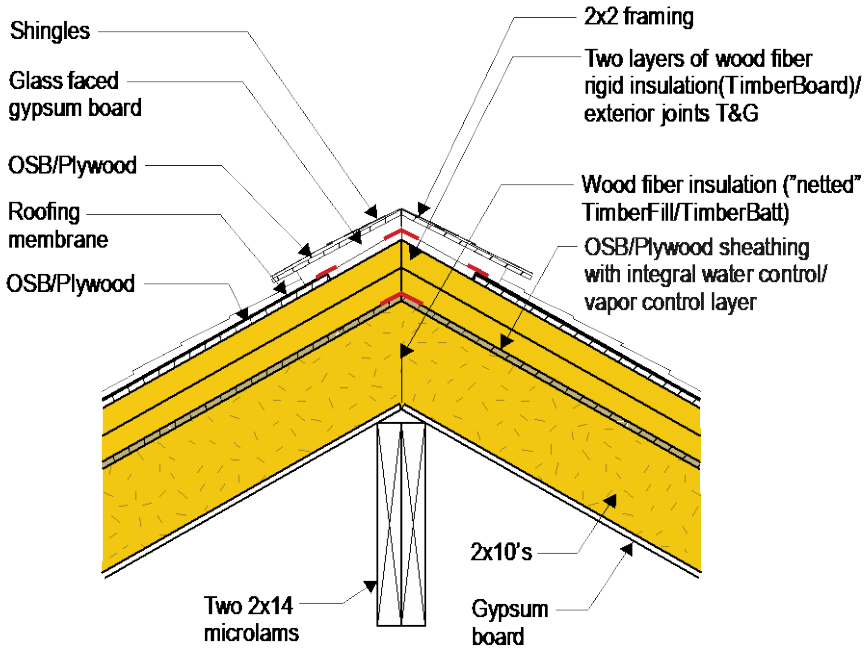

Moisture Content vs. Relative Humidity
Equilibrium Moisture Content (EMC) %
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Relative Humidity (RH) %

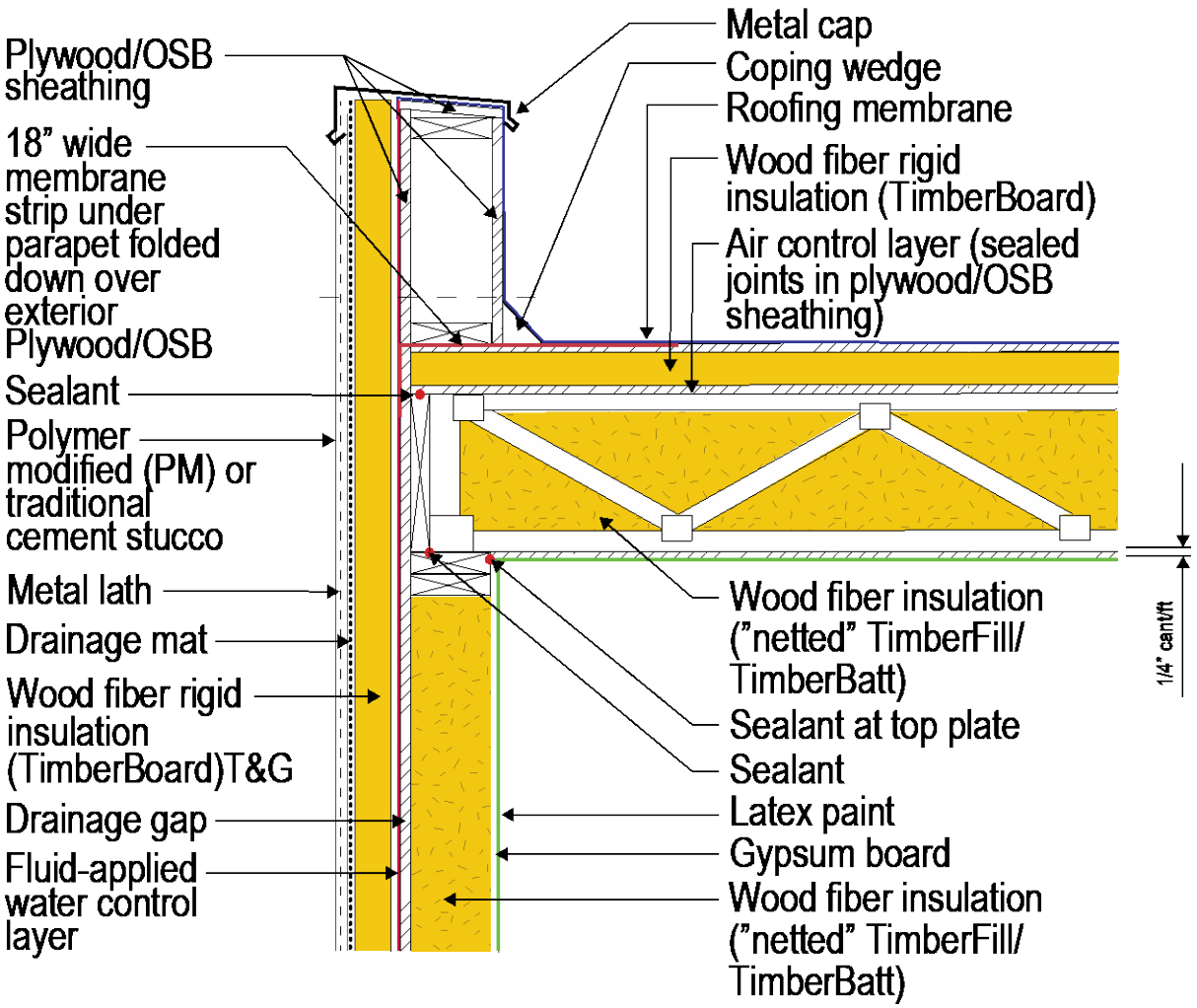
Wood floors…pre-condition to 9 percent m/c

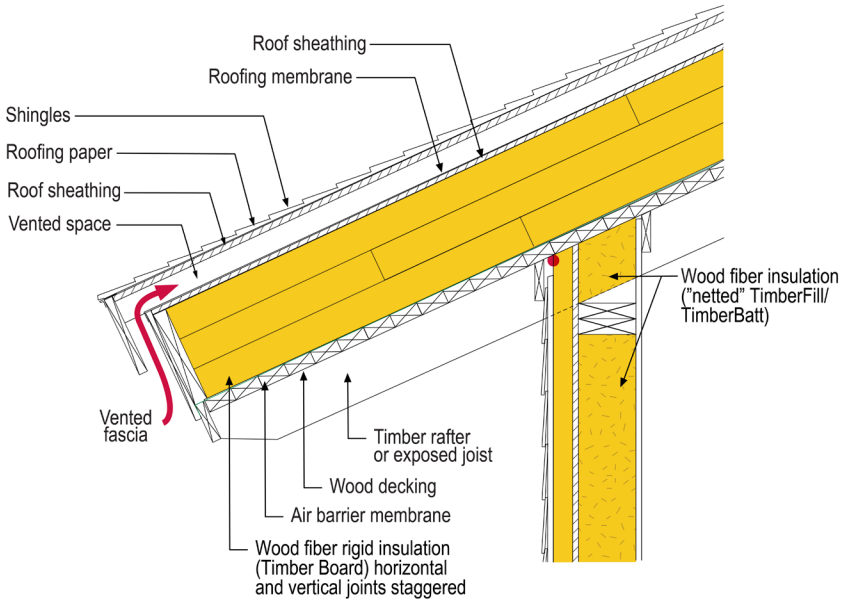

Siding
Wood fiber rigid insulation (TimberBoard)
Drainage gap
Building wrap
Sealant, adhesive or gasket (typ.)
2x4
Capillary break
Rodent protection for continuous rigid insulation
For insect protection provide 3'-0" of mulch and then drought-resistant plants
Ground slopes away from wall at 5% (6 in. per 10 ft.)
Wood fiber insulation ("netted" TimberFill/ TimberBatt)
T&G subfloor
1½" wood fiber rigid insulation (TimberBoard)
Plate under load bearing walls only
Fluid-applied vapor control layer
Polyethylene

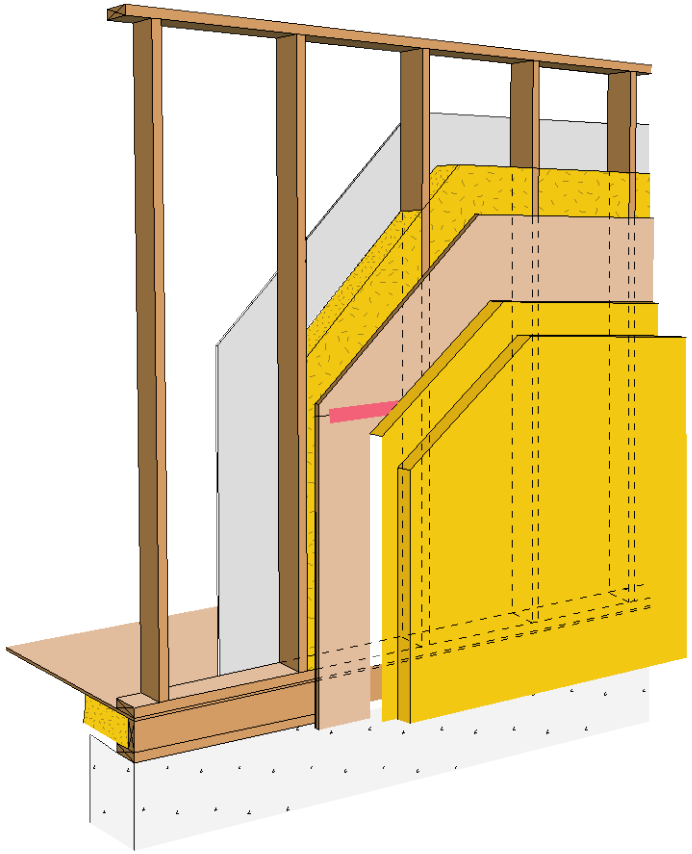

Shingles
Roofing paper
Roof sheathing
Wood fiber rigid insulation (TimberBoard)
Air control layer (air barrier)/Vapor control layer (vapor barrier)
Roof sheathing
Rafter/truss

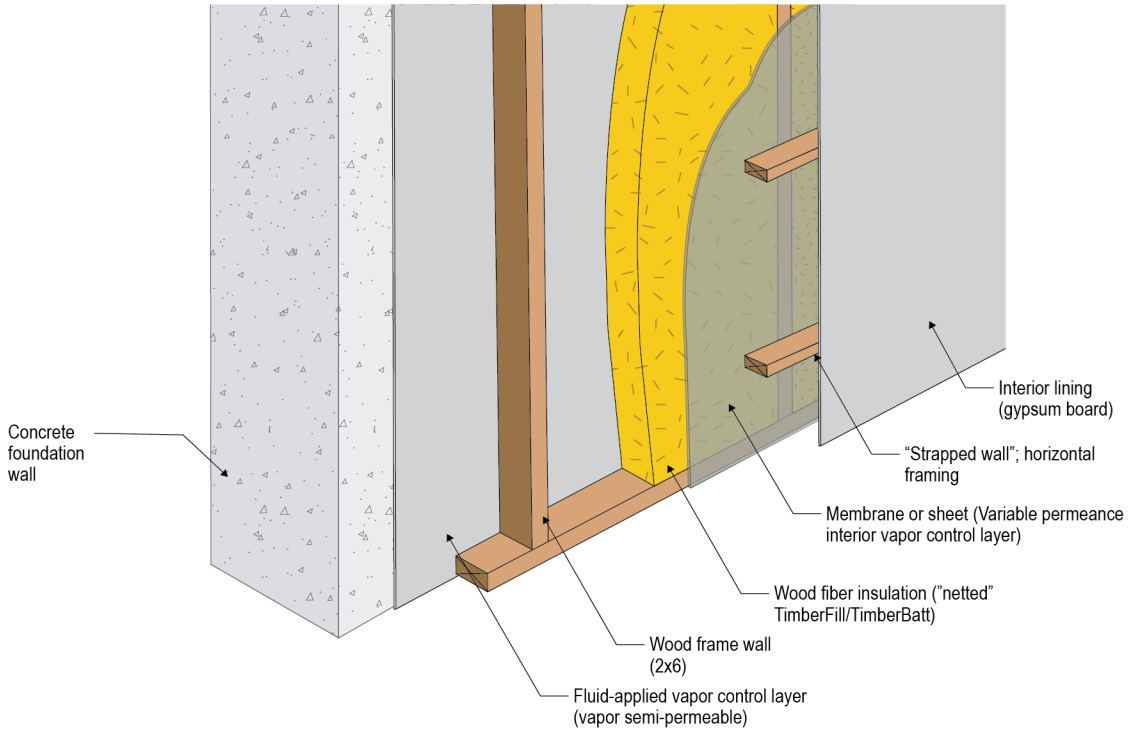

Shingles
Roofing paper
Roof sheathing
Wood fiber rigid insulation (TimberBoard) T&G
Drainage Gap
Water control layer/Air control layer (air barrier)/Vapor control layer (vapor barrier)
Roof sheathing
Wood fiber insulation ("netted" TimberFill/TimberBatt)


Shingles
Glass faced gypsum board
OSB/Plywood
Roofing membrane
OSB/Plywood
2x2 framing
Two layers of wood fiber rigid insulation(TimberBoard)/ exterior joints T&G
Wood fiber insulation ("netted" TimberFill/TimberBatt)
OSB/Plywood sheathing with integral water control/ vapor control layer
2x10's
Two 2x14 microlams
Gypsum board


Plywood/OSB sheathing
18" wide membrane strip under parapet folded down over exterior Plywood/OSB
Sealant
Polymer modified (PM) or traditional cement stucco
Metal lath
Drainage mat
Wood fiber rigid insulation (TimberBoard)T&G
Drainage gap
Fluid-applied water control layer
Metal cap
Coping wedge
Roofing membrane
Wood fiber rigid insulation (TimberBoard)
Air control layer (sealed joints in plywood/OSB sheathing)
Wood fiber insulation ("netted" TimberFill/ TimberBatt)
Sealant at top plate
Sealant
Latex paint
Gypsum board
Wood fiber insulation ("netted" TimberFill/ TimberBatt)
1/4" cant/ft


Roof sheathing
Roofing membrane
Shingles
Roofing paper
Roof sheathing
Vented space
Wood fiber insulation
("netted" TimberFill/
TimberBatt)
Vented
fascia
Timber rafter
or exposed joist
Wood decking
Air barrier membrane
Wood fiber rigid insulation
(Timber Board) horizontal
and vertical joints staggered




Concrete foundation wall
Interior lining (gypsum board)
"Strapped wall"; horizontal framing
Membrane or sheet (Variable permeance interior vapor control layer)
Wood fiber insulation ("netted" TimberFill/TimberBatt)
Wood frame wall (2x6)
Fluid-applied vapor control layer (vapor semi-permeable)