Water Control Layer
Air Control Layer
Vapor Control Layer
Thermal Control Layer
Cladding
Control layers
Structure
Ballast

Filter fabric

Control layers

Roof structure
Adapted from Baker, M.; Roofs, 1980; Courtesy National Research Council of Canada
Temperature (°C)

Hours of a summer day

From Baker, M.; Roofs, 1980
Hours of a winter day

From Baker, M.; Roofs, 1980
Insulation moved because of poor adhesion to deck and between layers

Top four courses of brick and wood blocking pulled inward by contracting membrane

Adapted from Baker, M.; Roofs, 1980; Courtesy National Research Council of Canada
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
Really Heavy Pink Stuff

Liquid Waterproofing over Concrete Deck
Wind across the corner of a roof produces a vortex spreading along edges from the windward corner.

Wind

No parapet

Low parapet

High parapet

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

Wall control layers

Roof control layers
Exterior - Cold
Water-shedding rain screen roof

Roof Space - Cold
Thermal control layer

Interior - Warm
Air control layer

From Baker, M.; Roofs, 1980
Building Science Corporation

- Roof insulation
- Insulation wind baffle
- 2” minimum space
- Water protection membrane
- Continuous soffit vent
- Vinyl or aluminum siding
- Rigid insulation (taped or sealed joints)
- Unfaced cavity insulation, cellulose or low-density spray-applied foam
- Gypsum board with vapor semi-permeable (latex) paint
- Consider increasing depth of insulation by using deeper trusses or oversized (longer) trusses
- Caulking or sealant
- Gypsum board with permeable (latex) paint
- Continuous ridge ventilation
- Attic ventilation
Note: Colored shading depicts the building’s thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.
$k_{\text{eff}} = 0.138 - 1.010 \rho + 3.233 \rho^2$

$R^2 = 0.79$
Solar radiation warms cladding

Warm air is trapped by overhang

Cladding warms air
Note: Colored shading depicts the building’s thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.
Diagram showing a roof system:
- **Roof membrane**
- **Fiberboard hygric buffer**
- **Rigid insulation**
- **Air barrier membrane**
- **Gypsum sheathing**
- **Fluted steel deck**
Shingles

Roofing paper

Minimum R-50 rigid insulation in two or more layers with horizontal and vertical joints staggered

Nail base for shingles (plywood or OSB) screwed through rigid insulation to wood decking or timber rafters

Air barrier membrane
Minimum R-50 rigid insulation in two or more layers with horizontal and vertical joints staggered.
Cold air falls toward bottom of joint

Rising air cools and vapor condenses on underside of top layer

Warm air rises toward cold side of SIP

Air returns to interior through accidental opening

Accidental opening on inside of joint allows warm moist air to enter
structural insulated panel
area prone to moisture damage
movement of air and moisture in panel joint towards roof peak
open joint
Sealant at this location would not have prevented failure.

Continuous sealant at this location, or at a location closer to the interior, would have prevented failure.

Continuous sealant at this location would have prevented failure.
Legend

- Green arrow: Upper level air flows
- Blue arrow: Lower level air flows
- Red arrow: Air flow at panel joints
Shingles
Roofing paper
R-19 batt insulation installed with wire stays or twine or netted cellulose
R-5 rigid insulation (vertical and horizontal joints offset from roof sheathing)
\( \frac{3}{8} \)” sheathing over rigid insulation
Roof sheathing
Sealant
Rigid insulation notched around roof trusses and sealed
Vinyl or aluminum siding
Rigid insulation
Building paper drainage plane
Underside of roof sheathing is typically the “first” condensing surface
Unfaced batt insulation
Gypsum board with vapor semi-permeable (latex) paint
The inside face of the roof sheathing forming the cavity is the first condensing surface.

OSB or plywood nail base for shingles.

R-30 unfaced batt ceiling insulation compressed to fit within 2x8 rafters or damp spray cellulose or “netted” dry blown cellulose or fiberglass.

R-5 rigid insulation (vertical and horizontal joints offset from roof sheathing).

Sealant

Rigid insulation notched around roof rafters and sealed.

Vinyl or aluminum siding.

Gypsum board ceiling with semi-vapor permeable (latex) paint.

Caulking or sealant

Unfaced batt insulation

Gypsum board with semi-vapor permeable (latex) paint.
Roofing tile

Roofing paper

Netted cellulose insulation or batt insulation installed with wire stays or twine

Roof sheathing

Underside of roof sheathing is typically the “first” condensing surface

Stucco

Unfaced batt insulation

Gypsum board with vapor semi-permeable (latex) paint

Rigid insulation

Building paper drainage plane
Building Science Corporation

Material Compatibility and Substitutions

OSB sheathing
Scupper
Cavity insulation; see Material Compatibility and Substitutions
Two layers OSB
Cavity insulation; see Material Compatibility and Substitutions
Polymer modified (PM) or traditional cement stucco
Metal lath

Gypsum board with semi-permeable (latex) paint
Sealant, adhesive or gasket at top plate
Caulking or sealant
2X6 24" o.c. advanced framing

Cavity insulation; see Material Compatibility and Substitutions

Sill gasket acts as capillary break
Gypsum board caulked, glued or gasketed to bottom plate; held up from slab
Concrete slab

Sub-slab stone layer (no fines); see Building Science Details
Concrete grade beam
Polyethylene vapor barrier extended under grade beam where it also acts as a capillary break

Perforated drain pipe added to "T" in order to couple sub-slab pressure field to vent stack

Ground slopes away from wall at 5% (6 in. per 10 ft.)
Weep screed flashing tucked behind drainage plane
Parging coat damproofed with latex paint to reduce water absorption
For termite protection provide 3'-0' of mulch and then drought-resistant plants

Soil gas ventilation stack
Sealant at all slab penetrations
Soil gas stack vented through flashed roof penetration

Roof flashing
Low density spray foam insulation

Asphalt shingles

Roofing paper

Roof sheathing

Raised heel truss

Rigid foam, or comparable, as backdam

Soffit

Roof underlayment sealed to drip edge

Non-occupiable space

Gypsum board with latex paint (acts as thermal barrier separating occupiable space from non-occupiable space)