Building Science

Roofs

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

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

Wall control layers

Roof control layers
Water-shedding rain screen roof

Thermal control layer

Air control layer

Exterior - Cold

Roof Space - Cold

Interior - Warm

From Baker, M.; Roofs, 1980
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

Continuous ridge ventilation

Attic ventilation

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
Note: Colored shading depicts the building’s thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.
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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.
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

Wood decking

Timber rafter or exposed joist
Minimum R-50 rigid insulation in two or more layers with horizontal and vertical joints staggered.
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

EXTERIOR

INTERIOR
Legend

- Green arrow: Upper level air flows
- Blue arrow: Lower level air flows
- Red arrow: Air flow at panel joints
New roofing system

Fully adhered membrane

Roof sheathing

Two layers of rigid insulation (joints staggered and offset)

Fully adhered membrane air barrier

Gypsum sheathing

Fluted metal deck
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)

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

Unfaced batt insulation

Gypsum board with vapor semi-permeable (latex) paint

Underside of roof sheathing is typically the “first” condensing surface
Mean monthly outdoor temperature

First condensing surface temperature (underside of roof sheathing) if R-5 rigid insulation is installed over roof deck

Dew point temperature at 50% R.H., 70°F

Dew point temperature at 40% R.H., 70°F
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

Rigid insulation (taped, shiplapped or sealed joints)

Unfaced batt insulation

OSB or plywood roof sheathing

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

Caulking or sealant

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

Rigid insulation

Building paper drainage plane

Unfaced batt insulation

Gypsum board with vapor semi-permeable (latex) paint