Spray Polyurethane Foam

Building Enclosures
The Perfect Wall
Water Control Layer
Air Control Layer
Vapor Control Layer
Thermal Control Layer
Ballast
Filter fabric
Control layers
Roof structure
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 finish

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 finish

Vapor Profile
Brick veneer cladding

Drained and vented cavity

Spray-applied closed-cell high-density foam (2 lb/ft³) water control layer (also air control layer, vapor control layer and thermal control layer)

Concrete masonry unit wall

Metal channel

Gypsum board interior lining

Latex paint
Brick veneer/stone veneer

Drained cavity

Spray-applied closed-cell high-density foam (2 lb/ft$^3$) water control layer (also air control layer, vapor control layer and thermal control layer)

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 finish
Brick veneer/stone veneer

Drained cavity

Spray-applied closed-cell high-density foam (2 lb/ft³) water control layer (also air control layer, vapor control layer and thermal control layer)

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 finish
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 sheathing, plywood or OSB
Spray foam insulation
Gypsum board
Latex paint or vapor semi-permeable textured wall finish
Brick veneer/stone veneer

Drained cavity

Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate

Spray foam insulation

Gypsum board

Latex paint or vapor semi-permeable textured wall finish
Brick veneer/stone veneer
Drained cavity
Drainage plane
Non paper-faced exterior sheathing, plywood or OSB
Spray foam insulation
Gypsum board
Latex paint or vapor semi-permeable textured wall finish
CMU infill assembly
HD spray foam
Concrete frame/slab
Oversized backer rod to support membrane strip
Membrane strip over primed surface
“Seat” in slab
Open joint
Steel stud infill assembly

Paperless gypsum sheathing

HD spray foam

Concrete frame/slab

Membrane strip over primed surface
Minimum overlap of 1"; the stiffness of the stud to track connection must reflect behavior at extreme locations.

Minimum required movement joint distance between leg of outer track and screw connecting stud to inner track.

Drilled expansion anchor

Outer track

Maintain required movement gap between gypsum board and floor slab

Do not screw gypsum board to outer track. Maintain required movement joint distance between drywall screws and leg of outer track.

Prepunched cut-out for expansion anchor clearance

Inner track
Liquid-applied membrane lining, sub-sill window flashing, air and water barrier transition membrane

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

Flashings

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

HD spray foam “filet” to be applied before rest of foam

HD spray foam

Air seal

Paperless gypsum sheathing
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
Spray-applied closed-cell high-density foam (2 lb/ft³) water control layer (also air control layer, vapor control layer and thermal control layer)

Vent and drain openings @ 24” o.c.

Shelf angle supported on stand-offs attached to cast-in plates

Vent openings

Use backer rod to fill deflection joint and debond water and air barrier

Adjustable masonry tie embedded in concrete block mortar joint
CMU
Peel and stick membrane strip
Backer rod
Spray-applied closed-cell high-density foam (2 lb/ft^3) water control layer (also air control layer, vapor control layer and thermal control layer)
Cavity
Brick veneer
Parapet flashing

Fully-adhered water control membrane

Tapered rigid insulation

Air control layer transition membrane

Fiberglass batt insulation

Peel and stick transition membrane; air and water control

Spray-applied closed-cell high-density foam (2 lb/ft³) water control layer (also air control layer, vapor control layer and thermal control layer)

Fiberglass batt insulation

Backer rod fills gap

Peel and stick transition membrane; air and water control

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

Light gauge steel framing (installed slightly proud of I-beam)

Metal deck

Air control membrane

Open web steel joist

Deflection track allows space for sheathing to move
Z-bar

HD spray foam

Steel stud

Exterior gypsum sheathing
“The Ugly”

“The Bad”

“The Good”
Beware Thermal Flanking

- Beware heat flow around window frame

Figure 1: Thermal Flanking

Figure 2: Flanking Reduced
Sill beyond

Carry membrane onto curtainwall shoulder, seal and mechanically clamp in place.

Water, air and vapor control membrane

Metal brake shape over rigid insulation

Sealant and backer rod

Thermal control (insulation) layer
DETAIL AT BRICK VENEER WALL / ROOF

REFERENCE DETAIL: REGISTERED PROFESSIONAL TO REVIEW PRIOR TO USE
Brick veneer

Building paper

Interior gypsum should extend to underside of floor deck and be sealed

Exterior sheathing

Metal stud wall

Cavity insulation

Top chord bearing truss

Return plenum operates under negative pressure relative to occupied space and exterior

Suspended ceiling

Interior gypsum
Seal around rough openings of windows and doors

Seal along top plates on exterior walls

Seal along bottom plate on exterior walls

Partitions: seal at top plate where adjacent to an unconditioned space

Seal along inside of bottom of first stud in interior wall

Seal gypsum board to first stud in the wall
Wind pressurizes chamber between inner and outer seal.

Sealant backer rod

Inner seal

Outer seal

Vent tube
Inner, protected seal

Outer, exposed seal

Drain and vent opening
Outer sealant on backer rod drained at vertical joints

Inner sealant on backer rod continuous for water and air control continuity

**Note:** Precast concrete is the water and air control layer

Panel connection cast into panel c/w leveling shims; fill with spray foam

Smoke seal (air seal) and firestop

Fill space between slab edge and back or panel with mineral fiber firestop

Line of outer sealant at panel joints

Line of inner sealant at panel joints

Precast panel (installed first)

Corrosion-resistant metal pin to connect panels without penetrating air and water layers

Gypsum board

Steel stud

Air-impermeable spray or board insulation

Cast in place anchor

Structural columns and walls should be held back from slab edge to allow for installation of air and thermal control layers
1" HD spray foam

4¼" cellulose or spray fiberglass

OSB/plywood sheathing

2x6 frame wall

Drainage plane

Air seal
OSB/plywood sheathing

Drainage plane

9” to 12” cellulose or spray fiberglass

1” HD spray foam

Gypsum board

2x6 frame wall

4½” cellulose or spray fiberglass

1” HD spray foam
OSB sheathing

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

Tyvek® StuccoWrap®

Weep screed flashing tucked behind drainage plane
Purge coat damproofed with latex paint to reduce water absorption

For termite protection provide 3'-0" of mulch and then drought-resistant plants
Ground slopes away from wall at 5% (6 in. per 10 ft.)

Metal cap
18" wide membrane strip
Coping wedge
OSB
Rubber roofing membrane

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

Soil gas stack vented through flashed roof penetration

Sealant at all penetrations

1/4" caulk/br

Soil gas ventilation stack

Sealant at all slab penetrations
Metal cap
OSB sheathing
Scupper
Sealant
Rigid insulation
OSB
Cavity insulation
Sealant
Polymer modified (PM) or traditional cement stucco
Metal lath
Building paper bond break over drainage plane

18" wide membrane strip under parapet folded down over exterior rigid insulation
Coping wedge
OSB
Rubber roofing membrane
Rigid insulation

Air barrier membrane (membrane roofing in very cold and cold climates; housewraps, building paper in all other climates)

Gypsum board with semi-permeable (latex) paint
Sealant, adhesive or gasket at top plate
Cavity insulation

1/4" cant/ft
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

Gypsum board with latex paint
(acts as thermal barrier separating occupiable space from non-occupiable space)
1" HD spray foam

2x6 top chord

OSB/plywood sheathing

Drainage plane

Cellulose or spray fiberglass; 8" nominal

Gypsum board

2x6 frame wall

4½" cellulose cavity insulation

1" HD spray foam
Roof cladding

Roof underlayment

2x6 top chord

1" HD spray foam

"Netted" cellulose; 8" nominal (R-23.5)
Roof cladding

Roof underlayment

3” HD spray foam (R-19.5)

6¼” cellulose or spray fiberglass (R-21)
Vented roof with I-joint

Notes:
- 1/4" vented air space connected to soffit and ridge vents
- Gypsum board as air barrier
- Use care at recessed fixtures
- Latex paint as primary vapor retarder

Unvented roof with I-joint

- Roof shingles
- Roofing felt
- Roof sheathing
- 1" XPS foam
- Low density spray foam
- Air space
3” spray polyurethane foam (2 lb/ft³ density)

1 1/2” metal stud wall

Gypsum board thermal barrier

3/4” drainage mat (filter fabric side facing up)

2” extruded polystyrene (XPS)

New concrete slab

Existing slab
Liquid applied membrane
waterproofing

Flanged window

Trim closure

Concrete sill

2x6 wood buck

Exterior wythe (repinted or coated with polymer cement slurry)

4 wythe masonry wall

Air seal

1 1/2" extruded polystyrene rigid insulation (XPS)

Plywood spacer

1x2 backdam

2" spray applied foam insulation (closed cell, high density)

Uninsulated steel stud assembly

Gypsum board
$S_{\text{crit}} \approx 0.7$
Capillary break on exterior foundation wall

Capillary break under slab

Capillary break on top of footing
Capillarity + Salt = Osmosis

- Mineral salts carried in solution by capillary water
- When water evaporates from a surface the salts left behind form crystals in process called efflorescence
- When water evaporated beneath a surface the salts crystallize within the pore structure of the material in called sub-efflorescence
- The salt crystallization causes expansive forces that can exceed the cohesive strength of the material leading to spalling
1. **Evaporation**

Water with salt in solution travels in porous material via capillary flow to surface where evaporation occurs.

2. **Salt**

Salt is left behind as water evaporates; process leads to an ever-increasing concentration of salt as evaporation continues.

3. **Water Rushes**

Water rushes to dilute concentration of salt leading to potentially huge hydrostatic pressures.

4. **Surface Spalling**

Surface breaks apart and flakes when hydrostatic pressure due to “osmosis” exceeds cohesive strength of material.

“Spalling”
Diffusion + Capillarity + Osmosis = Problem

- Diffusion Vapor Pressure: 3 to 5 psi
- Capillary Pressure: 300 to 500 psi
- Osmosis Pressure: 3,000 to 5,000 psi
Mortar "eaten" away as drying happens from within the mortar matrix.

Salts left behind on surface in the form of crystals ("efflorescence").

Evaporation from surface film of water.

Capillary flow of salts in solution.
Lime mortar “eaten” away over time “sacrificing” itself to protect brick and masonry units

Evaporation from thick lime-based mortar rendering

Capillary flow of salts in solution