



# DESIGN GUIDE

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Practical Strategies for  
Moisture, Air and Thermal Control



Written in collaboration with  
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# CONTENTS

<b>1. Physics of Building Enclosures</b> . . . . .	<b>4</b>
<b>2. Wall Systems</b> . . . . .	<b>14</b>
2.1. Thermal Bridging . . . . .	18
2.2. Punched Openings . . . . .	20
<b>3. Foundation Systems</b> . . . . .	<b>22</b>
3.1. Basement Foundations . . . . .	24
3.2. Crawlspace Foundations . . . . .	27
3.3. Slab Foundations . . . . .	30



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Dr. Lstiburek is an acclaimed educator who has taught thousands of professionals over the past three decades and has written countless papers as well as the best-selling *Builder Guides*. Fittingly, the *Wall Street Journal* has described him as “the dean of North American building science.” He has a joy for telling tall tales to his protégés and audiences.

Dr. Lstiburek's work ranges widely from providing expert witness testimony to overseeing research and development projects, to writing for the *ASHRAE Journal* and [BuildingScience.com](#). Dr. Lstiburek's commitment to advancing the building industry has had a lasting impact on building codes and practices throughout the world.

## 1. Physics of Building Enclosures

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At a fundamental level a building can be considered an environmental separator. It keeps the “outside” out and the “inside” in. While it is doing this it shouldn’t burn, be blown away or fall down. The following discussion focuses on the environmental separation aspects of building enclosures and not the fire control and structural aspects.

The environmental loads historically have been characterized as combined heat, air and moisture (HAM) transport. More recently they are referred to as hygrothermal loads and the process of evaluating their effect on building enclosures is called hygrothermal analysis. The following list defines the key hygrothermal control requirements for building enclosures:

- Control heat flow
- Control airflow
- Control water vapor flow
- Control rain
- Control ground water

These control requirements are governed by the Laws of Thermodynamics. Of the four Laws of Thermodynamics the 2<sup>nd</sup> Law is the most misunderstood and most relevant to environmental separation. The 2<sup>nd</sup> Law can be summarized as follows:

- Heat flow is from warm to cold
- Moisture flow is from warm to cold
- Moisture flow is from more to less
- Airflow is from a higher pressure to lower pressure
- Gravity acts down

Applying the 2<sup>nd</sup> Law to the hygrothermal control requirements yields the following control layers.

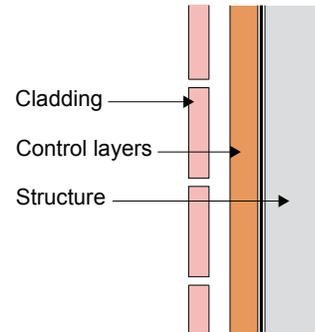
- Water control layer
- Air control layer
- Vapor control layer
- Thermal control layer

These control layers are listed in order of importance. All are important, but not equally important. The ranking is obvious from historic experience and the underlying physics. Controlling water in the liquid form (rain and ground water) has been the focus of master builders and architects for generations. Controlling air is a much more recent focus – less than a century. Controlling vapor is even more recent – less than a generation. Air movement transports significantly more water in the vapor form than does vapor diffusion and therefore air control is more important than the control of molecular water vapor transport (vapor diffusion). In common parlance, “air barriers” are more important than “vapor barriers”. Thermal control dates back millenniums – but getting it wrong has not led to durability failures. The thermal control layer failures have been typically limited to comfort issues and operating cost issues. Hence, thermal control layers are listed last on the control layer priority list.

The optimum configuration of the control layers for a wall assembly is graphically presented in Figure 1.1. While many configurations are possible, the most common will be discussed in this guide.

**Figure 1.1**

All control layers are located on the exterior of the structure



The water control layer, air control layer and vapor control layer are all located on the exterior of the structure. These three have been traditionally combined into a single control layer that can be a film or coating or membrane or a sheet good. The fourth control layer, the thermal control layer is typically located exterior to the other three control layers. This configuration allows this assembly to be constructed in all climate zones: cold, mixed, hot and humid or dry. Additionally, this configuration allows this assembly to enclose all interior environments in all climate zones: office, commercial, residential, institutional, pools, museums, art galleries, data processing centers. The sole exception are refrigerated buildings and cold storage facilities. In such assemblies the location of the thermal control layer is “flipped” with the other control layers – the thermal control layer now becomes located on the interior of the other three control layers.

- In cold climates, locating the vapor control layer on the interior of the thermal control layer results in this layer remaining warm therefore controlling condensation from occurring due to interior moisture sources.
- In hot climates, locating the vapor control layer on the exterior of the structure allows the drainage of condensation to the exterior – condensation that may occur on the exterior surface of the control layer due to exterior moisture surfaces. This condensed water is handled in the same manner as penetrating rainwater. Note that the water control layer and vapor control layer are in the same location and are typically the same material.
- In mixed climates, the configuration addresses interior moisture loads during the heating season in the same manner a similar assembly addresses interior moisture loads in cold climates. During the cooling season the configuration addresses exterior moisture loads in the same manner a similar assembly addresses exterior moisture loads in hot climates.

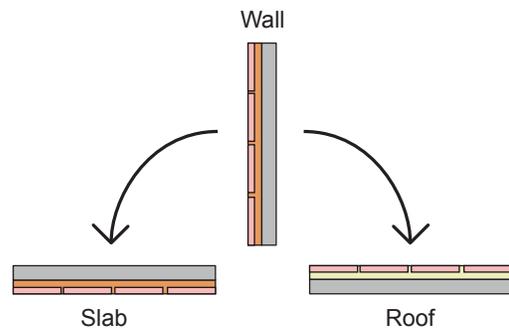
For this reason, this configuration is referred to as the “universal wall” or the “perfect wall”. It works in all climate zones for all interior environmental conditions with the exception noted.

The cladding is drained and back-ventilated in such assemblies. The function of the drainage is to control hydrostatic pressure that may result from penetrating rainwater. The function of the back-ventilation is to reduce inward vapor drive than may occur from “reservoir” claddings – claddings that are wetted during rain events that may store moisture and then exposed to solar radiation.

The same approaches can be applied to roofs and foundations – the argument being that similar loads and the same laws of physics apply (Figure 1.2).

**Figure 1.2**

The same approach can be applied to slab, wall and roof assemblies



The traditional configuration for the control layers of a roof assembly is graphically presented in Figure 1.3. Control layers are provided above and below the thermal control layer. The typical roof membrane functions as the water control layer, an air control layer and a vapor control layer above the thermal control layer – the insulation. A second membrane or layer or layers are provided below the thermal control layer – the insulation – and the function of this membrane or layers is to function as an air control layer and vapor control layer. The intent is to keep the rain and air and vapor from getting into the assembly from the top (“outside”) and to keep the air and vapor from getting into the thermal control layer from the bottom (“inside”). This configuration also works in all climate zones and for all interior environmental conditions – even for refrigerated buildings and cold storage facilities.

**Figure 1.3**

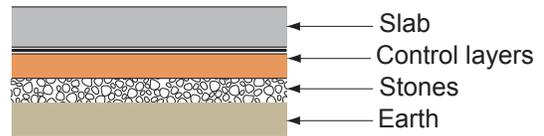
Control layers of a traditional roof assembly



The optimum configuration of the control layers for a foundation slab assembly is graphically presented in Figure 1.4. The key to the performance of this assembly is the granular or stone layer under the thermal control layer – the insulation – that functions as a capillary break controlling liquid water absorption in the thermal control layer. It is analogous to the “drained and back-ventilated” cladding of a wall assembly.

**Figure 1.4**

Control layers of a traditional foundation slab assembly



Wall assemblies, roof assemblies and foundation assemblies subsequently need to be integrated to function as a building enclosure. Conceptually, the approach is graphically illustrated in Figures 1.5 through Figure 1.11. The water control layer of the roof assembly is connected to the water control layer of the wall assembly that is then connected to the water control layer of the foundation assembly. Then the air control layer of the roof assembly is connected to the air control layer of the wall assembly that is then connected to the air control layer of the foundation assembly. The same conceptual approach is applied to the vapor control layer and thermal control layer.

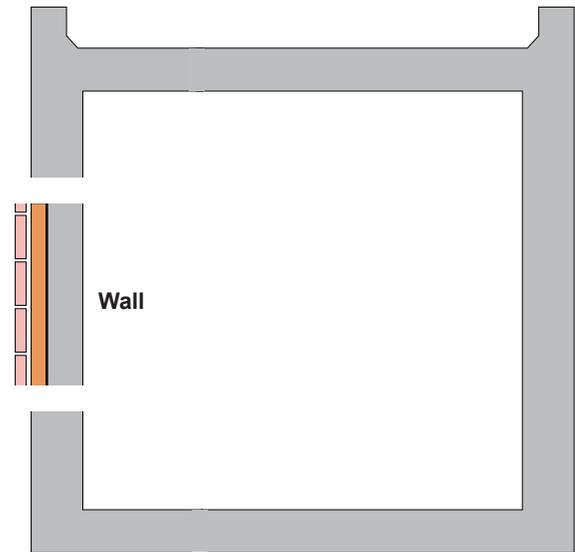
**Figure 1.5**

Continuity of control layers at roof, wall, and foundation interfaces



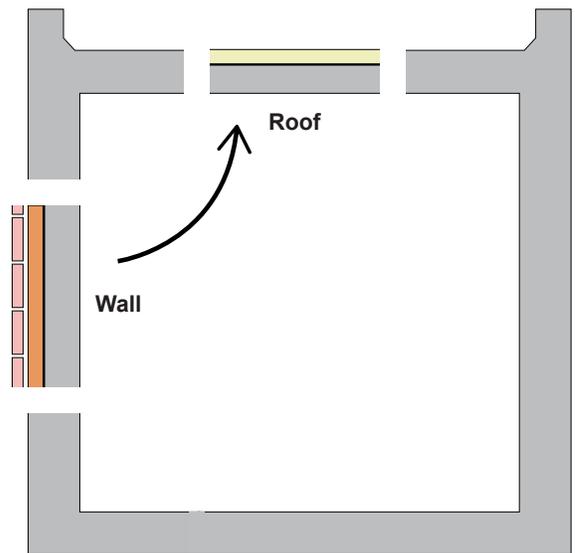
**Figure 1.6**

Integration of the wall assembly into control layer continuity



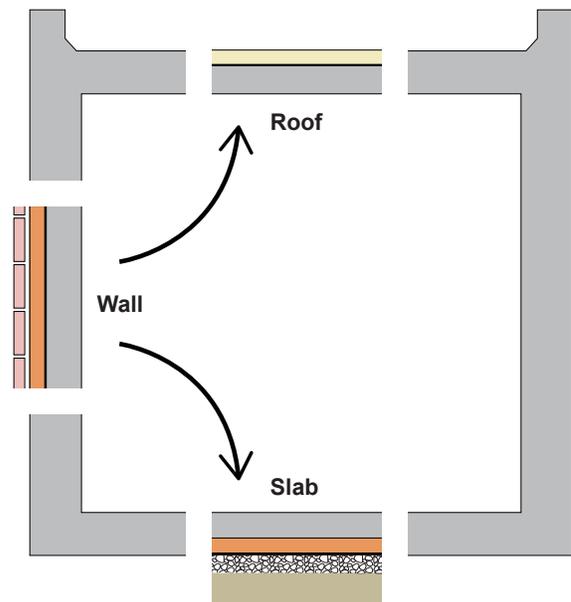
**Figure 1.7**

Connecting the roof assembly to wall for control layer continuity



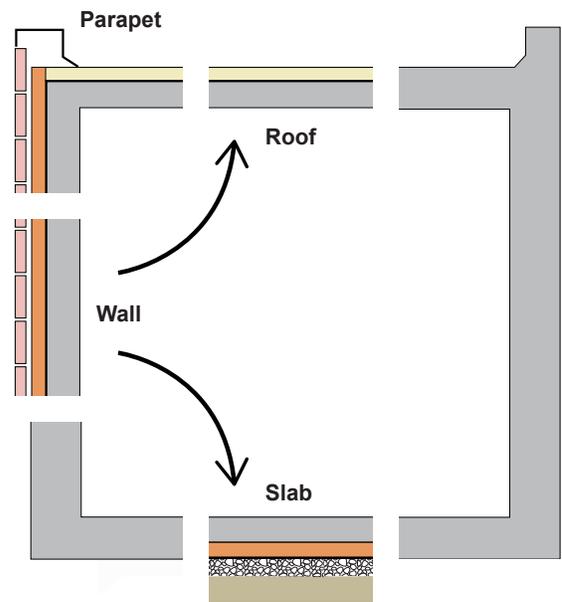
**Figure 1.8**

Continuous control layers across roof, wall, and slab assemblies



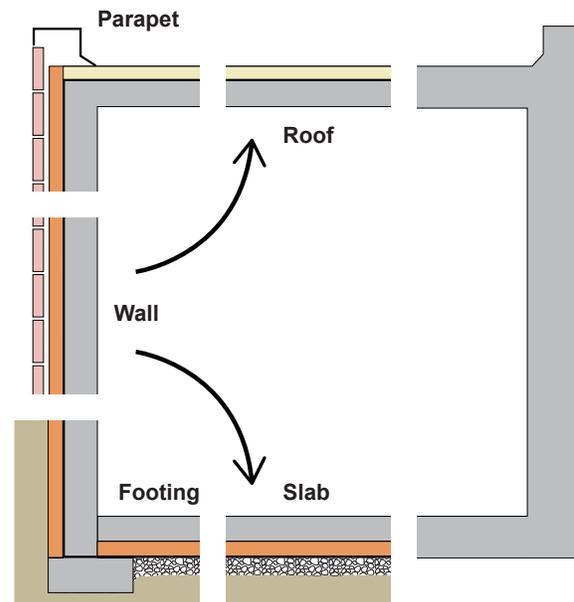
**Figure 1.9**

Complete enclosure integration with parapet detailing



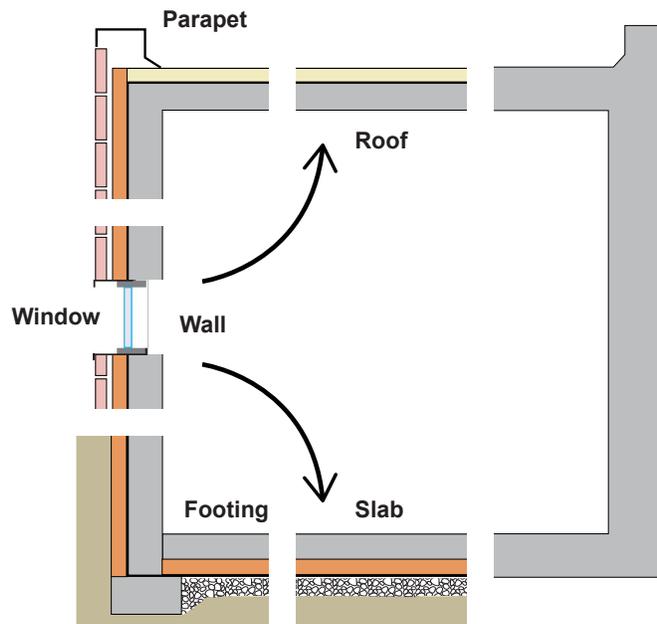
**Figure 1.10**

Integrating foundation wall — note that the continuity of the control layer is not possible at the footings for structural reasons



**Figure 1.11**

Continuity is most significant when interrupted at penetrations

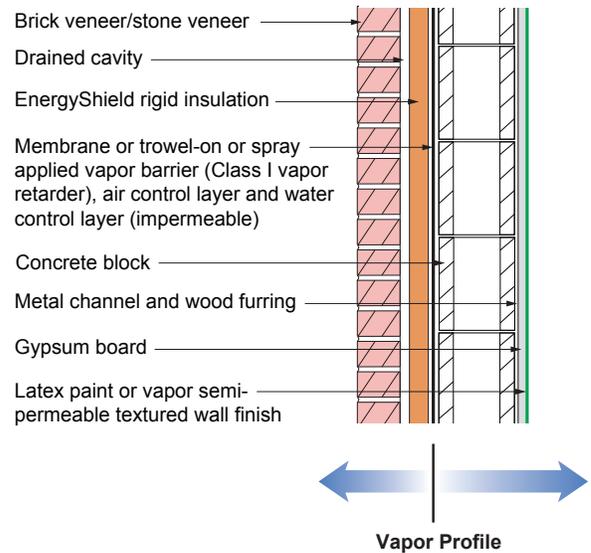


Continuity of the control layers is the key to the hygrothermal performance of building enclosures. That continuity historically has been demonstrated to be most significant where roofs meet walls and at penetrations such as punched openings for windows, doors, curtain wall connections, storefront connections and service openings for mechanical, electrical, plumbing and communication.

The three most common versions of the “site built,” “universal wall” or “perfect wall” are graphically presented in Figure 1.12, Figure 1.13 and Figure 1.14 – for masonry or concrete assemblies, for steel frame assemblies, and for wood frame assemblies respectively. In these three assemblies a myriad of products work successfully. Almost any exterior insulation works and almost any sheet good, spray system or trowel applied membrane works. Note the vapor profile: drying occurs to the interior from the bold line and to the exterior from the bold line in all climates.

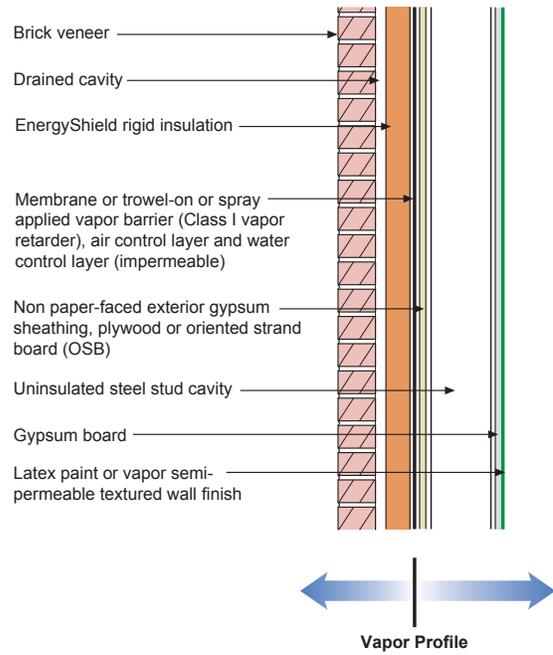
**Figure 1.12**

Control layers with a concrete block wall and masonry veneer



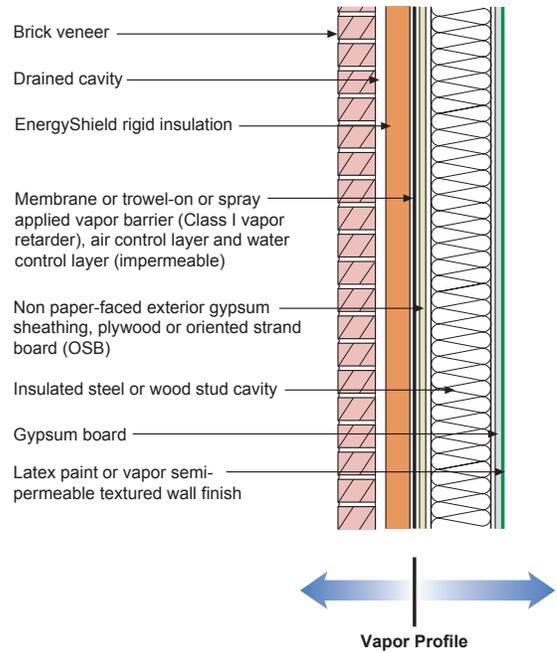
**Figure 1.13**

Control layers with an uninsulated steel stud cavity wall and masonry veneer



**Figure 1.14**

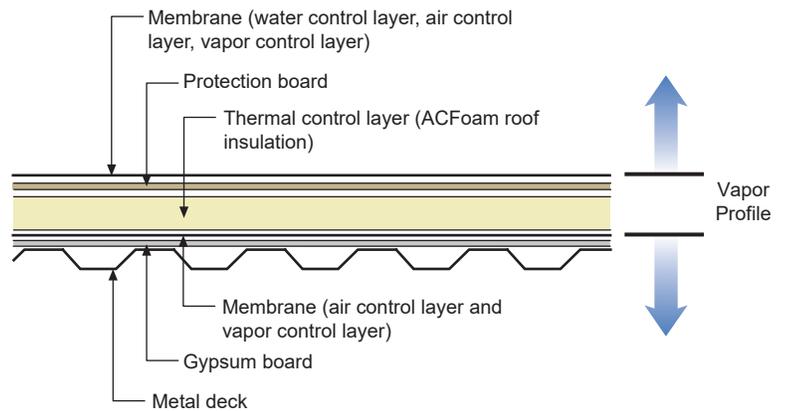
Control layers with an insulated stud wall and masonry veneer



The most typical version of a “site built” compact roof assembly is graphically presented in Figure 1.15. As noted previously, the roof membrane functions as the water control layer, an air control layer and a vapor control layer above the thermal control layer – the insulation. A second membrane is provided below the insulation and the function of this membrane is to perform as an air control layer and vapor control layer. Also, as previously noted, this assembly works in all climate zones and for all interior environmental conditions – even for refrigerated buildings and cold storage facilities. Note the vapor profile: drying occurs to the interior from the lower membrane and to the exterior from the upper roof membrane in all climate zones.

**Figure 1.15**

Control layers within a typical roof assembly



## 2. Wall Systems

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The most important non-structural and non-fire performance aspect of any wall system is its ability to control rainwater. Providing drainage behind claddings coupled with an effective water control layer is the most historically successful method of controlling rainwater in wall assemblies.

It is obvious to state that the function of the water control layer is to control rainwater. It is not obvious to state that in order for the water control layer to function it must be able to resist the driving forces that act on the rainwater that accesses the surface of the water control layer. The most significant of these forces is hydrostatic pressure followed by wind induced air pressure. Hydrostatic pressure resulting from “perched” rainwater is typically greater than wind induced pressures.

The best approach to address hydrostatic pressure is to prevent it from occurring or limiting its magnitude. Providing drainage is the most historically successful method of addressing hydrostatic pressure. Mitigating wind induced air pressures to control rainwater entry is more complex and generally not effective except at joints and small volume airspaces.

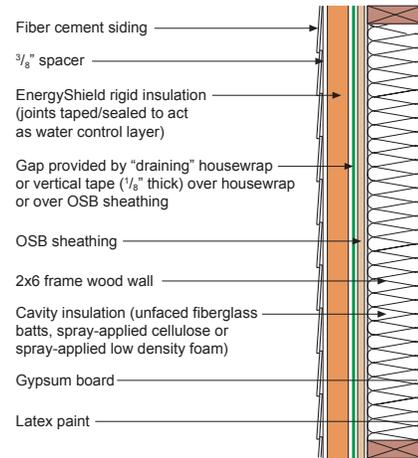
In general, two elements are necessary for successful rainwater control in a wall assembly. First, continuity of the water control layer. Second, providing a continuous drained air gap over this water control layer.

The size of the drained air gap is based on historic practice rather than the governing physics. A continuous air gap as small as 1/32-inch is typical for drained hardcoat stucco systems and is provided by textured weather resistive barriers or building wraps whereas a 1-inch air gap is typical behind brick veneers and its dimension is a historic artifact - “the thickness of a masons knuckles and fingers”. In commercial wall systems, a minimum continuous 3/8-inch gap for all cladding systems is recommended and this is based more on construction tolerances than physics. The key word to note is continuous. With brick and stone veneers and stucco renderings, this is typically done with a drainage mat and filter fabric. With panel claddings this is typically done with spacers and fastener systems.

Figure 2.1 illustrates a classic example of drainage behind rigid insulation where a “draining” building wrap provides the drainage. An additional drainage gap is located directly behind the siding/cladding layer. Figure 2.2 illustrates drainage behind rigid insulation and a stucco cladding. Figure 2.3 illustrates drainage behind siding installed over rigid insulation where the face of the rigid insulation provides the water control layer by virtue of the joints in the rigid insulation being taped/sealed. The difference between Figure 2.1 and Figure 2.3 is based on the rain exposure and structural requirements related to shear that typically require structural exterior sheathing such as plywood or OSB. Figure 2.3 should be limited to regions that experience less than 20-inches of annual rainfall (IECC Dry (B) climates) and to buildings no more than two stories in height.

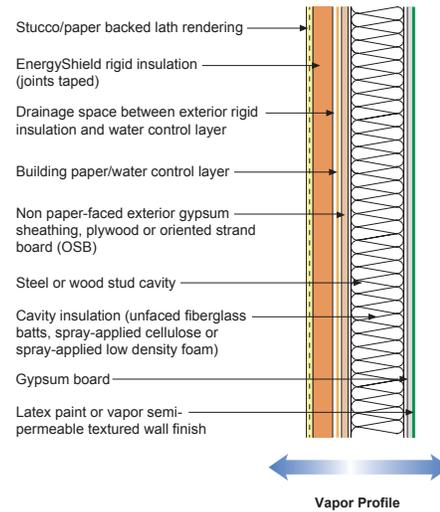
**Figure 2.1**

Primary drainage layer behind rigid insulation with an additional drainage gap behind cladding



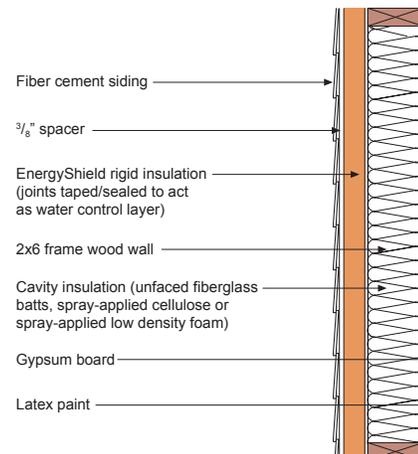
**Figure 2.2**

Continuous drainage space behind the rigid insulation in a stucco wall assembly



**Figure 2.3**

Rigid insulation as the primary drainage layer behind cladding in a typical stud wall assembly



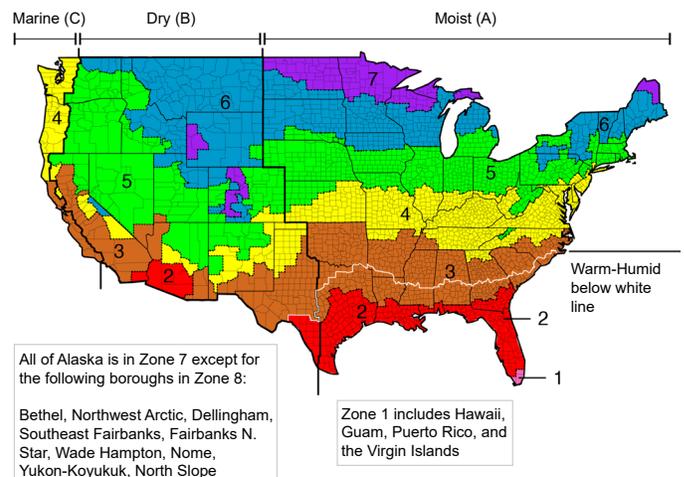
Condensation in wall assemblies is controlled by providing sufficient exterior rigid insulation to control the temperature of the condensing surfaces – typically the interior surface of the exterior sheathing or the interior surface of the exterior rigid insulation. The amount of rigid insulation is determined by the climate location (Figure 2.4) and the interior moisture load. The building code specifies the amount of insulation for residential and typical commercial occupancies (Table 2.1). A similar approach is used for roof assemblies and is building code specified (Table 2.2).

Note that where the temperature of the condensing surface is controlled by following the code requirements in Table 2.1 and Table 2.2 an additional interior vapor control layer (vapor barrier) is not required in typical assemblies. Further note that typical assemblies are not special use assemblies such as indoor swimming pools, humidified and pressurized hospitals, art galleries, museums and data processing facilities. These special use assemblies should be designed and constructed by experienced and knowledgeable architects, engineers, consultants and contractors.

Where the temperature of the condensing surface is controlled by following the code requirements in Table 2.1 and Table 2.2 an additional interior vapor control layer (vapor barrier) can be installed without the commonly assumed “risk” associated with “double vapor barriers” - preventing drying in either direction. The reason is that the temperature of the condensing surface is raised sufficiently to control condensation. Foil faced exterior rigid insulation can be used with an interior vapor barrier. Again, note that this does not apply to special use assemblies. Special use assemblies typically have only one vapor barrier and that vapor control layer is located immediately behind rigid continuous insulation – the “universal wall” or the “perfect wall” approach.

**Figure 2.4**

Department of Energy climate zones



**Table 2.1**

The building code specifies the prescriptive thermal control values in wall assemblies required by climate zone

CLIMATE ZONE	RIGID BOARD OR AIR IMPERMEABLE INSULATION	TOTAL CAVITY INSULATION	TOTAL WALL ASSEMBLY INSULATION	RATIO OF RIGID BOARD INSULATION OR AIR IMPERMEABLE R-VALUE TO TOTAL INSULATION R-VALUE
4C	R-2.5	R-13	R-15.5	15%
	R-3.75	R-20	R-23.75	15%
5	R-5	R-13	R-18	30%
	R-7.5	R-20	R-27.5	30%
6	R-7.5	R-13	R-20.5	35%
	R-11.25	R-20	R-31.25	35%
7	R-10	R-13	R-28	45%
	R-15	R-20	R-35	45%
8	R-15	R-13	R-28	50%
	R-20	R-20	R-40	50%

Adapted from Table R702.1 of the 2015 International Residential Code

**Table 2.2**

Insulation requirements for condensation control in roof assemblies is prescribed in the building code by climate zone

CLIMATE ZONE	RIGID BOARD OR AIR IMPERMEABLE INSULATION	CODE REQUIRED R-VALUE	RATIO OF RIGID BOARD INSULATION OR AIR IMPERMEABLE R-VALUE TO TOTAL INSULATION R-VALUE
1, 2, 3	R-5	R-38	10%
4C	R-10	R-49	20%
4A, 4B	R-15	R-49	30%
5	R-20	R-49	40%
6	R-25	R-49	50%
7	R-30	R-49	60%
8	R-35	R-49	70%

Adapted from Table R806.5 of the 2015 International Residential Code

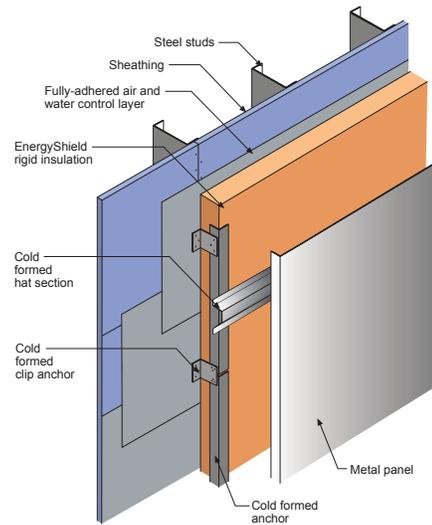
## 2.1. Thermal Bridging

A key performance aspect of the “site built,” “universal wall” or “perfect wall” is the continuous insulation layer – the thermal control layer – on the exterior of the structure. Attaching cladding systems through this layer can result in thermal bridging at the attachment penetration points degrading thermal performance. The most common approaches attempting to address this issue are graphically presented in Figures 2.5 through Figure 2.9. All of these approaches address the thermal bridging issue but nevertheless result in some degradation of thermal performance.

**Figure 2.5**

Cladding attachment using clip and hat channel systems through the insulation

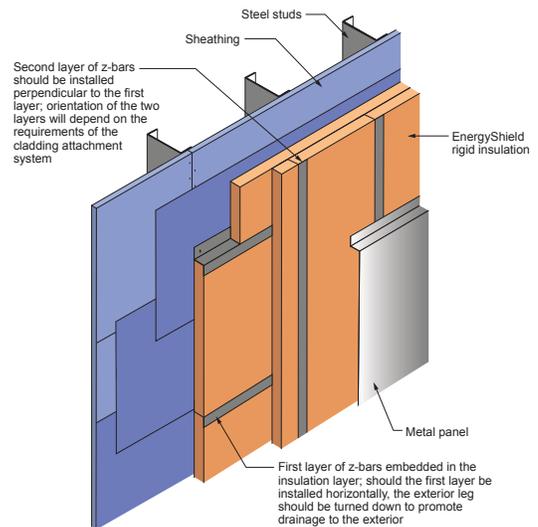
While this approach minimizes fastener penetrations, it still introduces some thermal bridging at the anchor points



**Figure 2.6**

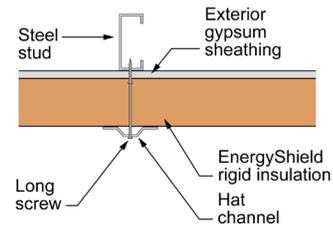
Cladding attachment using z-bar furring embedded in insulation layers

Even though the z-bars create thermal bridges, the two layer approach helps reduce the performance impact



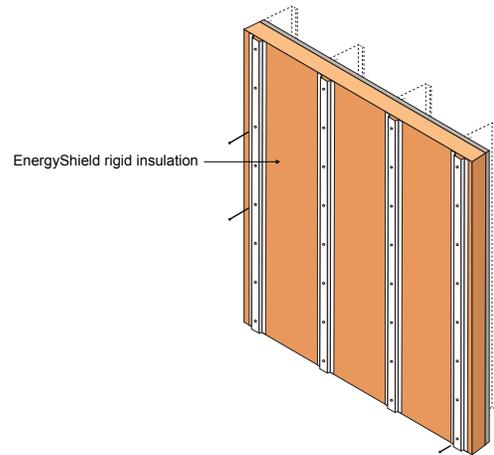
**Figure 2.7**

Cladding attachment illustrating a hat channel fastened directly to steel studs using long screws through the insulation



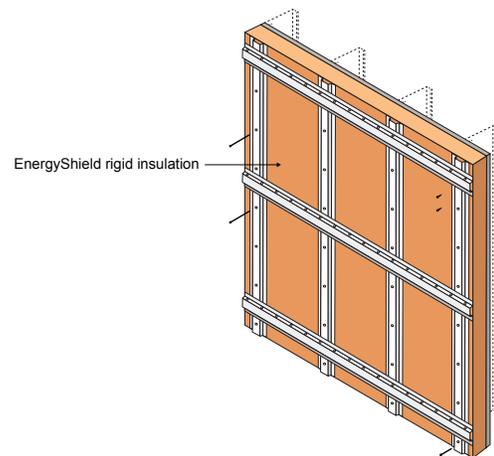
**Figure 2.8**

Attaching hat channels through insulation using long screws is a cost-effective approach providing a secure connection for cladding systems and can minimize thermal bridging with careful detailing and fastener spacing



**Figure 2.9**

Cladding attachment using clip and rail system reduces direct thermal bridging by limiting penetration points and using thermally broken components



## 2.2. Punched Openings

Windows and doors are installed in openings in the building enclosure often referred to as “punched openings”. The joints between window units and doors are required to meet the same control requirements as assemblies are required to meet in the field of the wall or the field of the roof – namely provide:

- Water control continuity
- Air control continuity
- Vapor control continuity
- Thermal control continuity

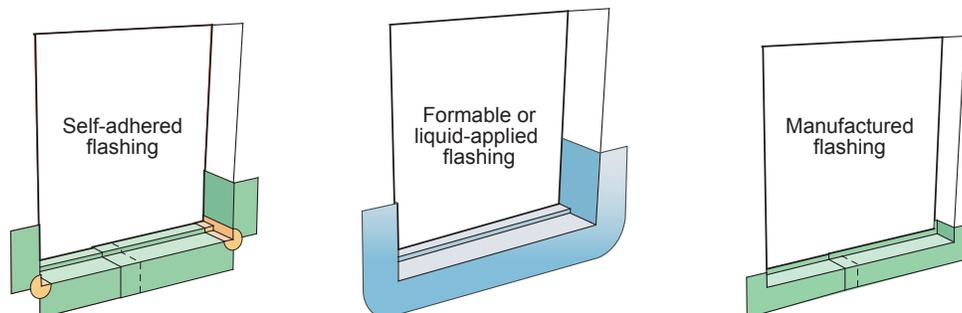
The water control element of a window or door should be connected to the water control element of the adjacent wall, the air control element of a window or door should connect to the air control element of adjacent wall, the vapor control element of a window or door should connect to the vapor control element of adjacent wall and finally the thermal control element of a window or door should connect to the thermal control element of the adjacent wall.

Figure 2.10 and Figure 2.11 illustrate continuity of the control layers at a window unit to wall connection. Note the interior and exterior sealant at the head whereas only a single interior sealant is provided at the jamb. The single interior seal allows drainage to occur at the bottom of the window as well as allowing air to enter at bottom of the window at the gap between the membrane closure and the bottom of the window unit. This air entry pressurizes the gap at the jambs and head utilizing the principle of pressure equalization to limit the effect of wind induced air pressures.

The membrane closure can be via a fully adhered membrane or a fluid applied flashing.

**Figure 2.10**

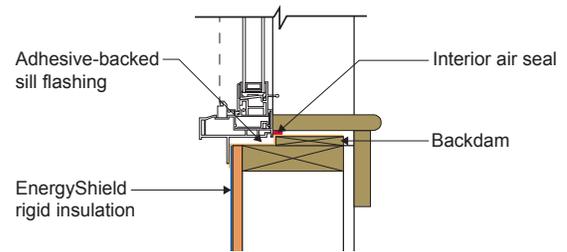
Typical detailing methods at window-to-wall transitions



## Figure 2.11

**Fig. 2.11a**

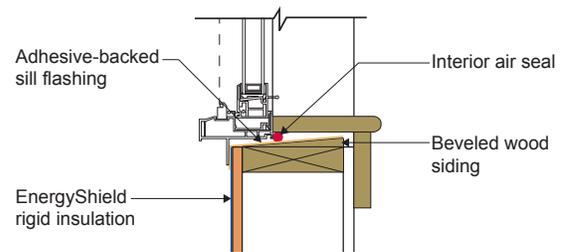
A strip of wood nailed at the back of the rough opening sill forms a dam to prevent water from draining into the interior



**Fig. 2.11a**

**Fig. 2.11b**

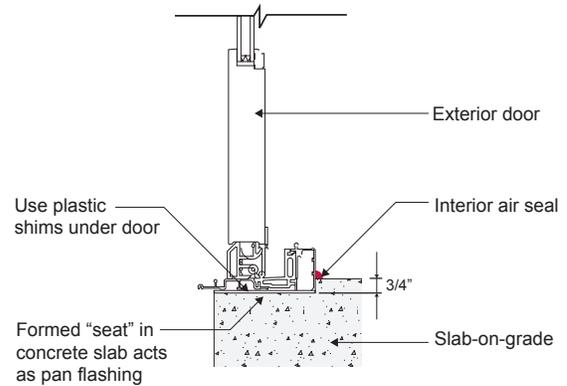
A piece of wood bevel siding nailed over the sill to create positive drainage towards the exterior is even better – note that the rough opening needs to be enlarged to account for this and tapered shims in the opposite direction of the slope may be required



**Fig. 2.11b**

**Fig. 2.11c**

Forming a depression in a cast-in-place floor slab creates a built-in drainage pan for mulled entry doors and sliders, which are prone to leak at joints



**Fig. 2.11c**

### 3. Foundation Systems

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The three common foundation approaches are basements, crawl spaces, and slabs. Each can be built with concrete or masonry. Each can be insulated on the inside or the outside. However, they all have to:

- Control liquid flow due to groundwater
- Control liquid flow due to capillarity
- Control soil gas
- Keep the water vapor out
- Let the water vapor out if it gets in

Groundwater control is principally accomplished by draining groundwater away from foundation wall perimeters, using free-draining materials such as sand, gravel, or drainage boards.

Capillary control is principally accomplished by installing capillary breaks to fill the pores in capillary susceptible materials such as concrete and masonry. The most common capillary break used in residential foundation construction is damp proofing. The damp proofing fills the pores in the concrete and masonry to control capillarity. Under concrete floor slabs, the stone layer combined with sheet polyethylene serves a similar function. Damp proofing the top of footings controls capillarity at this location.

Soil gas control (radon, water vapor, methane, herbicides, termiticides) is principally accomplished by controlling/limiting holes and controlling the pressure difference. Locating a granular drainage pad under concrete slabs can be integrated into a sub-slab ventilation system to control soil gas migration by creating a zone of negative pressure under the slab.

Controlling water vapor in foundations relies first on keeping it out, and second, on letting it out when it gets in. The issue is complicated by the use of concrete and masonry because there are thousands of pounds of water stored in freshly cast concrete and freshly laid masonry to begin with. This moisture of construction has to dry to somewhere, and it usually (but not always) dries to the inside.

For example, we put coarse gravel (no fines) and a polyethylene vapor control layer under a concrete slab to keep the water vapor and water in the ground from getting into the slab from underneath. The gravel and polyethylene do nothing for the water already in the slab. This water can only dry into the building. Installing flooring, carpets or tile over this concrete before it has dried sufficiently or if a top side vapor control layer is not installed is a common mistake that leads to mold, buckled flooring, and lifted tile. When installing these finishes over a wet slab, these problems can be solved by installing a top side vapor control layer.

Similarly, we install damp proofing on the exterior of concrete foundation walls and provide a water managed foundation system to keep water vapor and water in the ground from getting into the foundation from the exterior. Again, this does nothing for the water already in the foundation wall, typically initial construction moisture. Concrete and masonry when cast or constructed contain a great deal of water. It is not usually practical to allow this moisture to dry prior to installing interior surfaces. The installation of interior finishes of a foundation wall must be done in a manner that protects moisture sensitive materials, such as wood framing, gypsum board, and air permeable insulations. This can be accomplished in several ways.

One way is to install a layer of insulation in a manner that is air tight and moisture resistant – such as rigid insulation like foil-faced polyisocyanurate – with all seams and joints sealed, preventing interior air from contacting the interior surface of concrete and masonry foundation walls.

The insulation material limits the ability of the concrete or masonry wall to dry to the interior. This does not damage either concrete or masonry. Over time the foundation walls can dry upwards and outwards at grade. Letting interior air (that is usually full of moisture, especially in the humid summer months) contact cold foundation surfaces will cause condensation and wetting. If a frame wall is built inboard of the air tight insulation layers described above, the frame wall cavities should either be left uninsulated, or insulated without installing an interior vapor barrier (such as sheet polyethylene), thereby allowing the frame wall assembly to dry to the interior, as it is unable to dry to the exterior.

### 3.1. Basement Foundations

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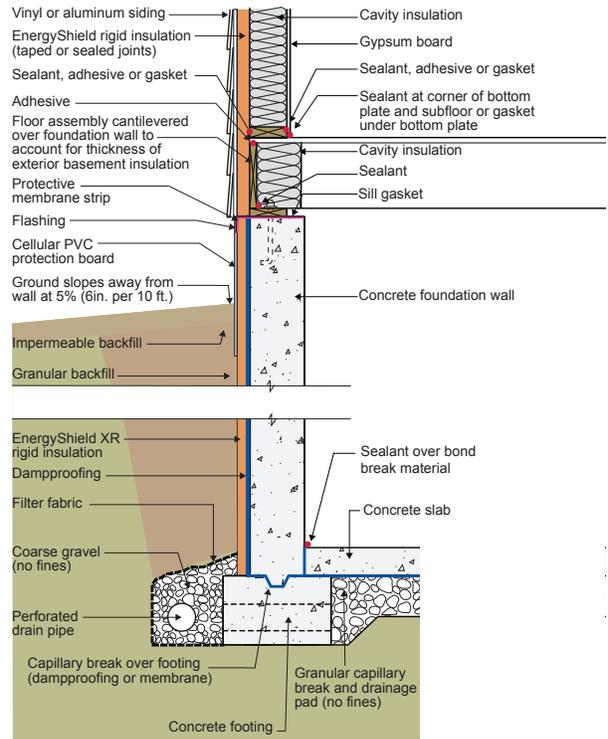
The traditional approach to basement moisture control has been to locate the water control on the outside and then allow drying to the inside. Drainage, water control layers (water-proofing), capillary control layers (damp-proofing), and vapor control layers (damp-proofing) have historically been located on the outside of basement perimeter walls and crushed stone layers and plastic vapor barriers have been located under concrete slabs. The operative principle has been to keep the liquid flow due to groundwater and the liquid flow due to capillarity out of the structure and locate vapor control layers (vapor barriers) on the outside – and allow inward drying to the basement space where moisture can be removed by ventilation or dehumidification.

Two generic basement foundation approaches are typical: insulate the inside or insulate the outside. The most logical location from the physics perspective is to locate the insulation on the outside. By locating the insulation layer outward of the structure and outward of the control layers the foundation is kept at a constant temperature and the insulation system does not interfere with the inward drying of the assembly. Exterior basement insulation is completely compatible with the traditional approach for foundation water control.

A framed wall assembly can be located to the interior of the interior rigid insulation. No interior vapor control layer is located within the frame wall thereby permitting inward drying. All interior concrete surfaces are covered with the rigid insulation layer – particularly at the top of the wall and at foundation step downs. Exterior rigid insulation can be located at the rim joist floor framing to control summer condensation. When insulating sheathing is not used on the exterior, rigid insulation should be installed to the interior of the rim joist or an air impermeable insulation be applied at the rim joist assembly. Note the capillary break at the top of the footing. Further note the air sealing of the rigid insulation at the top of the concrete floor slab – a sealant is used to seal the top of the concrete slab to the rigid insulation and an additional sealant is used to seal the rigid insulation to the interior of the concrete perimeter foundation wall. These two seals are necessary to control soil gas ingress.

**Figure 3.1**

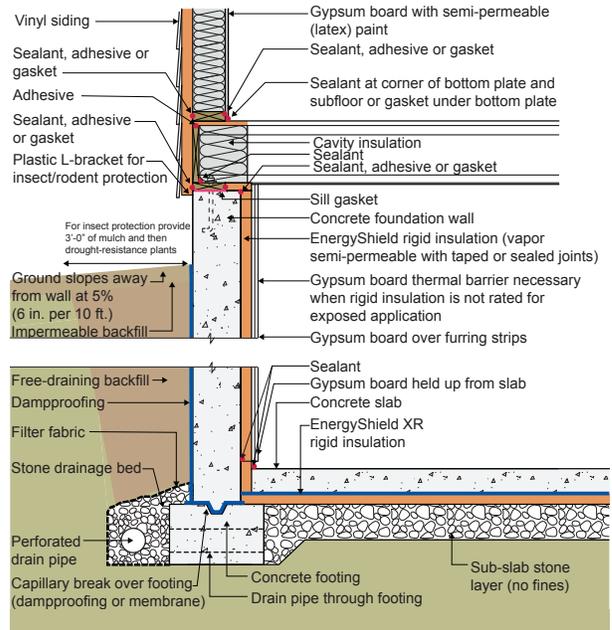
**Concrete Basement with Exterior Rigid Insulation**



Insulating existing structures may be more difficult so locating insulation layers to the interior would be more practical. However, this can often conflict with the traditional approach of foundation water control – namely inward drying. Constructing frame walls, insulating the resulting cavity and covering with an interior plastic vapor barrier is common and often leads to odor, mold, decay, and corrosion problems.

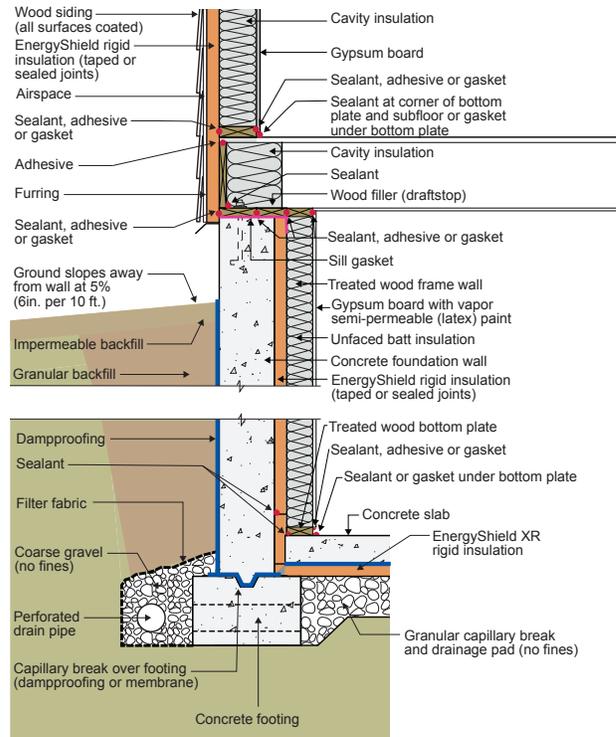
**Figure 3.2**

**Concrete Basement with Interior Rigid Insulation**



**Figure 3.3**

**Concrete Basement with Interior Rigid Insulation and an Interior Insulated Frame Wall**



## 3.2. Crawlspace Foundations

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The traditional approach to crawlspace moisture control has been to vent them – connect them to the outside. In the past when crawlspace sub-floors were not insulated and the occupied spaces above them were heated and not air-conditioned, the sub-floor framing was typically warmer than the ground and framing remained dry. With the advent of installing thermal insulation in floor framing and air-conditioning, vented crawlspace construction became more complex. The crawlspace needed to be completely disconnected from a moisture perspective from the occupied space. The alternative was to completely connect the crawlspace to the occupied space – in essence construct it like a mini-basement and condition it.

Two fundamental approaches to crawlspace construction and moisture control exist. The crawlspace is either vented and not conditioned and connected to the outside – or the crawlspace is not vented and conditioned and connected to the inside.

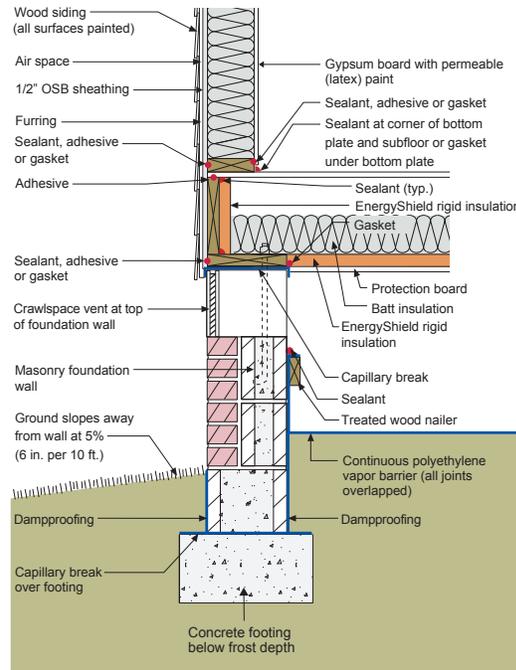
When crawlspaces are completely connected to the building, they must be conditioned. There has to be a means of removing moisture from the crawlspace when the crawlspace is connected just like there has to be a means of removing moisture from any interior space. This is done with controlled air change during heating seasons and dehumidification via air conditioning (or via dehumidifier) during cooling seasons. Buildings are “conditioned” and conditioning means controlling temperature and relative humidity.

The key to the assembly in Figure 3.4 is the use of an air control layer and vapor control layer at the underside of the floor framing. The air control layer and vapor control layer can be a layer of insulating sheathing such as foil faced polyisocyanurate. In most regions the exterior air is above the dewpoint temperature of both the ground surface temperature in crawlspaces and the temperature of the floor assembly. The rigid insulation protects the floor assembly from condensation.

A ground cover is also recommended to limit evaporation of water from the soil. The interior grade should be higher than the exterior grade. Floor cavity insulation should be located in contact with the rigid insulation. Rim joists should be internally insulated with rigid insulation to control condensation or an air impermeable insulation should be applied to the interior of the rim joist. Alternatively, exterior insulating sheathing can be used.

**Figure 3.4**

**Vented Crawlspace with Rigid Insulation**

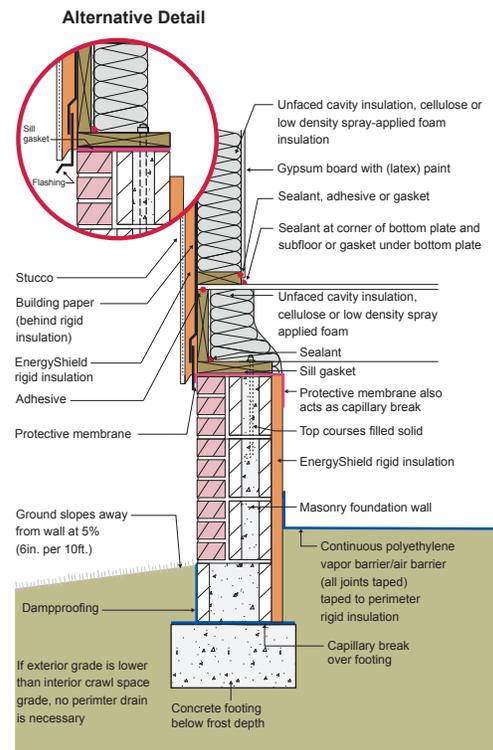


A provision for moisture removal must be provided by conditioning the crawl space (Figure 3.5) with a duct distribution system with supply and return air, or by installing a dehumidifier or by exhaust venting the crawlspace with an exhaust fan.

Non-water sensitive rigid insulation, such as polyiso insulation, should be installed at the perimeter and rigid insulation should be installed at rim joist areas (either internally or externally). The interior grade should be higher than the exterior grade. A ground cover should be installed such that it also acts as both an air control layer and a vapor control layer (vapor barrier).

**Figure 3.5**

**Conditioned Crawlspace with Rigid Insulation**



### 3.3. Slab Foundations

Capillary control is necessary for slab-on-grade construction. Monolithic slabs need plastic ground covers that extend under the perimeter grade beam and upwards to grade. Additionally, the exposed portion of the slab edge that is exposed to the outside should be painted with latex paint to reduce water absorption and a capillary break should be installed under perimeter wall framing.

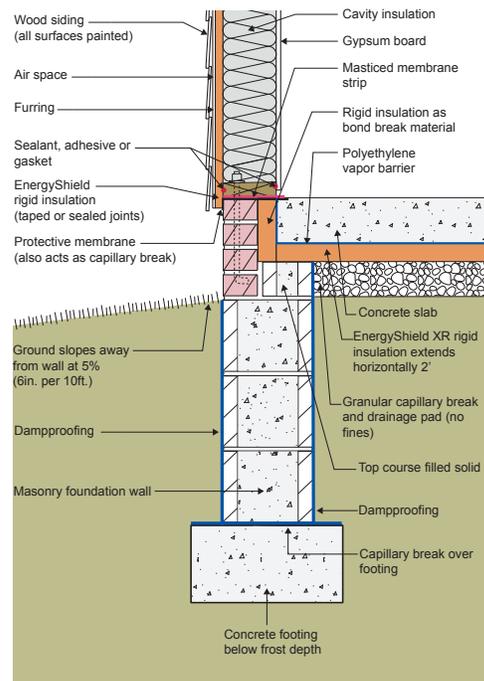
Insulation can be installed on the underside of slab foundations, on the perimeter of slab foundations, or on the top of slab foundations – or some combination. The issue of concern is thermal bridging associated with discontinuity of the insulation.

Note the thermal uncoupling of the concrete slab from the stem wall in Figure 3.6. The rigid insulation also acts as a bond break disconnecting the concrete slab from the stem wall. The rigid insulation extends inwards horizontally and is located on a granular capillary break. A sheet polyethylene vapor barrier is located over the top of the rigid insulation in direct contact with the underside of the concrete slab.

The membrane strip that is sealed with mastic connecting the top of the stem wall to the top of the concrete slab acts as a capillary break as well as an insect barrier.

**Figure 3.6**

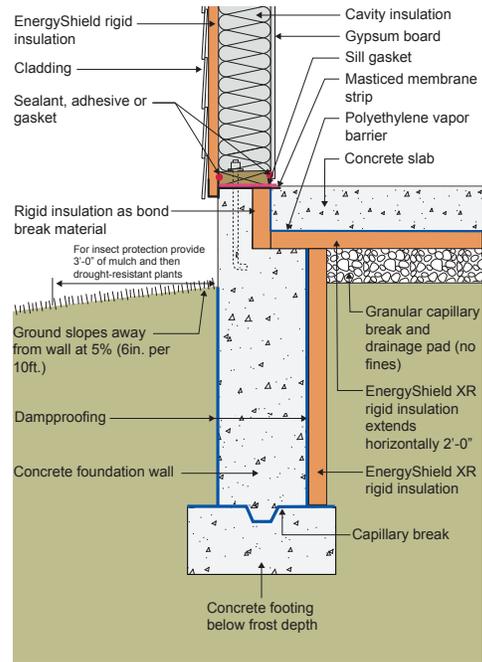
**Insulated Stem Wall Slab Foundation**



In Figure 3.7, an additional layer of rigid insulation is located to the interior of vertical surface of the stem wall extending from the top of the footing to the underside of the horizontal rigid insulation under the concrete slab. Note the capillary break on the top of the footing and the interior and exterior damp proofing of the stem wall.

**Figure 3.7**

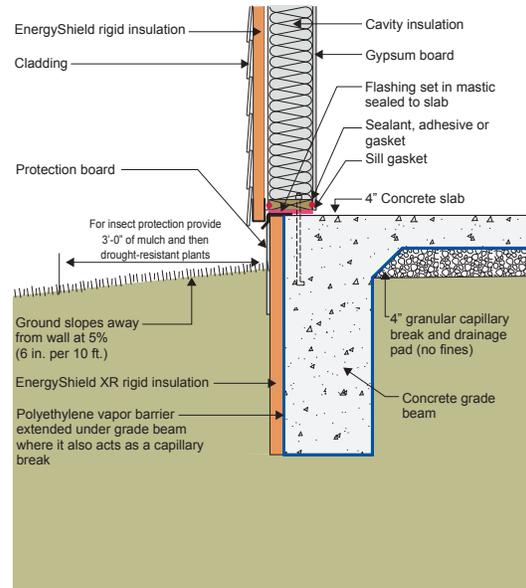
**Insulated Stem Wall Slab Foundation**



The insulation shown in Figure 3.8 can be installed within the formwork prior to placing the concrete along with the polyethylene vapor control layer (vapor barrier) so that it extends under the grade beam so that it can effectively act as a capillary break. The metal flashing that is sealed with mastic connecting the top of the stem wall to the top of the concrete slab acts as a capillary break as well as an insect barrier.

**Figure 3.8**

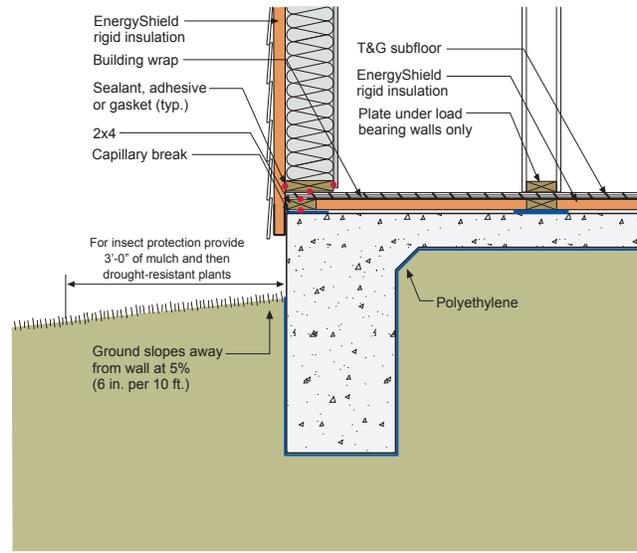
**Externally Insulated Monolithic Slab Foundation**



The polyethylene vapor control layer (vapor barrier) under the monolithic slab foundation shown in Figure 3.9 and Figure 3.10, should extend under the grade beam and then vertically to grade so that it can effectively act as a capillary break. It is recommended that a vapor permeable liquid closed building wrap be installed under the wood subfloor to protect the insulation layer from topside occupant spillage of water and other fluids.

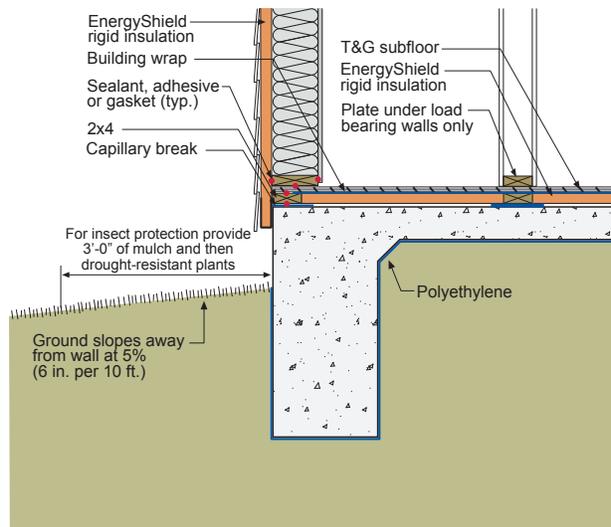
**Figure 3.9**

**Topide Insulated Monolithic Slab Foundation**



**Figure 3.10**

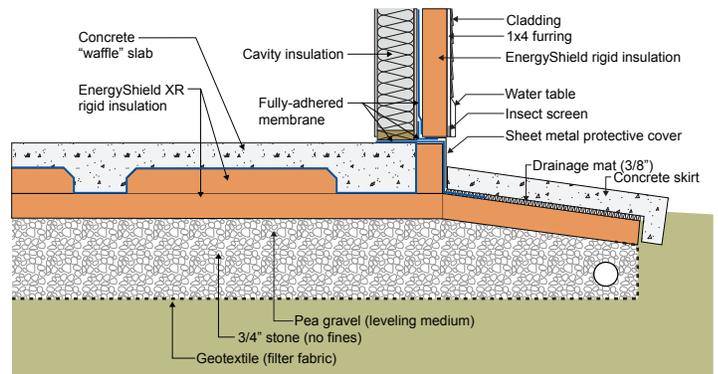
**Topide Insulated Monolithic Slab Foundation with Brick Veneer**



In colder hygrothermal regions, frost protection is provided by horizontal insulation extending outward of the perimeter of the slab foundation (Figure 3.11). The horizontal extension is typically equal to the frost depth. The horizontal insulation is protected by a concrete skirt cast over a drainage mat. The entire foundation assembly is constructed over a granular capillary break and drainage pad connected to a perimeter drain.

**Figure 3.11**

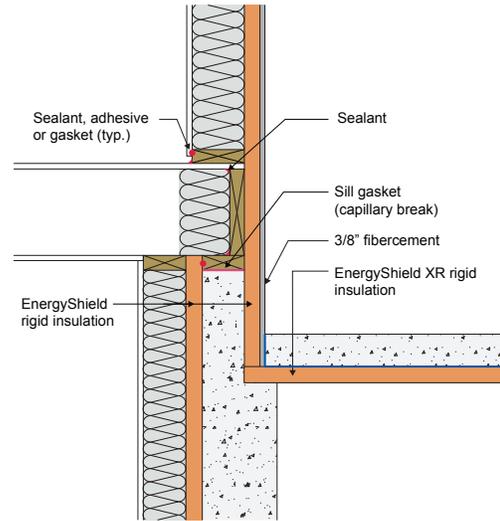
**Shallow Frost Protected Slab Foundation**



It is becoming increasingly common in Mixed, Marine, and colder hygrothermal regions to insulate garage foundations in anticipation of conditioning the garage at a future date. Figure 3.12 and Figure 3.13 illustrate two of the typical approaches.

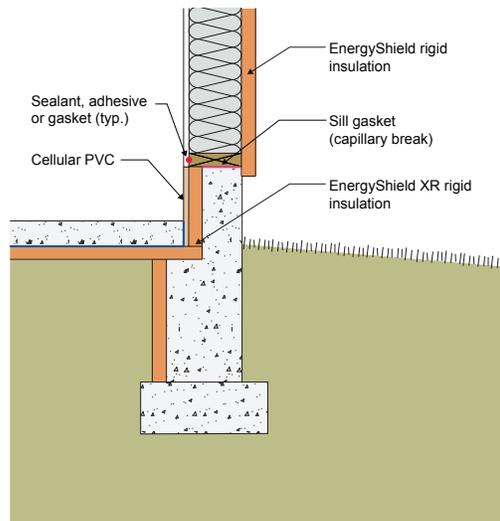
**Figure 3.12**

Building to garage foundation connections with an insulated interior foundation wall and under slab insulation



**Figure 3.13**

Building to garage foundation connections with an insulated slab on grade



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