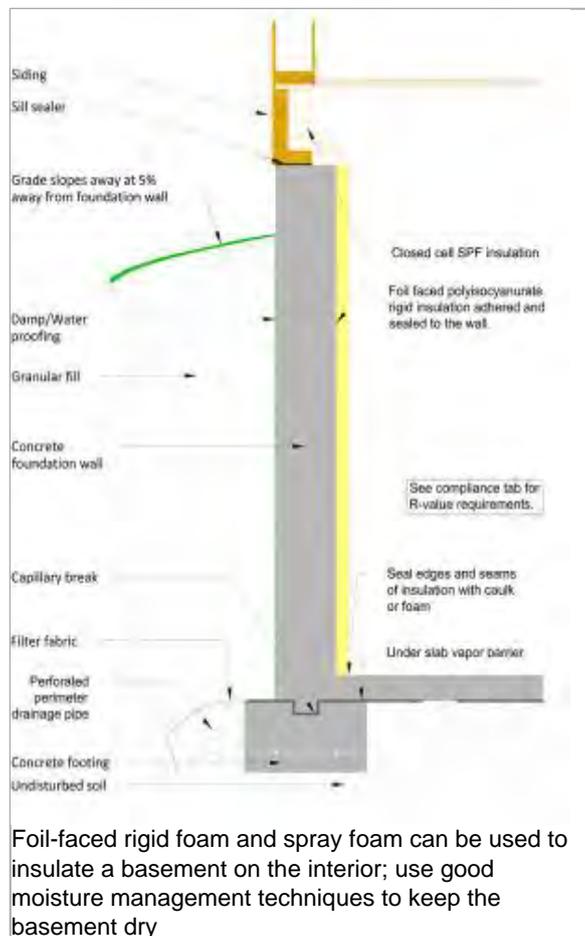


# Air Sealed, Insulated Basements

Last Updated: 11/21/2017

## Scope



Insulate a basement to improve the overall thermal performance of the building and provide more dry, usable conditioned space for home occupants and for HVAC equipment.

- Address site drainage and plan for [water/moisture management](#).
- Assess risks posed by insects and other pests. (See the International Code Council's guide, [Pest Prevention by Design](#).)
- Assess and address Radon issues. (See the EPA's guide [Building Radon Out: A Step-by-Step Guide on How to Build Radon-Resistant Homes](#), Also see Building Science Corporation's information sheet on [Soil Gas Control](#).)
- Design and install safe combustion systems in the home. (See the [pre-retrofit assessment guide on combustion appliances](#).)
  - Sealed combustion equipment is strongly recommended.
  - Include carbon monoxide detectors.
- Determine code, program, and/or other goals and requirements for basement insulation.
- Consider insulating the foundation walls using exterior rigid insulation, insulated concrete forms, or prefabricated panels. If these are impractical (due to pest issues or because it's an existing building), consider interior insulation systems.
- Install systems per code requirements and manufacturer specifications.
- Verify systems are installed properly and other systems (such as drainage systems, combustion appliances, etc.) are operating safely.

See the Compliance Tab for related codes and standards requirements and criteria to meet national program such as DOE's Zero Energy Ready Home program, ENERGY STAR Certified Homes, and Indoor airPLUS.

## Description

Because basements are largely below grade and because winter ground temperatures are often warmer than winter air temperatures, the potential for heat loss from a basement is smaller than from the above-grade portions of a home's envelope. While insulation levels below grade need not be as high as those of above-grade walls, insulating basements is critical in order to achieve the energy and comfort goals of high-performance homes.

This guide describes good practices for insulating basements in new and existing homes. This is by no means an exhaustive list; rather, it is a short list of systems that can work well, can comply with current codes, and can be practically implemented by builders and contractors.

Before insulating a basement, be sure to assess (and address if necessary) key health, safety and durability issues. These include:

- Site/building [drainage and water management](#)
- [Combustion safety](#)
- Radon (See the EPA's guide [Building Radon Out: A Step-by-Step Guide on How to Build Radon-Resistant Homes](#), Also see Building Science Corporation's information sheet on [Soil Gas Control](#).)
- Insect/pest concerns (See the International Code Council's guide, [Pest Prevention by Design](#).)

## Where to Insulate?

### Foundation Walls or First Floor?

One of the first questions to answer when determining a basement insulation strategy is: Where to install the insulation on the basement walls or on the underside of the first floor?

#### Insulating at the Walls

In most cases insulating the basement walls—and possibly the slab—results in better performance. Insulating the basement walls, rather than under the first floor, brings the basement within the thermal envelope or conditioned space of the home and connects the basement thermally to the rest of the house. This will keep the basement warmer during the winter. In the summer, a conditioned basement will usually be dryer than the alternative. A warmer, dryer basement can have much more value as a functional, usable space. It also provides better conditions for HVAC equipment.

In extremely cold climates, insulating the basement walls may be critical to keep temperatures in the basement above freezing (which is important if there are any mechanicals or plumbing in the basement). If heating equipment is located in the basement (e.g., a boiler or furnace, water heater, ducts, etc.), the heat losses from this equipment may provide all the heat needed to keep an insulated basement comfortable and usable.

During the summer months, because the ground is generally cooler than the air within the home, connecting the basement to the conditioned space will reduce the cooling load. It's true that good basement wall insulation will limit this cooling effect, but even a home with a well-insulated basement will generally require less air conditioning energy than the same home with insulation beneath the first floor.

#### Insulating Under the First Floor

Insulating under the first floor, rather than along the walls will result in an uninsulated basement that is disconnected from the rest of the house from a thermal standpoint. While insulating beneath the first floor may result in lower performance overall, there are some scenarios where this strategy is still chosen. Reasons for this include:

- Water management. If moisture management strategies do not keep the basement consistently dry (e.g., if the area is prone to seasonal flooding), insulating at the first floor may be the best option to avoid repeated damage to water-susceptible materials.
- Combustion safety. It is strongly recommended that air-tight buildings not include natural-draft combustion appliances within the insulated enclosure. If natural-draft appliances are located in the basement and are not likely to be replaced with noncombustion or sealed-combustion direct-vent appliances in the near future, air sealing and insulating at the first floor may be a safer option than air sealing and insulating the basement walls and floor. For information on assessing combustion safety see these guides:
  - [Combustion appliance zone testing](#)
  - [Pre-Retrofit Assessment of Combustion Appliances](#)
- Cost. While insulating the basement walls generally results in better performance, this strategy is often more expensive. Some choose to insulate at the floor purely for cost reasons.

### Inside or Outside of Foundation Walls?

Basement walls can be insulated along either the inside surface or the outside surface of the exterior walls. Insulating on the

outside of a foundation wall is usually only a practical option in new construction due to the excavation costs associated with an exterior installation. Most retrofit strategies involve installing insulation on the inside of the foundation walls unless major excavation is already necessary for foundation repair or site water management.

In most cases, insulating on the outside can result in better moisture management of the foundation assembly, but there are challenges with protecting the insulation at and above grade. These challenges lead many designers and builders of new homes to choose interior basement insulation. Examples of both strategies—as well as challenges and limitations of each—are discussed in the Description section.

## Systems Described

While there are many viable basement insulation strategies, a few common systems are described in this guide:

- Exterior rigid insulation on concrete walls
- Insulated Concrete Forms (ICFs)
- Precast foundations.
- Interior insulation
  - foil-faced rigid foam left exposed
  - rigid foam covered with drywall
  - spray foam covered with drywall.

## Exterior, Rigid Insulation on Block or Poured Concrete Walls

Extruded polystyrene (XPS) foam, rigid fiberglass, and mineral wool boards are the most common materials for insulating the exterior of foundation walls. None of these materials retains water, so long-term thermal properties should not be significantly affected by moisture.

Rigid fiberglass and mineral wool boards have thermal resistance of approximately R-4 per inch ( $\text{ft}^2\text{hr}^\circ\text{F}/\text{Btu-in}$ ). To achieve the same R-value as XPS insulation, the thickness of these insulations must be approximately 25% greater than XPS (which is R-5 per inch).

In most cases, insulation on the exterior of basement walls can result in drier foundation assemblies and basement conditions. Because of the difficulty of accessing the foundation exterior in existing buildings, exterior foundation insulation is usually only practical for new construction. Other key challenges for exterior insulation systems are:

- protecting the insulation at and above grade
- insect and pest management
- transitions between foundation insulation and above-grade walls
- achieving higher R-values can be more difficult than with interior insulation (although a combination of both interior and exterior insulation is possible).

One common—though unacceptable—solution to protecting insulation at and above grade is simply to not insulate above-grade sections of the foundation wall (Figure 1). In this scenario, the un-insulated portion of the foundation wall (at grade and above) is exposed to the coldest temperatures. (Figure 2 shows an inside view of the wall shown in Figure 1; condensation and ice have formed on the inside surface of the wall.) Research has shown that insulating the top portion of the wall is by far the most critical for thermal performance; insulating only below-grade portions of the wall is ineffective in stopping heat transfer.

Insulation must be extended to the top of the foundation wall to provide a seamless thermal barrier in conjunction with the above-grade walls (Figure 3). This above-ground insulation must be protected with a durable material that can withstand weather, sunlight, impacts, etc. (Figure 4). Protective materials can include stucco, fiber-cement boards, fiberglass panels, vinyl sheets, aluminum coil stock, or even pressure-treated plywood. (For more options see this article, [How to Finish Exterior Foundation Insulation](#)).

Another potentially tricky detail is integrating the extra dimension of the foundation insulation into the above-grade walls. There are many solutions to this; two are presented here. In Figure 5, above-grade walls also incorporate rigid exterior insulation. In this case, there is usually not much difference between the two planes. If the above-grade walls do not have exterior insulation, there must be a curb, flashing, or transition that protects the insulation, manages drainage well, and is aesthetically acceptable. One possible solution is presented in Figure 6.

When considering any external foundation insulation strategy, it is critical to consider insects and pest management. While termites and other pests do not eat foam, they can easily tunnel through foam to reach wooden building components. Many insect management strategies incorporate a “vision strip,” typically a 3-inch gap in the insulation extending across the top of the foundation wall that exposes the concrete, so termite activity is visible. Another strategy is a termite “shield,” typically a piece of metal flashing that extends over the top of the foundation wall and extends from the sill or insulation transition. These strategies do not necessarily stop termites, but the devices will force bugs out of the insulation where their presence can be noticed. See

more information in the "Insect and Pest Management" section in the Ensuring Success tab.



**Figure 1.** Exterior fiberglass insulation on this new home was (incorrectly) cut to terminate below-grade after backfill, which will expose the above-grade portions of the foundation wall to cold temperatures. (Source: [Measure Guideline: Basement Insulation Basics](#))



**Figure 2.** Because the above-grade portions of the wall lack exterior insulation, condensation and even ice form during cold winter conditions. (Source: [Measure Guideline: Basement Insulation Basics](#)).



Figure 3. Exterior XPS basement insulation is correctly installed to completely cover the foundation wall.  
(Source: [Measure Guideline: Basement Insulation Basics](#)).



Figure 4. Rolled fiberglass sheets are installed to protect exterior XPS at and above grade.  
(Source: [Measure Guideline: Basement Insulation Basics](#)).

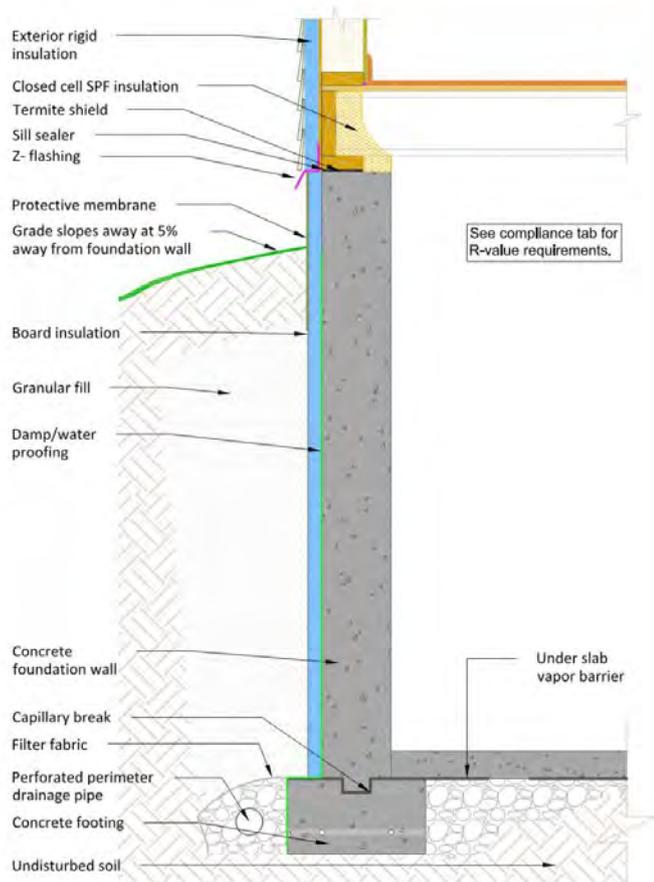


Figure 5. The exterior foundation walls and above-grade frame walls are both covered with exterior rigid insulation (Image courtesy of [Steven Winter Associates](#)).

## Insulated Concrete Forms (ICFs)

When making poured concrete foundation walls, builders typically use wood or metal forms to hold the concrete in place until it hardens. Another option is to use insulated concrete forms (ICFs) where the forms consist of rigid foam that stays in place after the concrete is poured to form a lasting layer of insulation on the inside and outside surface of the concrete wall. The rigid polystyrene foam (either EPS or XPS) is connected with polymer spacers to form large (e.g., 9"x18") hollow blocks that are stacked in courses like bricks to form a hollow wall (Figure 7). The wall is reinforced with steel rebar that is run horizontally and vertically through the spacers then the hollow space is filled with concrete (Figure 8). Many ICF systems include vertical plastic or metal nailing strips to which interior and exterior finishings can be attached. See the guide, [Insulated Concrete Forms](#) for more information.



Figure 7. ICF bricks are stacked to form hollow walls that are reinforced with steel rebar before the concrete is poured in. (Source: [Measure Guideline: Basement Insulation Basics](#)).



Figure 8. ICFs can be used below and above grade to construct the entire wall. (Source: [Measure Guideline: Basement Insulation Basics](#)).

Instead of “sandwiching” concrete between the foam layers, another system sandwiches the rigid foam insulation between two layers of concrete. This approach can solve concerns about thermal barriers, some moisture issues, and possibly pest management concerns.

## Pre-Cast Foundation Walls

Precast concrete foundations have a significant presence in several regional markets, in particular in the Northeast and Midwest. Not surprisingly, both of these regions are dominated by full basement foundations in residential construction, and they have robust pre-cast concrete industries. Very simply, pre-cast foundations are factory-produced concrete panels designed for a

specific project, shipped to a job site, and set by a crane and set crew. A very simple foundation could consist of as few as four panels; larger, more complicated foundations require more. The simplest panels are monolithic reinforced concrete slabs, while more sophisticated panels can be pre-insulated “sandwich” panels (with a layer of rigid insulation sandwiched between two layers of concrete). Another version is a thin-shelled rib system that includes thin (2-inch thick) panels with monolithically poured top bond-beams, bottom footers, and evenly spaced concrete ribs. Some of these thin-shelled rib systems have insulation adhered to the interior side of the shell and wrapped around the ribs; these systems come in various R-values. The ribs are usually faced with sheet metal which is placed over the rigid foam to serve as a nailing surface for the ribs, which act like walls studs. The cavities between the ribs can be filled with additional blown or batt insulation.

Pre-cast panels are typically set on a compacted crushed stone base with no additional footing needed (Figure 9). The crushed stone base is placed and compacted uniformly over the entire foundation area (including under the slab). The first panel is meticulously located to pre-surveyed points, and the remaining panels are positioned in reference to it. Joints between panels are typically treated with two large beads of poly-butyl caulk with come-along bolt connections used to draw the panels together, then the below-grade surface is treated with one of a variety of damp-proofing or moisture-proofing techniques.

Pre-cast foundations can be set in a single day. Panel bracing is critical prior to backfilling, so the floor deck will have to be installed with limited at-grade access. The time savings are also labor savings, but material costs for pre-cast foundations are generally higher. Total installed costs are similar to those of poured concrete foundations (especially near precast plants) and are dependent on local market conditions.



Figure 9. A precast insulated concrete panel foundation is set in place on a base of crushed rock. (Source: [Measure Guideline: Basement Insulation Basics](#)).

## Insulation on Interior of Foundation Walls

In existing homes, interior basement insulation is often the only practical option. Even in new construction, challenges with protecting insulation at grade and above, as well as integrating the extra dimensions of exterior insulation, lead some builders to install interior insulation. Building America researchers have found that the best interior basement wall insulation strategies have several key features:

- Insulation is directly in contact with the basement wall and there is no channel for air movement between the insulation and the concrete.
- The assembly is air sealed so that basement air (and the moisture in it) cannot move into the insulation assembly.
- No moisture-sensitive materials are in contact with the concrete walls or floor (this is often addressed by building codes).

### Exposed, Foil-Faced, Polyisocyanurate Board

Most residential building codes require foam insulation to be covered with a thermal barrier (2015 IRC, Section R316.4). The most common type of barrier is drywall. Attaching drywall over foam can be costly; however, it is often already factored into project costs if the basement will be finished for living space. At least one manufacturer of foil-faced, polyisocyanurate board insulation has a product that is allowed to remain exposed per an International Code Council Evaluation Services report (ICC 2006, NER-681). In many jurisdictions, this product can be left exposed against basement walls without drywall or an additional thermal barrier.

Insulation may be fastened with either construction adhesive or with mechanical fasteners into the concrete. (Figure 10 shows insulation attached using 1x strapping as a base for the fasteners.) Polyisocyanurate has an R-value of approximately R-6 per inch ( $\text{ft}^2\text{hr}^\circ\text{F}/\text{Btu-in}$ ). Typically one inch is installed to meet R-5 requirements, two inches are installed to reach R-10, and three inches are installed to reach R-15.

The polyiso boards should be completely sealed to each other and to the concrete wall (Figure 11). There should be no avenue for air movement between the foam and the foundation wall. Insulation seams can be sealed with caulk, foam, foil tape, or polypropylene tape. Caulk or foam should be used at the edges of the insulation (near the sill, the slab, around windows or doors, etc.).

As with most systems described here, spray foam can be a good option to seal and insulate the sill and band joist areas. Many codes allow for this small area of foam to be left exposed in these locations (2015 IRC, Section R316.5.11).



Figure 10. Foil-faced polyiso foam is held in place along the interior of a basement wall with nails or screws through the furring strips. Seams are sealed with foil tape and all edges are sealed with caulk or foam. (Source: [Measure Guideline: Basement Insulation Basics](#)).

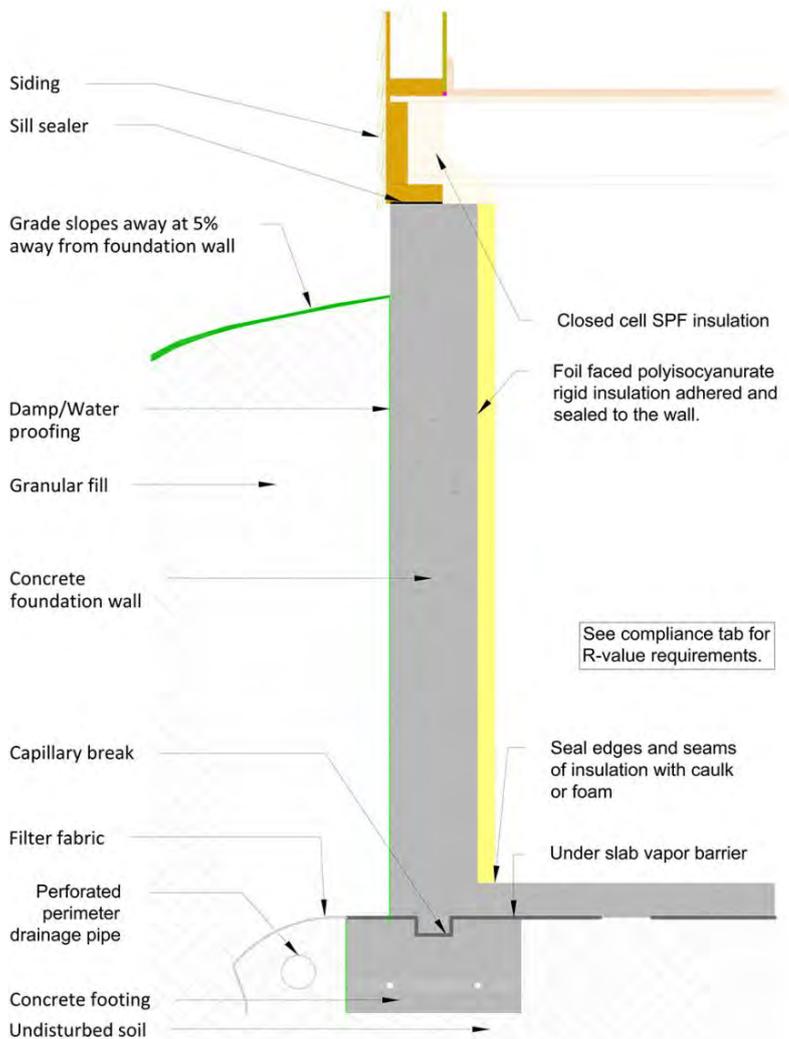


Figure 11. Foil-faced polyiso insulation is sealed to the interior of the concrete foundation wall with caulk or adhesive (Image courtesy of [Steven Winter Associates](#)).

## Polystyrene Board with Drywall

Both unfaced expanded polystyrene (EPS) and extruded polystyrene (XPS) rigid foam are common basement insulation materials, but they cannot be left exposed without a thermal barrier (2015 IRC Section R316.4). The most common such barrier is ½-in. drywall.

Of these two foams (EPS and XPS), XPS is more commonly used, simply because it has a higher R-value (R-5 per in. rather than R-4). To meet R-5, R-10, and R-15 code requirements, one, two, and three inches of foam are required respectively. One commonly cited drawback of XPS is that its blowing agent is a potent greenhouse gas, although manufacturers are exploring alternatives with lower global warming potential.

As with the polyisocyanurate foam insulation systems, XPS foam can be attached to the wall with construction adhesive or with mechanical fasteners. Seams in the foam should be sealed, and the top and bottom edges should be sealed to the concrete with caulk or foam. In one method of mechanical attachment, fasteners are attached through 1x furring strips. This furring then serves as a base for attaching drywall with screws. Using these furring strips against irregular walls can be more challenging. As concrete surfaces are not always smooth, the drywall may follow any irregularities in the furring or wall shape. While wires can be run in the gap between the drywall and the foam, electrical boxes (when installed) must be recessed and cut into the foam.

To overcome these challenges, some builders choose to install a more conventional framed wall to the inside of the rigid foam (Figure 12). Framing cavities can be filled with batts or other appropriate cavity insulation. With the addition of frame cavity insulation, less rigid foam may be required to meet target R-values. For example, one inch of XPS in conjunction with a 2x4 wood-framed wall (20% framing factor) and R-13 fiberglass batts results in an effective R-value of approximately 15 ft<sup>2</sup>h<sup>2</sup>°F/Btu.



Figure 12. XPS is installed along basement walls before constructing a framed wall. (Source: [Measure Guideline: Basement Insulation Basics](#)).

## Spray Foam with Framing and Drywall

Sprayed polyurethane foam can provide excellent air sealing and thermal resistance in many envelope systems. The chief drawback to the product is cost; it is usually more expensive to install than rigid foam boards. Like unfaced foam boards, spray foam must be covered with a thermal barrier. While spray foam can be effective in many types of foundation walls, with very irregular walls (such as stone foundations), spray foam is one of the only options for excellent thermal and moisture performance. As open-cell spray foam can absorb and retain water (up to 40% by volume), closed-cell foam is recommended for most foundation wall applications.

A recommended spray-foam system for a poured-concrete or block wall is shown in Figure 13. Framing is installed at least one or two inches away from the interior surface of the foundation wall to allow for a continuous layer of foam to be blown behind the framing. Drywall (which provides the required thermal barrier) is attached to 2x4 framing in this detail. As with the XPS system discussed above, it's possible to use a hybrid system with spray foam directly against the foundation wall and cavity insulation within the framing. It may also be practical to use 2x3 framing or steel framing in some applications.

It bears repeating that proper moisture management is critical for basements. The figures in these sections show examples of moisture control strategies that may or may not be appropriate for a specific home. Proper water management should be assessed on a case-by-case basis.

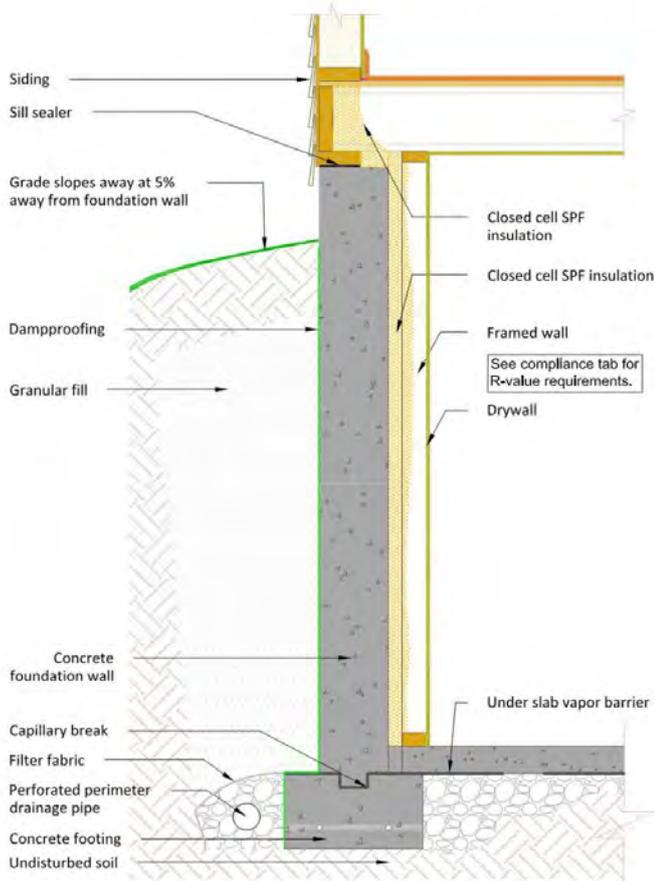


Figure 13. Closed-cell spray foam insulates the inside surface of a foundation wall and provides a thermal break between the concrete and a 2x4 framed wall.

The remaining cavity space can be filled with fiberglass or mineral wool insulation; the stud wall must be covered with drywall to provide the code-required thermal barrier.

(Image courtesy of [Steven Winter Associates](#)).

# Ensuring Success

## Moisture Management

Basements are essentially holes in the ground. As such, they are susceptible to filling with water. Water management is critical in providing for overall durability and healthy basement conditions. Water issues can be related to rain or storm water run-off, ground water intrusion, movement of moist air, water vapor movement, or bulk water leaks from inside the basement (e.g., plumbing leaks). Insulating basement walls without adequately addressing moisture management can simply mask problems down the road. In some cases, insulation can trap water in assemblies and cause more severe problems.

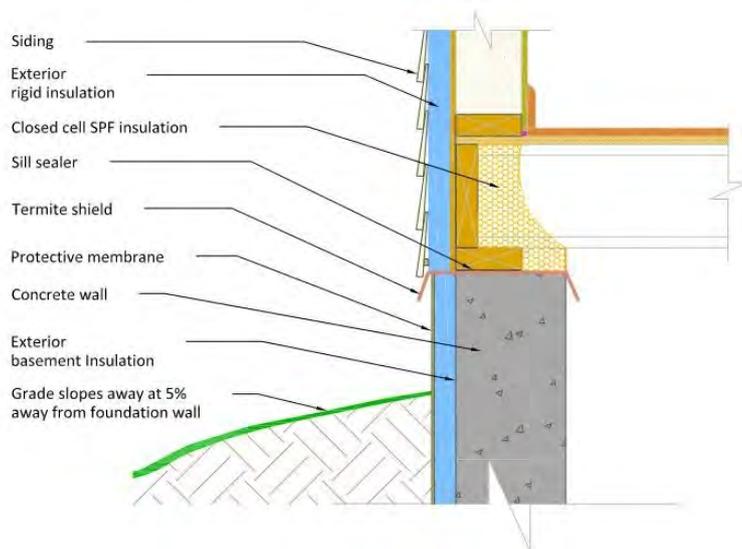
Moisture management **MUST** be addressed before insulating a basement. There is a great deal of information in the Solution Center on this [topic](#).

## Insect and Pest Management

Insect problems vary tremendously from region to region and even locally within regions. Termites eat wood, and precautions should be taken for any wood assemblies located near grade. Termites do not eat most insulation products (such as foams and fiberglass), but they can tunnel through these materials to reach food sources in the building.

When termites tunnel through insulation, they are generally not visible. Some codes require a “vision strip,” which is basically a gap in the insulation that force pests to come out into the open. Vision strips do not stop insects, but they make them more noticeable. In areas with a high likelihood of termites, regular inspections should be conducted. If termites are present, their mud tunnels will likely be visible where they cross the vision strip in search of food. When pests are identified, other pest control measures must be taken.

Vision strips have a significant drawback: they require gaps in the insulation. These gaps are generally near grade where insulation is most important thermally (because of the larger temperature differentials). Where possible, the authors recommend the use of termite shields rather than gaps in insulation. A termite shield usually consists of a strip of metal flashing that is laid over the top of the foundation wall and below the sill plate. The metal extends out over the top of the rigid insulation installed on the interior or exterior surface of the foundation wall. It won't necessarily stop termites from getting up into the wood framing but, because they can't chew through the metal, they will have to come out of the insulation to go around it. The mud tunnels they leave on the metal shield will be a visible indicator that they are present. Once detected other pest treatment steps can be taken.



A termite shield extends over the top of the foundation wall and the exterior rigid foundation insulation. The shield separates the insulation on the foundation wall from the exterior rigid insulation on the above-grade frame walls.

There are also insulation products available (including some XPS foam boards) with pesticides incorporated into them. Manufacturers of these products often recommend termite shields or similar barriers be used as well.

Termites can represent a substantial durability risk in some areas. Where termites are present, termite shields or other measures should be included in the insulation strategies presented in this guide. If effective pest management cannot be incorporated effectively into the foundation insulation systems, other strategies should be considered (such as insulating beneath the first floor). Some more [rigorous resources for pest management](#) are presented elsewhere in the Solution Center.

## Combustion Safety

Basements are often home to combustion appliances (boilers, furnaces, water heaters, etc.). Atmospherically vented appliances—where exhaust gases are drawn up a flue by natural convection—require substantial amounts of air in the room in which the atmospherically vented appliance is located (referred to as the combustion appliance zone or CAZ). When the appliance is located in an uninsulated basement, that air is often drawn through cracks and air leaks around windows and at rim

joists. If the basement is later insulated and air sealed, those air sources will be sealed off, which can cause problems with proper combustion of atmospherically vented appliances and can potentially lead to dangerous conditions such as back drafting.

The insulation details presented here emphasize air sealing. While poured concrete walls do not leak air, the sills and rim joists are notorious air leakage areas. Before and after sealing and insulating a basement, ensure that combustion appliances are operating appropriately and safely. The best way to avoid combustion problems is to install non-combustion equipment or sealed-combustion equipment. Sealed-combustion, direct-vented appliances draw air directly from outside through their own dedicated air inlet pipes and they exhaust air directly outside through sealed flues so they do not draw air from the CAZ. If combustion equipment other than sealed-combustion equipment is present in a home, have a qualified contractor assess combustion safety before and after retrofitting, as described in the guides [Combustion Appliance Zone Testing](#), and [Pre-Retrofit Assessment of Combustion Appliances](#).

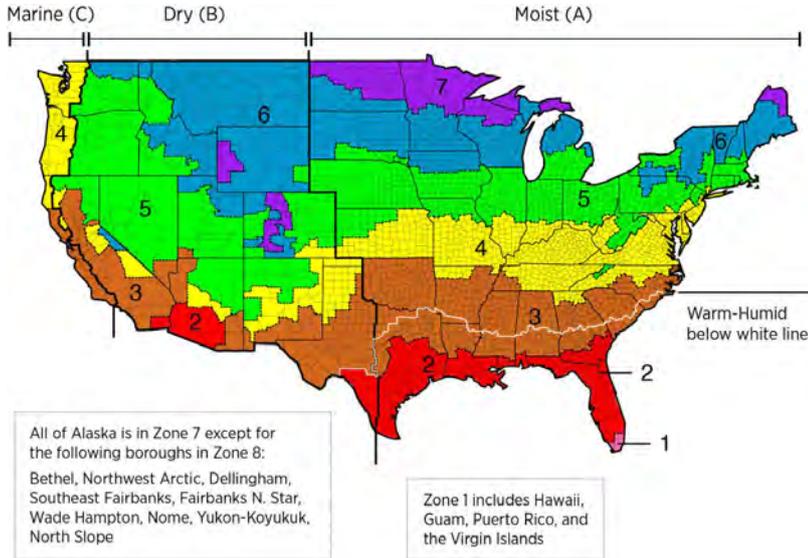
## Radon

Radon is a radioactive gas that occurs naturally in some soils and rocks and can cause health problems at higher concentrations. For more information on radon testing and mitigation, see this Solution Center guide on [radon mitigation](#) and the EPA website [Radon-Resistant New Construction Builder/Contractor Resources](#).

# Climate

During warm seasons in humid climates, humid air can leak into an air-sealed basement through cracks, such as around windows and rim joists. This humid air can condense on cooler surfaces such as floor joists or below-grade wall surfaces, causing moisture issues in the basement. In cold climates an uninsulated basement can expose HVAC equipment and plumbing located therein to excessively cold temperatures. See the Compliance tab for prescriptive requirements for insulation levels in the International Energy Conservation Code and International Residential Code.

Consult with local code authorities regarding foundation inspection requirements for termites and requirements for radon mitigation. Also see the Ensuring Success tab for more information and resources on these topics.

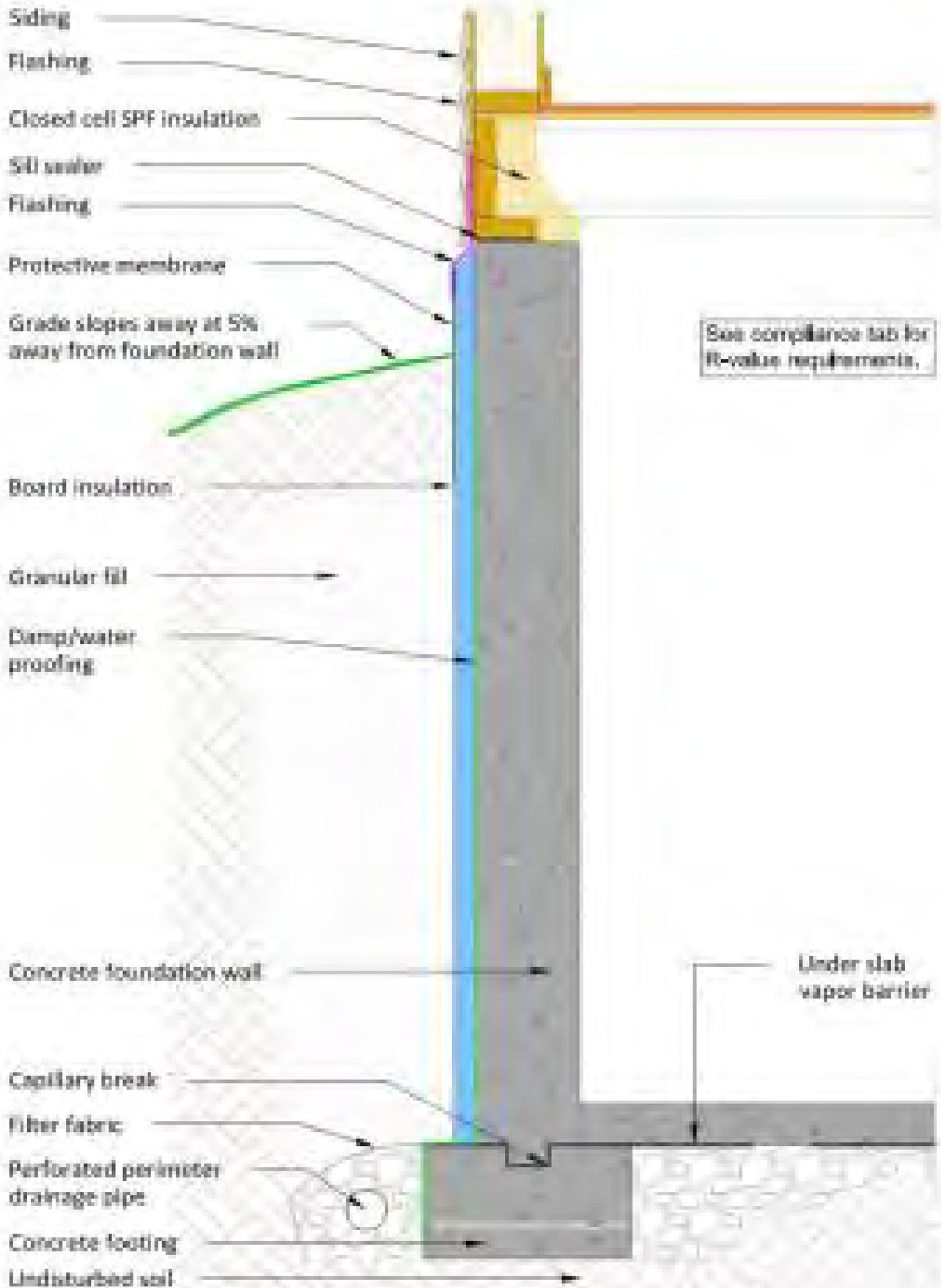


# Training

Right and Wrong Images

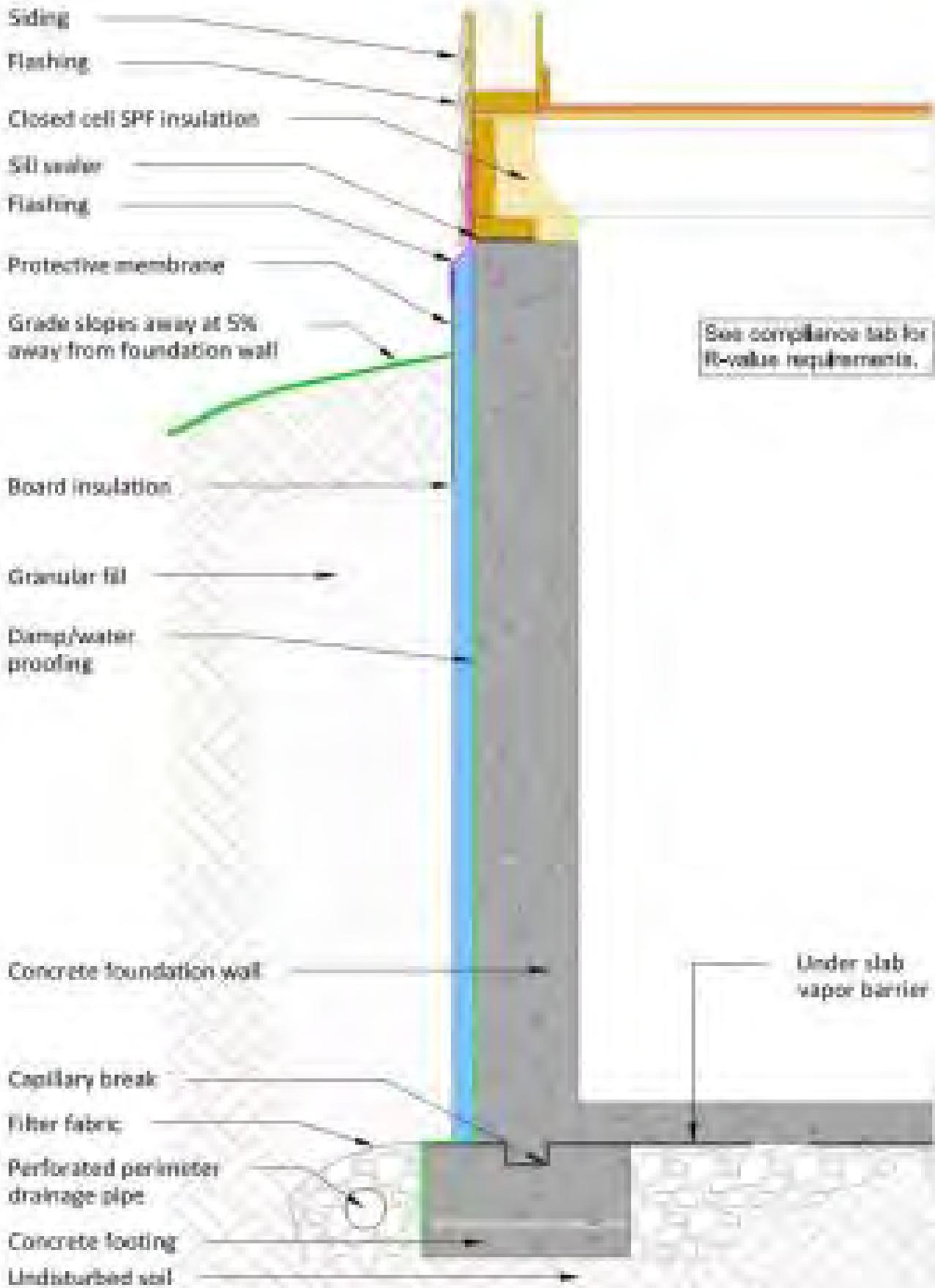
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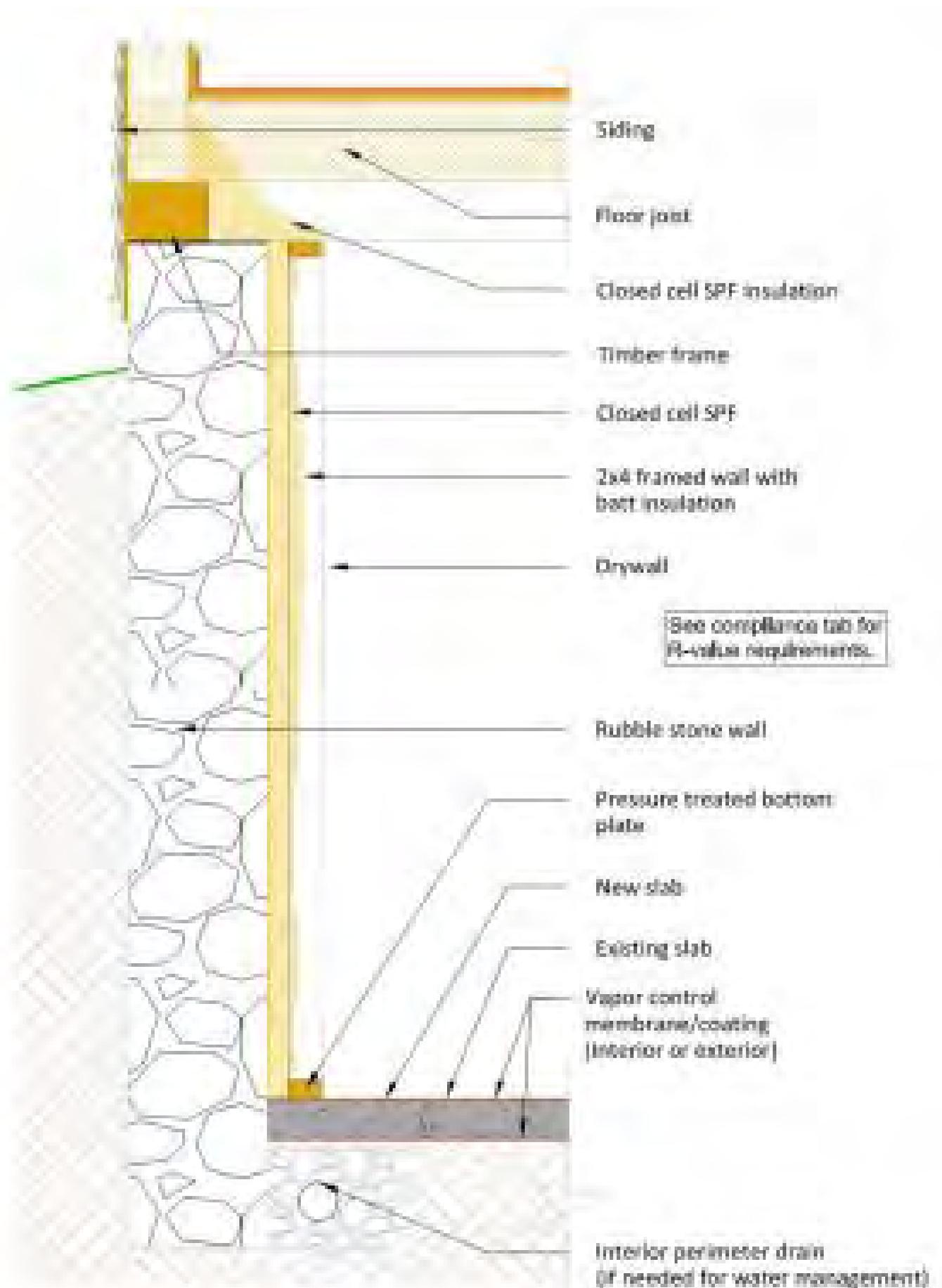
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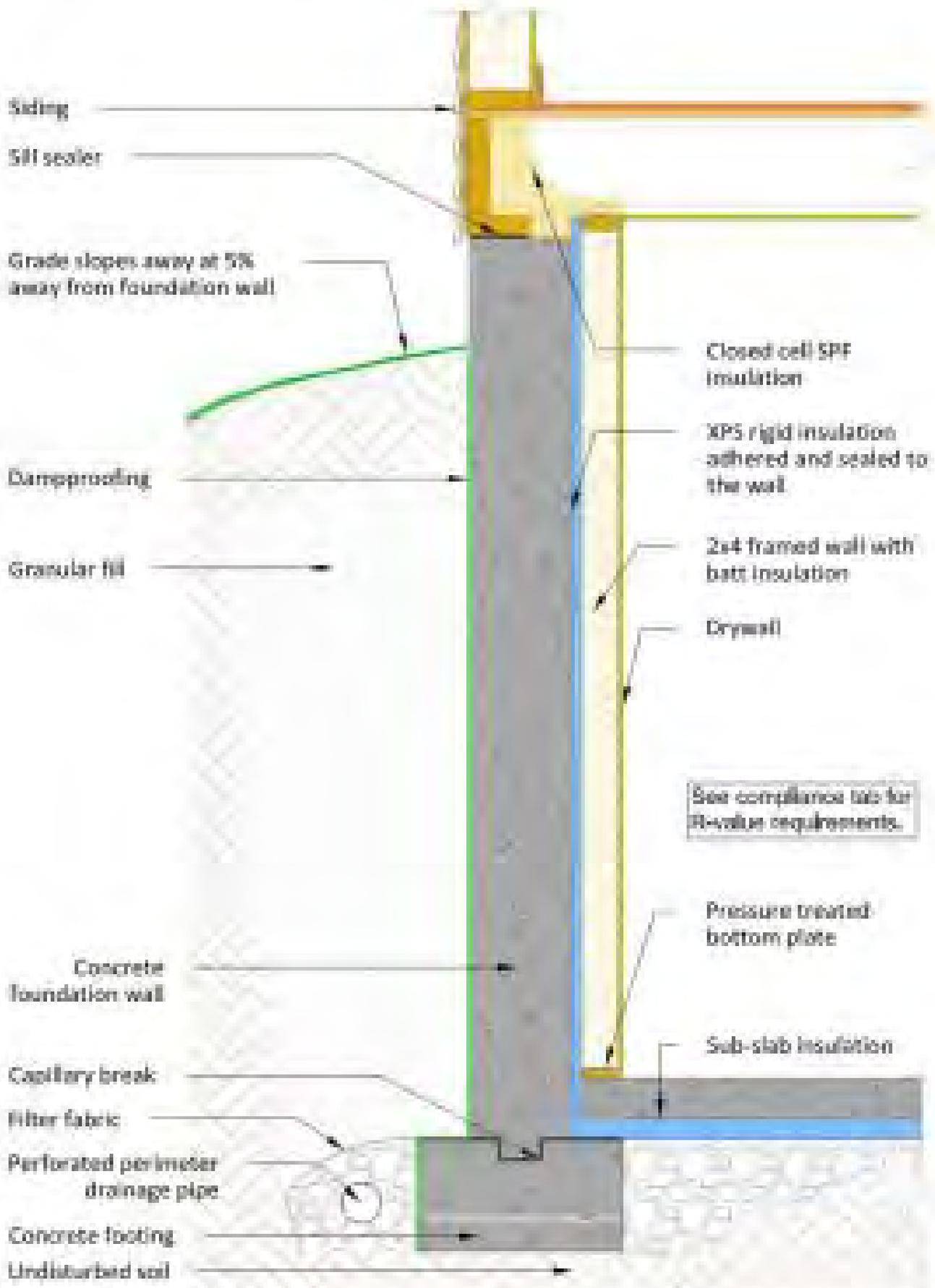
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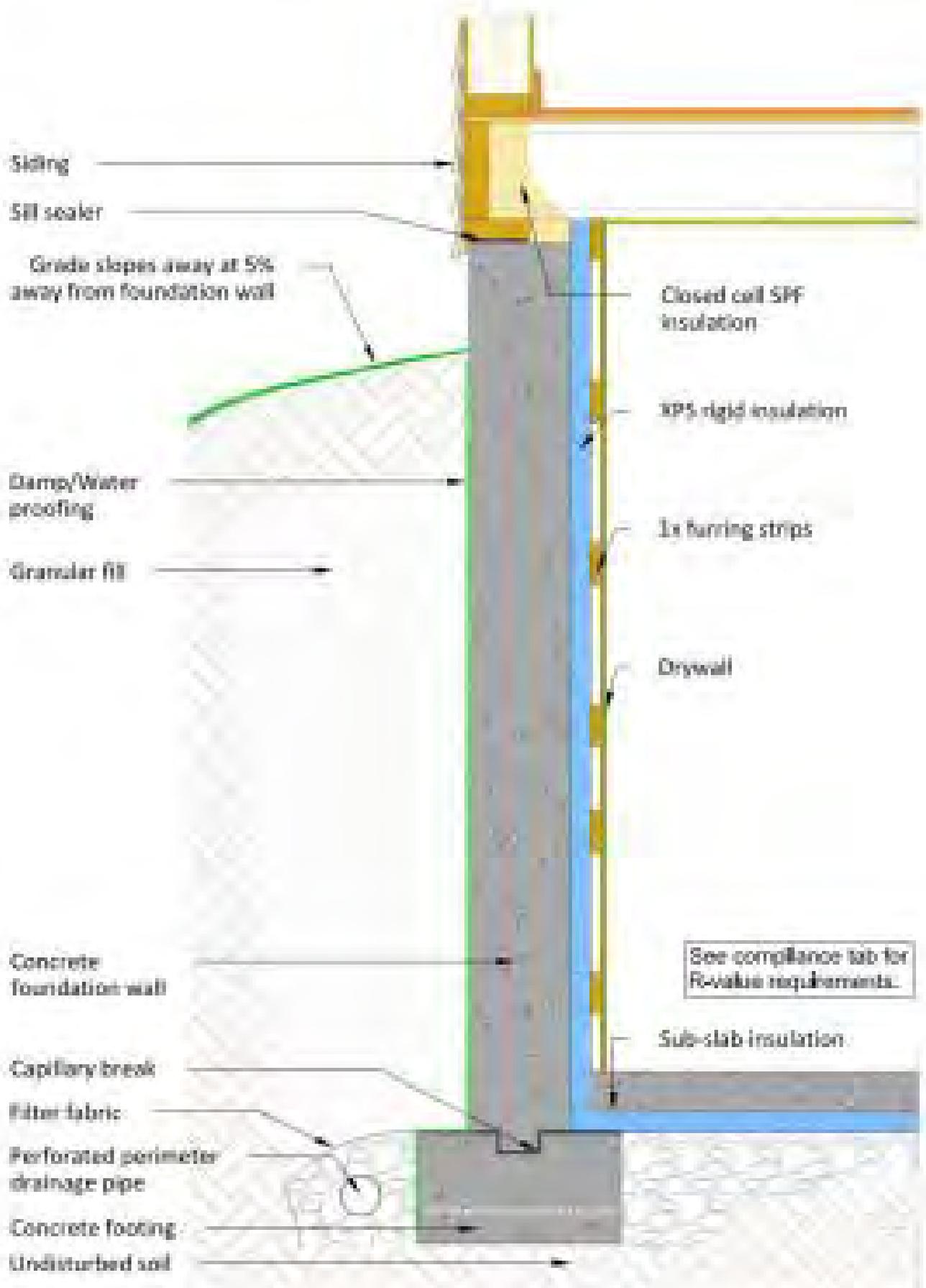
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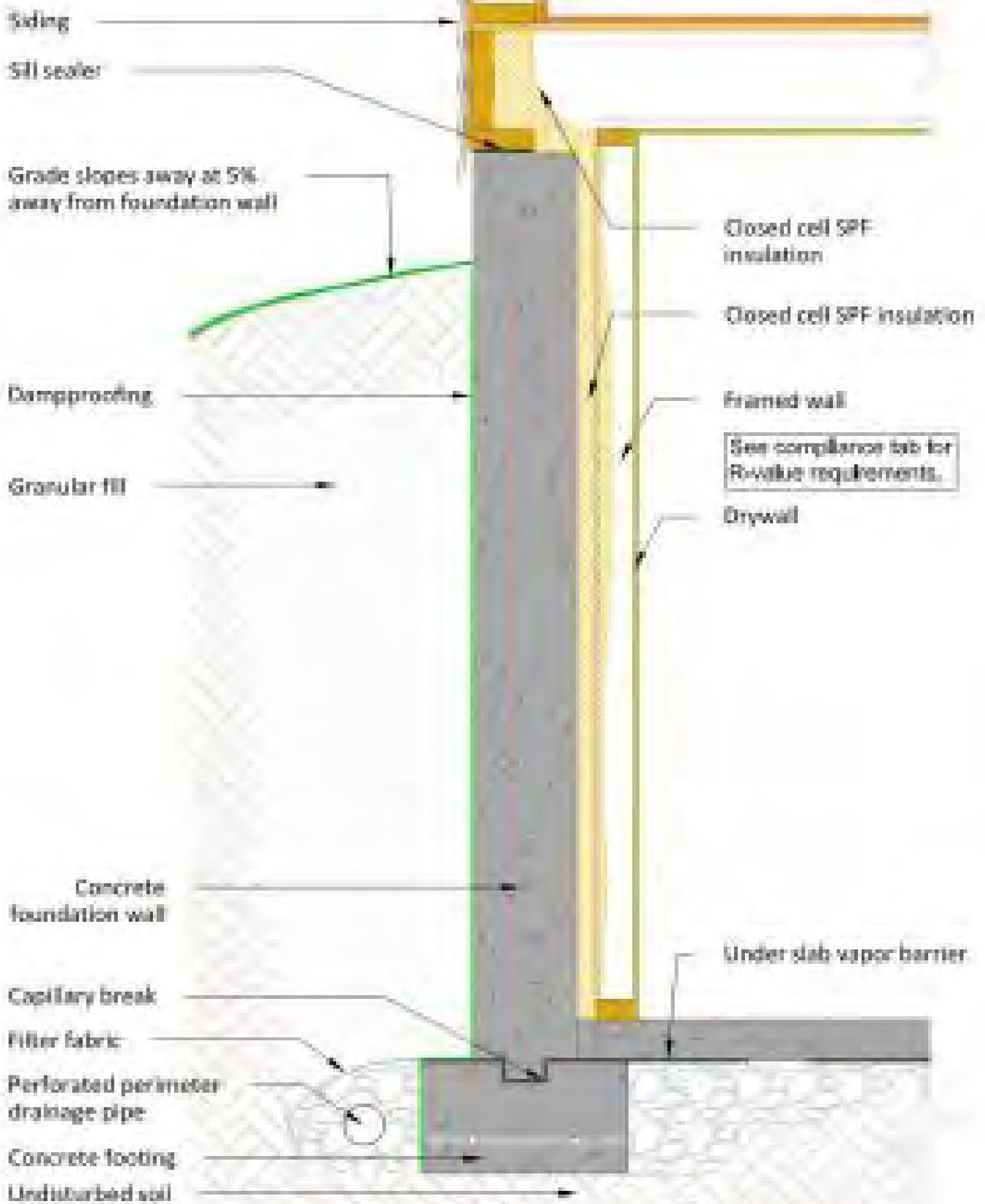
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CAD FILE: [Int XPS, furring.dwg](#)

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CAD FILE: [Spray foam, conc wall.dwg](#)

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# Compliance

The Compliance tab contains both program and code information. Code language is excerpted and summarized below. For exact code language, refer to the applicable code, which may require purchase from the publisher. While we continually update our database, links may have changed since posting. Please contact our [webmaster](#) if you find broken links.

## [ENERGY STAR Certified Homes \(Version 3, Rev. 08\)](#)

ENERGY STAR Certified Homes requires that ceiling, wall, floor, and slab insulation levels meet or exceed those specified in the 2009 International Energy Conservation Code (IECC) with some alternatives and exceptions, and achieve Grade 1 installation per RESNET Standards (see [2009 IECC Code Level Insulation – ENERGY STAR Requirements](#) and [Insulation Installation \(RESNET Grade 1\)](#)).

## [DOE Zero Energy Ready Home](#)

The U.S. Department of Energy Zero Energy Ready Home National Program Requirements specify as a mandatory requirement (Exhibit 1, #2.2) that, for all labeled homes, whether prescriptive or performance path, ceiling, wall, floor, and slab insulation shall meet or exceed 2012 IECC levels. See the guide [2012 IECC Code Level Insulation – DOE Zero Energy Ready Home Requirements](#) for more details.

The DOE Zero Energy Ready Home National Program Requirements also specify as a mandatory requirement (Exhibit 1, #3) that ducts are located within the home's thermal and air barrier boundary.

(16) Exceptions and alternative compliance paths to locating 100% of forced-air ducts in home's thermal and air barrier boundary are:

- a. Up to 10 ft of total duct length is permitted to be outside of the home's thermal and air barrier boundary.
- b. Ducts are located in an unvented attic, regardless of whether this space is conditioned with a supply register.
- c. Ducts are located in a vented attic with all of the following characteristics:
  1. In Moist climates (Zones 1A, 2A, 3A, 4A, 5A, 6A and 7A per 2012 IECC Figure R301.1) and Marine climates (all "C" Zones per 2012 IECC Figure R301.1), minimum R-8 duct insulation with an additional minimum 1.5 in. of closed-cell spray foam insulation encapsulating the ducts; total duct leakage  $\leq$  3 CFM25 per 100 ft<sup>2</sup> of conditioned floor area; and ductwork buried under at least 2 in. of blown-in insulation.
  2. In Dry climates (all "B" Zones per 2012 IECC Figure R301.1), minimum R-8 duct insulation; total duct leakage  $\leq$  3 CFM25 per 100 ft<sup>2</sup> of conditioned floor area; and ductwork buried under at least 3.5 in. of blown-in insulation. Note that in either of these designs the HVAC equipment must still be located within the home's thermal and air barrier boundary.
- d. Jump ducts which do not directly deliver conditioned air from the HVAC unit may be located in attics if all joints, including boot-to-drywall, are fully air sealed with mastic or foam, and the jump duct is fully buried under the attic insulation.
- e. Ducts are located within an unvented crawlspace.
- f. Ducts are located in a basement which is within the home's thermal boundary
- g. Ductless HVAC system is used.

The DOE Zero Energy Ready Home program requires compliance with [EPA's Indoor airPLUS program](#). Item 1.4 under moisture control in that program's checklist requires that basements or crawlspaces are insulated, sealed, and conditioned.

## [2009 IECC, 2012 IECC, 2015 IECC, and 2018 IECC](#)

Building codes vary by region, state, and even locally, but most regions in the United States use some version of the International Residential Code (IRC) and/or the International Energy Conservation Code (IECC). Basement insulation requirements from these codes are shown in Table 1. Check [energycodes.gov](#) for codes used in your state.

2009 IECC R402.2.7 (2012 IECC R402.2.8, 2015 IECC and 2018 IECC R402.2.9). Basement walls. Walls associated with conditioned basements shall be insulated from the top of the basement wall down to 10 feet below grade or to the basement floor, whichever is less. Walls associated with unconditioned basements shall meet this requirement unless the floor overhead is insulated in accordance with Sections 402.1.1 and 402.2.6.

**Table 1.** Basement Wall Insulation Requirements for IRC and IECC 2009-2018

Climate Zone	2009 IRC	2009 IECC	2012 IRC, 2015 IRC, 2012 IECC, 2015 IECC, 2018 IRC, 2018 IECC
1	0	0	0
2	0	0	0
3	5/13	5/13	5/13
4 except marine	10/13	10/13	10/13
5 and marine 4	10/13	10/13	15/19
6	10/13	15/19	15/19
7 & 8	10/13	15/19	15/19

Typical R-values for common insulation materials discussed here are summarized in Table 2.

**Table 2.** Typical R-values for common basement insulation materials.

Insulation Type	R-value per inch (ft <sup>2</sup> h°F/Btu-in)	Air barrier?	Vapor Barrier?
Fiberglass	2.5 – 4	No	No, depends on facing
Mineral wool (Mineral fiber)	3 – 4	No	No, depends on facing
Expanded polystyrene (EPS)	3.8 – 4.4	Yes	Typically Class III (2.6 Perm-inch)
Extruded Polystyrene (XPS)	5	Yes	Typically Class II (1.2 Perm-inch)
Polyisocyanurate (Polyiso)	Approx. 6	Yes	Depends on facing, typically Class I
Polyurethane Spray Foam (high-density)	Approx. 6	Yes	Typically Class II (1 Perm-inch)

**[2009 IRC, 2012 IRC, 2015 IRC, and 2018 IRC](#)**

For IRC 2009-18 insulation requirements, see Table 1 above. Insulation requirements are described in Chapter 11 Energy Efficiency. Water management details are described in R405 Foundation Drainage and R 406 Foundation Waterproofing and Dampproofing.

## More Info.

Access to some references may require purchase from the publisher. While we continually update our database, links may have changed since posting. Please contact our [webmaster](#) if you find broken links.

### Case Studies

1. [Interior Foundation Insulation Upgrade - Madison Residence Madison, WI](#)  
**Author(s):** ORNL  
**Organization(s):** ORNL  
**Publication Date:** October, 2013  
*Case study of a basement retrofit of a 1916 home in Madison, Wisconsin, home that involved installing dimple drain mat and closed-cell spray foam on interior of basement wall and an interior footing drain to manage moisture before finishing an existing basement.*
2. [New Whole-House Solutions Case Study: Exterior Rigid Foam Insulation at the Edge of a Slab Foundation, Fresno, California](#)  
**Author(s):** IBACOS  
**Organization(s):** IBACOS  
**Publication Date:** October, 2013  
*Case study describing application of exterior rigid foam insulation on a foundation system.*
3. [Technology Solutions Case Study: Exterior Rigid Foam Insulation at the Edge of a Slab Foundation, Fresno, California](#)  
**Author(s):** IBACOS  
**Organization(s):** IBACOS  
**Publication Date:** October, 2013  
*Case study describing installation of exterior rigid foam insulation on a slab foundation.*
4. [Technology Solutions Case Study: Innovative Retrofit Foundation Insulation Strategies, Minneapolis, Minnesota](#)  
**Publication Date:** August, 2015  
*Case study describing methods to retrofit foundations and basements in climate zones 6 and 7.*

### References and Resources\*

1. [2018 IECC - International Energy Conservation Code](#)  
**Author(s):** ICC  
**Organization(s):** International Code Council  
**Publication Date:** November, 2017  
*Code establishing a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems, and service water heating systems in homes and commercial businesses.*
2. [2018 IRC - International Residential Code for One and Two Family Dwellings](#)  
**Author(s):** ICC  
**Organization(s):** International Code Council  
**Publication Date:** August, 2017  
*Code for residential buildings that creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy and electrical provisions for one- and two-family residences.*
3. [Building America Special Research Project - High-R Foundations Case Study Analysis](#)  
**Author(s):** Smegal, Straube  
**Organization(s):** BSC  
**Publication Date:** August, 2013  
*Research study describing a number of promising foundation and basement insulation strategies that can meet the requirement for better thermal control in colder climates while enhancing moisture control, health, and comfort.*
- 4.

**Critical Seal (Spray Foam at Rim Joist)**

**Author(s):** BSC

**Organization(s):** BSC

**Publication Date:** September, 2009

*Information sheet about air sealing.*

5. **Measure Guideline: Basement Insulation Basics**

**Author(s):** Aldrich, Mantha, Puttagunta

**Organization(s):** CARB, NREL

**Publication Date:** October, 2012

*Document describing good practices for insulating basements in new and existing homes.*

6. **Pest Prevention by Design: Authoritative Guidelines for Designing Pests out of Structures**

**Author(s):** SF Environment

**Organization(s):** SF Environment, ICC

**Publication Date:** November, 2012

*Report providing strategies for designing structures to prevent pest entry.*

\*Publication dates are shown for formal documents. Dates are not shown for non-dated media. Access dates for referenced, non-dated media, such as web sites, are shown in the measure guide text.

## Contributors to this Guide

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