Bulk Water Control Methods for Foundations

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Abstract:

Successfully executing strategies to control bulk water for foundations is critical for building durability, indoor air quality, and creating acceptable conditions and/or living spaces within the foundation space. Although the energy impacts of properly done bulk water control are small to insignificant, it should be considered a base requirement for any high performance house. In addition, measures such as basement insulation are predicated on properly managed foundation bulk water.

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BUILDING TECHNOLOGIES PROGRAM

Bulk Water Control Methods for Foundations

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Contents

List of Figures

List of Tables

Definitions

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing And Materials
EPS	Expanded polystyrene (rigid foam insulation)
ICC	International Code Council
IRC	International Residential Code
OSHA	Occupational Safety and Health Administration
Pa	Pascal; SI unit of pressure (equivalent to one newton per square meter)
US DOE	United States Department of Energy
US EPA	United States Environmental Protection Agency
XPS	Extruded polystyrene (rigid foam insulation)

Executive Summary

Successfully executing strategies to control bulk water for foundations is critical for building durability, indoor air quality, and creating acceptable conditions and/or living spaces within the foundation space. Although the energy impacts of properly done bulk water control are small to insignificant, it should be considered a base requirement for any high performance house. In addition, measures such as basement insulation are predicated on properly managed foundation bulk water.

The fundamental concepts that must be understood at the planning phase (or during the initial inspection of an existing home) are the following:

- **Surface water must be managed**: the impermeable roof surfaces concentrate rainfall at points around the perimeter of the building; this water must be shed off and away from the foundation. This is typically done with gutters/eavestroughs and downspouts that are directed away from the foundation (or run to a storm sewer, if permitted), correctly grading the site away from the foundation, and reducing the water permeability of the surface around the foundation. The goal is to saturate or "load" the soils around the foundation with as little additional water as possible.

- **Ground water must be managed**: in order to prevent water entry into the foundation, it is necessary to prevent water accumulation against the foundation walls and/or under the slab (or ground cover). Water accumulation results in hydrostatic head pressure, which will push water through any available joints, imperfections, or cracks in the foundation. Accumulation is prevented by the use of drainage: measures include the use of free draining backfill and/or drainage board around the foundation wall, a functional footing drain directed to daylight (a downhill location) or a sump, and drainage via granular fill below the slab.

In terms of system interactions, improvement of bulk water control in foundations can only improve conditions for other building systems. For instance, control of roof drainage and directing it away from the building will reduce the extent of splashback onto exterior walls, thus improving durability and reducing the risk of aesthetics problems.

In terms of evaluating cost-value comparisons, it must be noted that repair of a failed foundation bulk water control system is time consuming, disruptive to occupants, destructive to exterior landscaping, and very expensive. It is likely that it is more cost-effective to specify foundation bulk water control details during the construction phase, rather than retrofitting measures to foundations showing bulk water problems.

Bulk water control measures are typically retrofitted to existing foundations when water control issues (and complaints) need to be solved, when the basement space is being renovated into conditioned space, and/or when interior insulation is being installed.

The above grade measures described previously apply to retrofit situations; in fact, many problem cases can be solved with grading and surface drainage. It is always better to intercept groundwater before it gets to a foundation wall. Exterior perimeter drainage is always preferable to interior perimeter drainage. However, in renovations, exterior perimeter drainage may not be present or may not be practical or possible. In such cases, interior perimeter drainage can be used and connected to an interior sump pump.

Another technique is to use an exterior impermeable material to minimize rain and groundwater entering below grade spaces, commonly known as an “apron,” “skirt,” or “ground roof.” This detail could be considered a “below grade overhang” for shedding water away from the foundation and preventing soil saturation. This method has the advantage of improving bulk water control of the foundation with minimal excavation (i.e., not down to the footings).

1 Home and/or Document Inspection

Successfully executing strategies to control bulk water for foundations is critical for building durability, indoor air quality, and creating acceptable conditions and/or living spaces within the foundation space. Although the energy impacts of properly done bulk water control are small to insignificant, it should be considered a base requirement for any high performance house. In addition, measures such as basement insulation are predicated on properly managed foundation bulk water.

The fundamental concepts that must be understood at the planning phase (or during the initial inspection of an existing home) are the following, and as demonstrated in Figure 1:

Surface water must be managed: the impermeable roof surfaces concentrate rainfall at points around the perimeter of the building; this water must be shed off and away from the foundation. This is typically done with gutters/eavestroughs and downspouts that are directed away from the foundation (or run to a storm sewer), correctly grading the site away from the foundation, and reducing the water permeability of the surface around the foundation. The goal is to saturate or "load" the soils around the foundation with as little additional water as possible.

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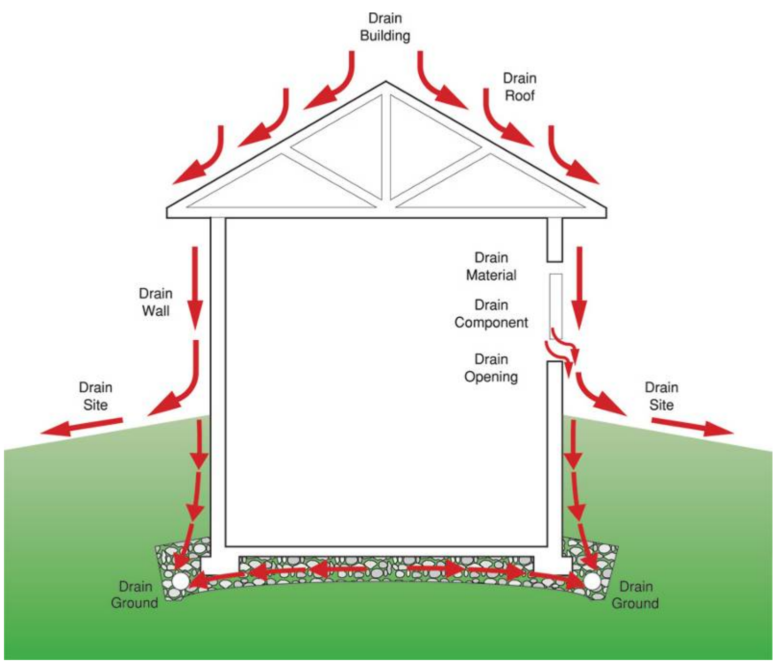

Figure 1. Foundation Bulk Water Control Overall Concepts

A full discussion of basements can be found in Lstiburek 2006 ("Understanding Basements").

The specific strategies that must be implemented (or inspected for) will be covered in more detail in Section 3, "Strategy Implementation Details." But common signs of moisture problems in existing foundations can be manifested as visible water or puddles, staining of interior (or visible) finishes, mold growth, and efflorescence (water-borne white mineral salt deposits). Note that interior finishes or insulation may conceal the presence of bulk water issues for extended periods of time, and problems may not be evident until damage is extensive (as shown in Figure 4). Some guidance on diagnosing moisture issues is given by US EPA (2010) under "Moisture (Mold and Other Biologicals)" and US EPA (2009) (under "Moisture Control → Water Managed Site and Foundation").

Figure 2. Wall water seepage patterns (at form tie penetration in cast concrete wall)

Figure 3. Active seepage through cast concrete foundation wall (following rain event)

Figure 4. Bulk water damage concealed behind interior finishes/insulation

Figure 5. Negative grade issues (accumulation refrozen roof runoff near foundation)

In addition, additional information can be gleaned by characterizing foundation bulk water issues by their frequency and/or time of occurrence. For instance, wetting events could be close to constant in nature (i.e., occurring throughout the year), or seasonal (e.g., only during spring/fall rains, or rising groundwater conditions). In addition, physical the location can provide some indication to the cause (close to an area of exterior wetted soil or disconnected downspout).

2 Tradeoffs

2.1 System Interaction

In general, improvement of bulk water control in foundations can only improve conditions for other building systems. For instance, control of roof drainage and directing it away from the building will reduce the extent of splashback onto exterior walls, thus improving durability and reducing the risk of aesthetics problems.

As discussed above, interior insulation or interior finishing of a basement is not recommended unless bulk water issues are brought under control.

One potential negative system interaction might be moisture-sensitive expansive soils: suddenly reducing the moisture content of the soil surrounding the foundation might result in shrinkage, ground movement, and foundation movement/cracking. These types of soils are known to occur in Texas, California, Virginia and Colorado.

2.2 Cost and Performance Tradeoffs

In general, cost decisions to execute (or not execute) foundation bulk water control details are not made on a quantitative basis. In contrast, energy upgrade measures can be quantified in terms of simple payback, energy return on investment, or other metrics. These metrics can be compared in terms of their relative value, providing a useful go/no-go measurement.

Failures of bulk water control measures will result in homeowner complaints, builder callbacks, durability issues, and potential indoor air quality issues, all of which would result in significant financial liabilities. Therefore, the decision to invest or not invest in a given measure is based on a risk assessment (either formal or informal), depending on soil conditions, site conditions, foundation type, and other factors. These conditions vary widely and can be affected by local and site variations. Some guidance is provided by various model codes. For instance, the International Residential Code (ICC 2009) allows for the elimination of foundation drainage under certain soil conditions (see §R405: Foundation Drainage). It must be realized, though, that any elimination of bulk water control measures increases risks of problems.

Overall, it must be noted that repair of a failed foundation bulk water control system is time consuming, disruptive to occupants, destructive to exterior landscaping, and very expensive. It might be most cost-effective to maximize bulk water control measures during construction of the foundation, as opposed to retrofits after problems occur. As an example of this type of comparison, an air gap membrane (a highly robust strategy easily installed during construction) has a material cost of roughly 50¢ per square foot. For a 1200 sf footprint house (30’ x 40’), this would be roughly $500 in materials. In comparison, excavation and retrofit of exterior basement drainage details might have costs in the range of several thousand to tens of thousands of dollars.

In existing houses, measures are typically taken when there is a complaint of bulk water intrusion into the foundation, or problems are found due to bulk water intrusion (e.g., basement mold issues). At that point, cost-performance trade offs are typically a smaller concern than solving the problem. Note that exterior retrofit measures that require excavation should be executed with appropriate safety measures. For instance, services must be located and identified, and OSHA-approved methods should be used for excavation (OSHA 1999; see Section V: Chapter 2 Excavations: Hazard Recognition In Trenching and Shoring).

Critical Takeaways

In general, improvement of bulk water control in foundations can only improve conditions for other building systems.

Interior insulation or interior finishing of a basement is not recommended unless bulk water issues are brought under control.

It is likely that it is more cost-effective to specify foundation bulk water control details during the construction phase, rather than retrofitting measures to foundations showing bulk water problems.

Important Definitions

See Important Definitions in Section 3 for full listing.

Contractor/Homeowner Safety

OSHA Technical Manual; Section V: Chapter 2 Excavations: Hazard Recognition In Trenching and Shoring

References to other Guidelines, Codes and Standards

[ICC] International Code Council, (2009). 2009 International Residential Code for One- and Two-Family Dwellings, Country Club Hills, IL: International Code Council, Inc.

[OSHA] U.S. Department of Labor, Occupational Safety & Health Administration (1999). OSHA Technical Manual, TED 01-00-015 [TED 1-0.15A]. Washington, DC: S. Department of Labor, Occupational Safety & Health Administration.

3 Strategy Implementation Details

Rainwater, surface water and groundwater will wick through concrete and masonry materials. This can be a problem in two ways: building materials touching the foundation may grow mold, decay, corrode or dissolve; or the migrating water might evaporate into the basement or crawlspace and cause high humidity and/or condensation problems in the foundation and the upper part of the building. The fundamental principles of groundwater control are to keep rainwater away from the foundation wall perimeter and to drain groundwater with sub-grade perimeter drains before it gets to the foundation wall. This applies to basements, crawlspaces and slabs regardless of whether they are newly constructed or undergoing rehabilitation.

This section is broken down into several portions, starting with an explanation of above grade strategies in detail (including roof runoff and exterior grading), and then below grade strategies (including foundation wall drainage, footing drains, sump pit drainage, and capillarity through footings). This is followed by example building sections for basements, crawl spaces, and slabs on grade. The section concludes with a description of various available retrofit measures for addressing bulk water problems in existing foundations.

3.1 Above Grade Measures

Many foundation bulk water problems start with above grade drainage issues, and this should be the first place examined when diagnosing issues in existing buildings. The primary means of addressing these issues is with careful management of roof water runoff, and proper exterior grading.

3.1.1 Roof Runoff

Impermeable roof surfaces concentrate rainfall at points around the perimeter of the building; this water must be shed off and away from the foundation. Roof overhangs will help shed water away from the foundation, and also protect the above grade walls.

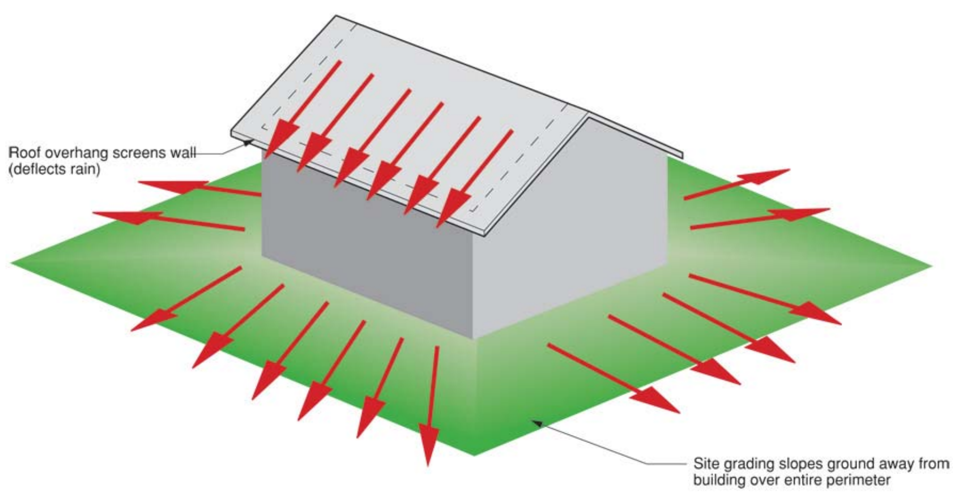

Figure 6. Directing roof runoff away from building using overhangs and grading

Part of the solution to keep water away from foundation is to use gutters/eavestroughs and downspouts that are directed away from the foundation (or run to a storm sewer, if permitted).

Note that roof runoff must not be directed into the ground near the building, and especially not the perimeter foundation drain. Infiltrating rain water into the ground is not a problem in itself: the problems occur when it is done next to the building. A below-surface drain adjacent to the building must be directed to a dry well or storm sewer away from the building (see Figure 7).

Figure 7. Downspout directed to in-ground drain (<u>not</u> connected to footing drain system)

Overall, the goal is to saturate or "load" the soils around the foundation with as little additional water as possible.

The roof design can also result in bulk water "point" concentrations. For instance, the design in Figure 8 and Figure 9 concentrates rainfall from roughly 25% of the entire roof in a 6' length.

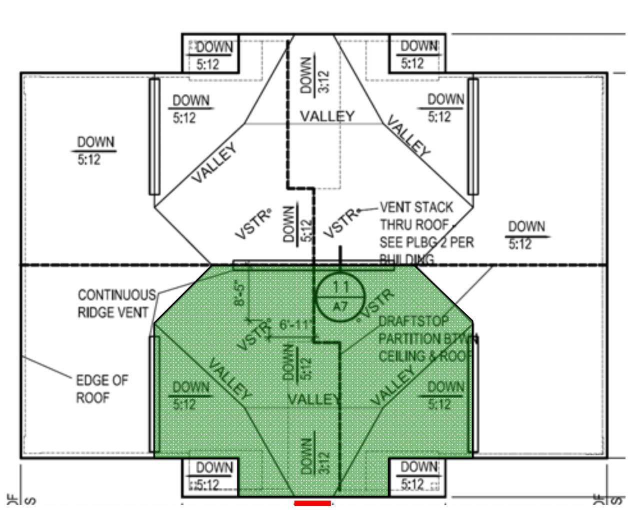

Figure 8: Rainwater concentration due to roof geometry (runoff location indicated by red bar)

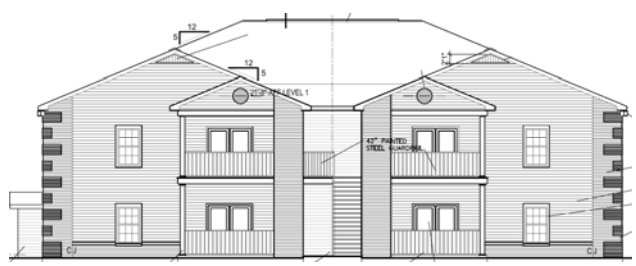

Figure 9. Front elevation of roof design with geometry/rainwater concentration issues

This could be addressed with measures such as an impermeable surface where this large runoff would occur (pavement, impermeable clay cap), or the use of a drainage swale (an in-ground gravel “surface gutter” carrying water away from the building). Large roof valleys and roof-wall intersections can also create similar type of roof water concentrations.

3.1.2 Exterior Grading and Surface Runoff

Correct exterior grading and drainage of surface water are also critical for preventing foundation bulk water issues. In fact, it might be futile to try to correct foundation wetness issues without first addressing surface problems.

The basic requirement is to correctly grade the site away from the foundation; a problem case is demonstrated in Figure 10 below.

Figure 10. Negative grade issues (accumulation refrozen roof runoff near foundation)

Backfilling during construction can be critical for preventing grading problems. Improperly compacted fill will settle over time, resulting in a negative slope. Builders are often hesitant to extensively compact fill adjacent to foundation walls, given the potential for damage to the foundation wall. Typical recommendations are to use hand-operated equipment, compacting in “lifts” of 6-12 inches, depending on soil type. Similarly, utility trenches leading to the foundation should be properly compacted to avoid depressions and negative grading.

With slab foundations, site grading is critical. Direct the water away from the building perimeter so that the ground next to the foundation does not get saturated. Do not over-water plantings near the house. Ideally, plantings would be kept away from the house. If it is still necessary to have planting adjacent to the building, consider installing a French drain right beside the house and dampproof the edge of the slab foundation (see Lstiburek 2008 “Concrete Floor Problems”).

Another measure is to reduce the water permeability of the surface around the foundation: this can be done using impermeable pavement (asphalt or concrete) or an impermeable clay cap. Of course, proper grading becomes even more important with impermeable surfaces.

Snow accumulation can also be the cause of foundation bulk water problems, especially when large amounts of snow have built up adjacent to the house. During thaw periods, this concentration of snow can deposit substantial amounts of water at the foundation wall, and/or dam in further water if the geometry is unfavorable.

3.2 Below Grade Measures/Groundwater

In order to prevent water entry into foundations, it is necessary to prevent water accumulation at the below grade portions of the building enclosure (the foundation walls and the slab/ground cover). Water accumulation results in hydrostatic head pressure, which will push water through available joints, imperfections, or cracks in the foundation. Furthermore, water in contact with masonry materials can wick through them: this is known as capillarity.

Accumulation is prevented by the use of drainage: measures discussed below include the installation of free draining backfill and/or drainage board around the foundation wall, a sub-grade perimeter drainage system (e.g., footing drain directed to daylight or a sump), and drainage via granular fill below the slab. In addition, capillary water uptake through the footings is discussed, with appropriate preventative measures.

3.2.1 Foundation Wall Drainage

Most foundation assemblies (and most wall assemblies) are a combination of screens and barriers. The "drain screen" foundation involves using a free-draining backfill such as gravel or sand to direct water downwards to a perimeter drain and away from the building. Alternately (or in combination with a free-draining backfill), a synthetic drainage board (e.g., an "air gap membrane") can be used. Overall, the goal is to keep water from building up against the foundation wall sufficiently to form a significant hydrostatic head.

This free-draining material is installed outboard of a concrete or masonry foundation barrier wall that is damp-proofed to prevent water absorption. Note that damp-proofing is a minimum code requirement for below-grade walls enclosing interior space (ICC 2009).

Figure 11. Dampproofing applied to cast concrete foundation wall

However, it should be noted that typical foundations have dampproofing applied to them, not waterproofing. Dampproofing is typically not able withstand significant hydrostatic head pressure, which makes the use of drainage very critical. Even below-grade walls that are ostensibly “waterproof” (i.e., with an adhesive-applied membrane) have been documented to fail at poorly connected seams (in combination with poorly draining soils). In that case, the addition of a drainage layer (an air gap membrane) solved the issues.

Some water penetration and absorption is tolerated by the concrete and masonry as long as this penetrating water can be released to the interior or above grade in a controlled manner. This of course is typically complicated by interior basement finishing and insulation. Typically, interior insulation systems and finishes should be vapor permeable in order to allow this penetrating water to pass into the interior space and be removed by the mechanical system or by ventilation.

One highly robust strategy to ensure drainage is to use a drainage layer product. Examples include an “air gap membrane,” which is a semi-rigid dimpled moisture-impermeable polymer sheet good that allows drainage in the air gap formed between the foundation and the membrane (see Figure 12), and draining rigid fiberglass board, which also functions as insulation (see Figure 13). These strategies make foundation drainage much less sensitive to the drainage qualities of the backfill material. There is anecdotal evidence from Ontario’s home warranty program that the addition of air gap membranes significantly reduce the incidence of builder callbacks for basement bulk water leakage.

Figure 12. Air gap membrane/drainage board, showing drainage paths (c/o Cosella Dörken)

Figure 13. Exterior foundation insulation using draining rigid fiberglass board

Air gap membranes can be used alone, over dampproofing (as shown in Figure 14), or in conjunction with rigid insulation (as shown in Figure 15).

Figure 14. Air gap membrane applied over dampproofing on cast concrete wall

Figure 15. Air gap membrane applied over waterproofing membrane and insulation

3.2.2 Footing Drains

Bulk water must be drained from the lowest portions of the foundation (below the interior finish floor level): this is the function of the footing drain, which is in turn drained to daylight or to a sump pit and pumped out. It keeps ground water levels below interior floor levels, and also drains away any water that has been collected by the foundation wall drainage system.

In addition, underneath the basement slab (or a crawl space floor that is below exterior grade), there is a granular drainage pad, composed of coarse gravel (no fines). The slab is cast directly on top of a polyethylene vapor diffusion barrier: no sand “blotter” layer should be used between the slab and polyethylene (see Lstiburek 2008 “Concrete Floor Problems”).

Figure 16. Flexible footing drain installed, with pre-installed filter fabric mesh

The footing drain should be located within a bed of coarse gravel, surrounded by a filter fabric (geotextile) wrap (a.k.a. "drainage burrito") which prevents clogging of the gravel with sediment.

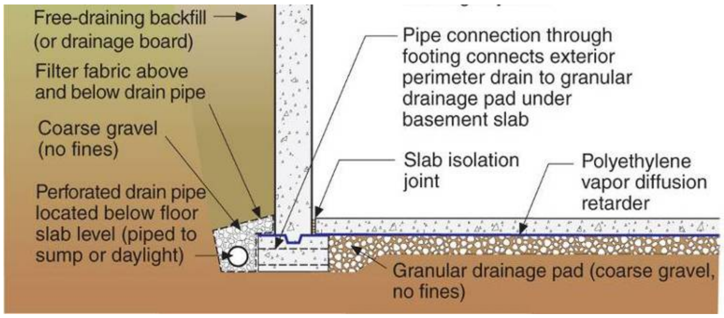

Figure 17. Section view of perimeter drain connection to granular sub-slab drainage

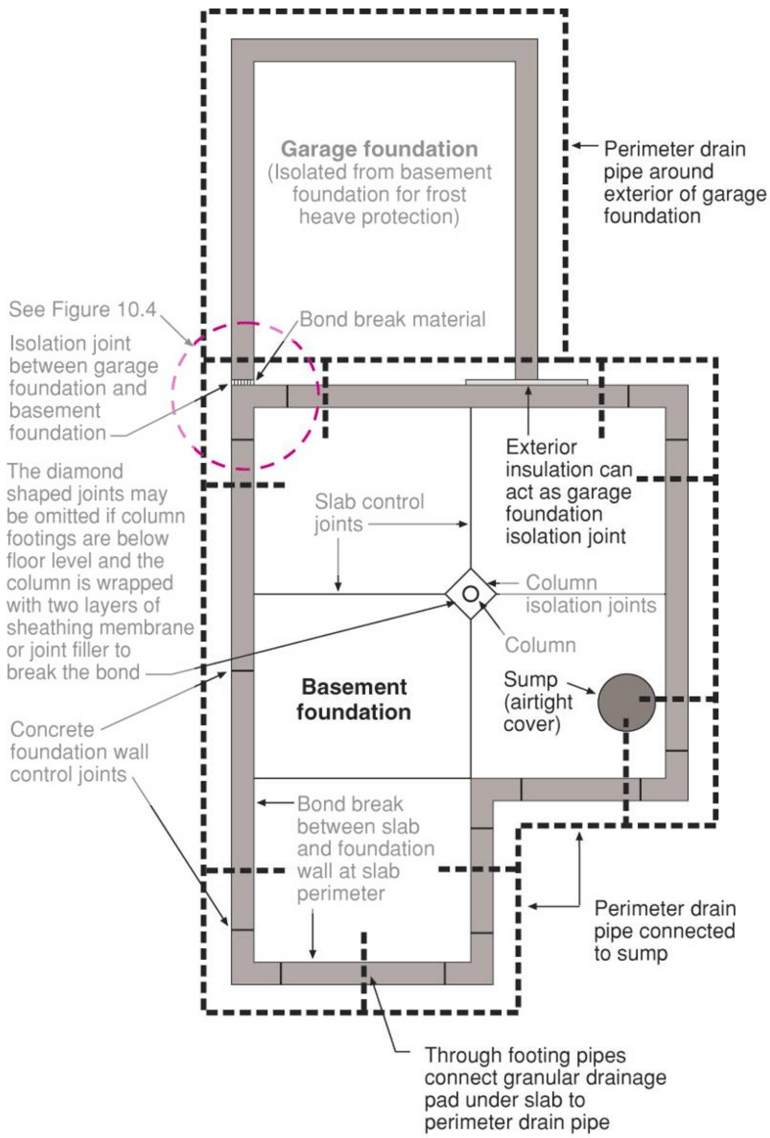

Figure 18. Sub-grade drainage system

Note that the perimeter footing drain is periodically connected to the sub-slab granular drainage pad via cross-connections (see Figure 17 and Figure 18). This is done to provide redundant drainage: if the perimeter drain becomes blocked over time, there is an alternate drainage path providing a bypass back to the sump pit.

Serious groundwater issues are beyond the scope of this document; these decisions are under the purview of geotechnical engineering. However, it should suffice to say that building a foundation with the finished floor at a level below typical ground water levels is extremely risky, and will require significant running of the sump pump system to dewater the ground adjacent to the foundation. In some retrofit cases, it has been more cost-effective to raise the floor level above current ground water levels.

3.2.3 Sump Pit Drainage

The perimeter drain can be connected to an interior sump pit, which in turn should also be well-connected to the sub-slab gravel field. This is often done with the use of a perforated sump liner basket. Failure to connect the sub-slab gravel to the drainage system can result in hydrostatic head buildup within the gravel field, and flooding of the basement through joints and imperfections in the slab, as per Figure 19 and Figure 20.

Figure 19. Flooded basement due to saturated granular fill under slab

Figure 20. Demonstration of saturated/ pressurized granular fill at sump pit (LH hole)

In addition, the outflow from the sump pit must be directed to a storm sewer or a dry well away from the foundation. Depositing the outflow next to the foundation will result in simply "recycling" water in and out through the foundation drainage system.

The sump pit should have an airtight cover for indoor air quality reasons; the sump can be a source of soil gases (including radon, water vapor, herbicides, termiticides, methane, etc.), which can be detrimental to occupant health.

3.2.4 Capillarity Through Footings

In modern foundations, capillary moisture transport through foundations walls (i.e., "wicking" through solid materials) is almost completely addressed by standard details. Capillary control is provided at foundation wall (by dampproofing) and at the floor slab (via the granular capillary break and polyethylene vapor barrier). However, there is a direct capillary connection between the bottom of the footing (which rests below the bottom of the footing drain) and the interior of the foundation wall, as shown in Figure 21. This moisture can be a source of problems if impermeable or moisture-sensitive materials are used as interior finishes at the foundation wall.

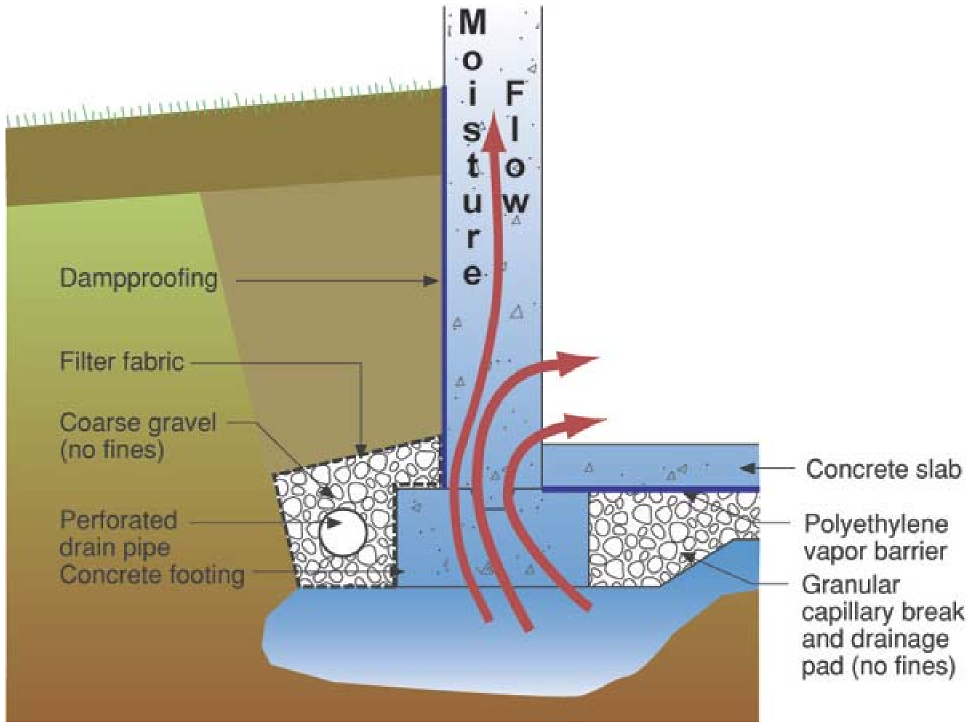

Figure 21. Capillary uptake of water through footing-to-foundation-wall connection

These issues can be prevented by the use of a capillary break at the top of the footing. Some acceptable materials to address this issue include asphalt-based coatings (i.e., standard dampproofing), waterproof membranes, cementitious coatings (cement-based waterproofing, polymer modified), latex paint based waterproofing coatings, and silanes/siloxanes (although unlikely due to cost). Some applications are shown in Figure 22 and Figure 23 below.

Figure 22. Capillary break using liquid-applied dampproofing on top of footing

Figure 23. Capillary break using proprietary roll-applied material during casting of footing

3.3 Example Building Sections

The following building sections show the combination of strategies that should be applied for basement, conditioned crawl space, and slab on grade foundation types. They incorporate the strategies described in detail in previous sections.

3.3.1 Basement

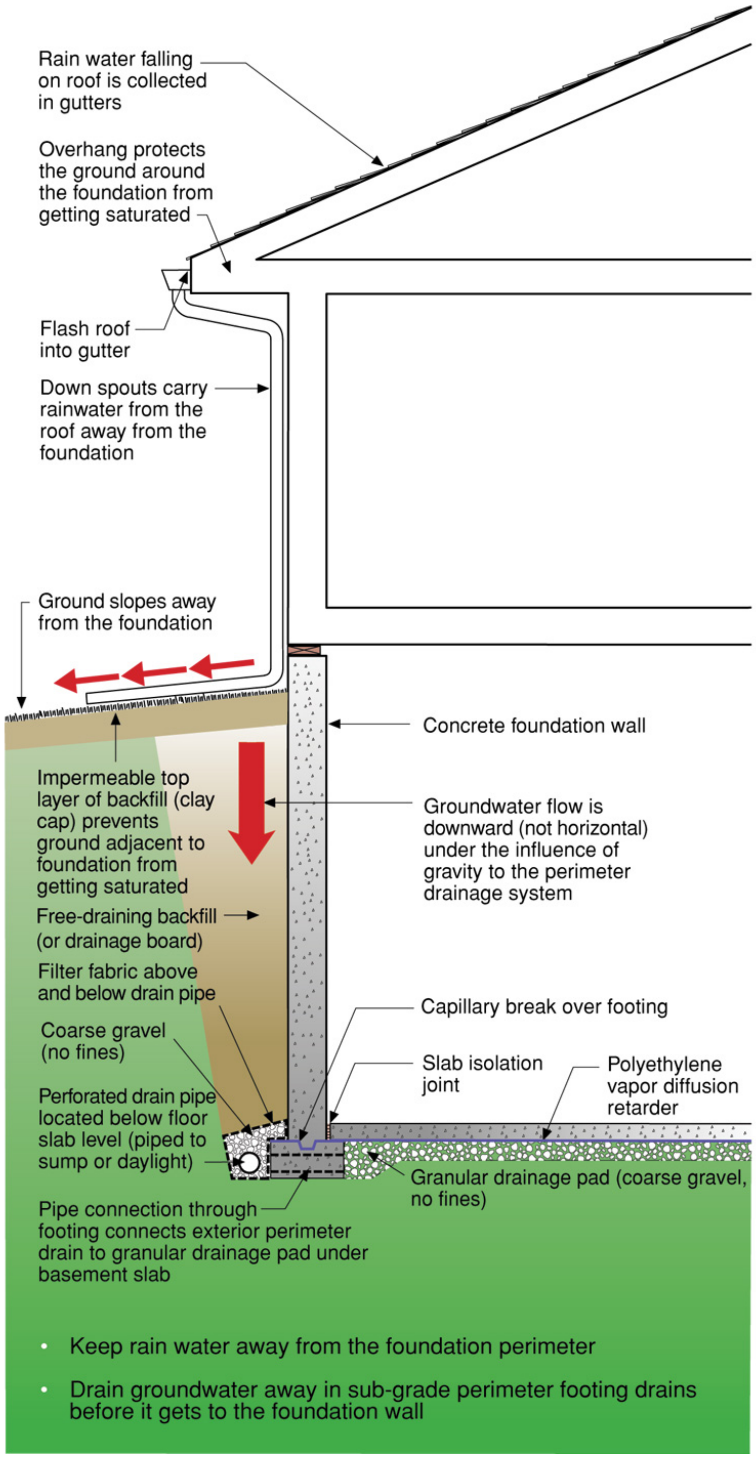

Figure 24. Basement foundation bulk water control example building section

3.3.2 Conditioned Crawl Space

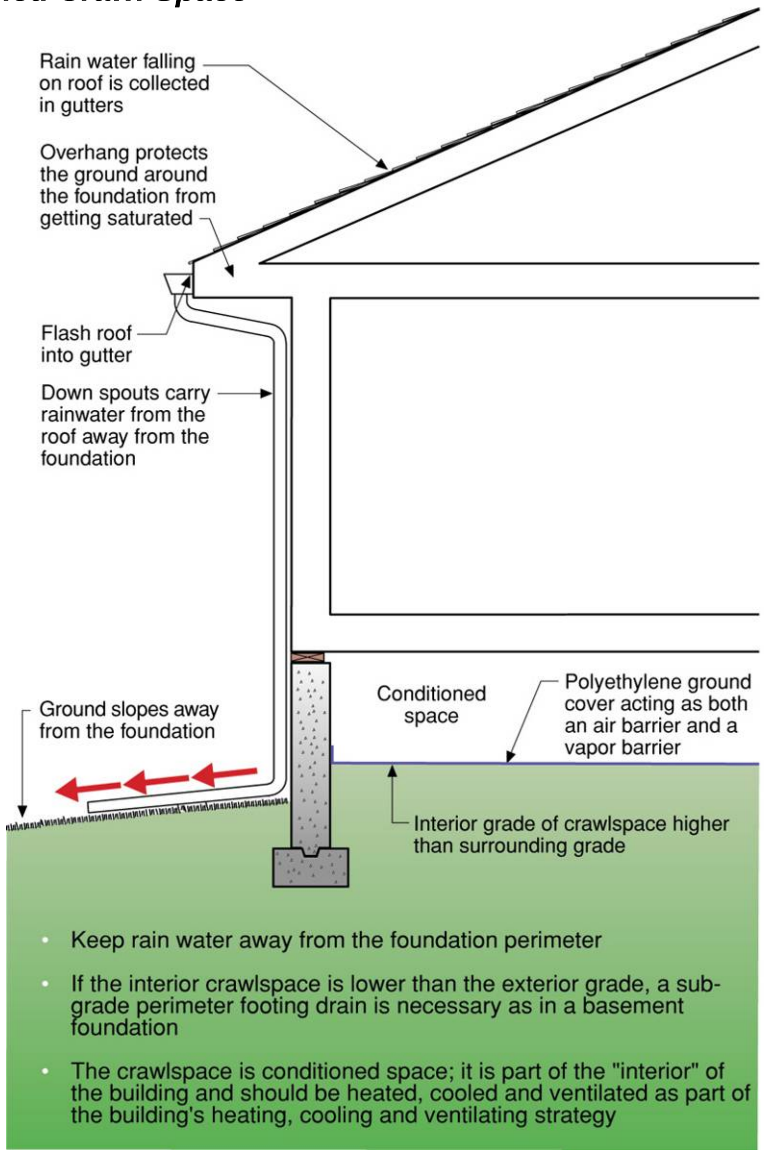

Figure 25. Crawl space foundation bulk water control example building section

3.3.3 Slab on Grade

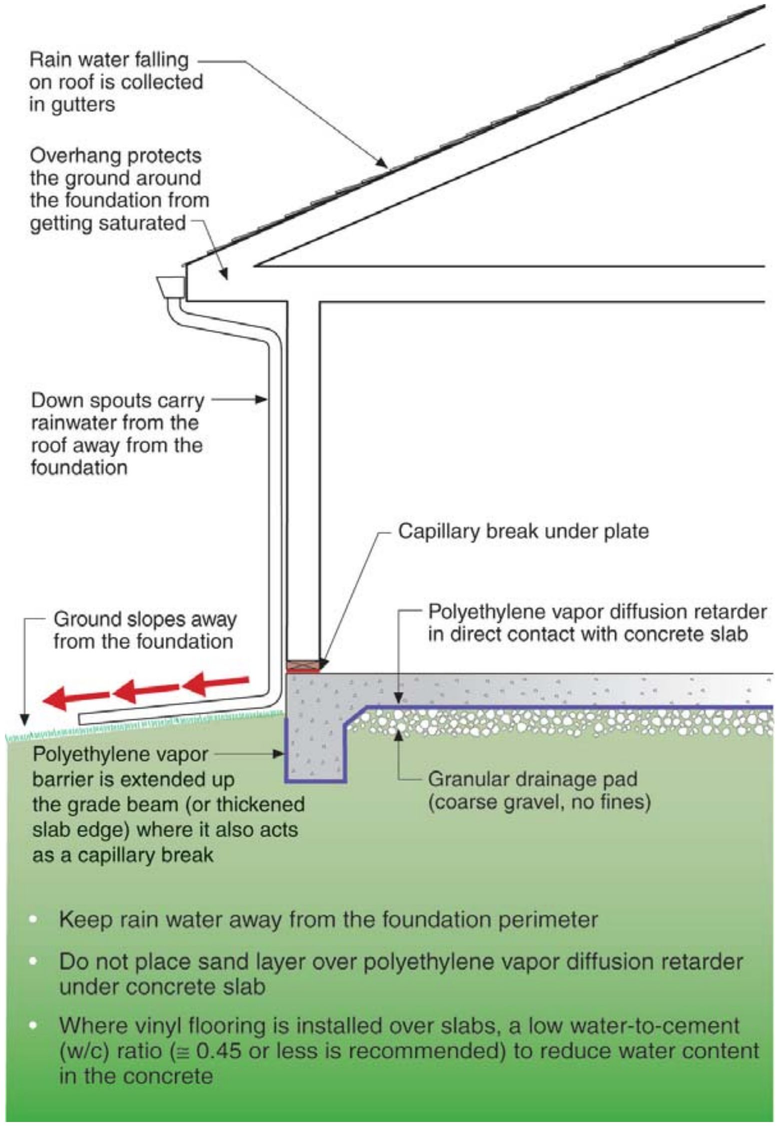

Figure 26. Slab on grade foundation bulk water control example building section

3.4 Retrofit Measures

Bulk water control measures are typically retrofitted to existing foundations when water control issues (and complaints) need to be solved, when the basement space is being renovated into conditioned space, and/or when interior insulation is being installed.

The above grade measures described previously apply to retrofit situations; in fact, many problem cases can be solved with grading and surface drainage. However, groundwater issues can still occur even with a properly graded and drained site.

It is always better to intercept groundwater before it gets to a foundation wall. Exterior perimeter drainage is always preferable to interior perimeter drainage. However, in renovations, exterior perimeter drainage may not be present or may not be practical or possible. In such cases, interior perimeter drainage can be used and connected to an interior sump pump. Interior sump pits/crocks must be fitted with airtight gasketed covers to prevent soil gas entry. This interior perimeter drainage may be combined with an interior drainage layer. Where an interior drainage layer is used, it must be gas tight (meets requirements for air barrier materials/assemblies) and vapor tight (Class I vapor control layer) relative to the interior. This interior drainage layer can be sheet membrane waterproofing, or an air gap membrane.

An example of this type of retrofit is shown in Figure 27; it is applicable to a variety of foundation material types, including those with an uneven interior surface (i.e., rubble foundations). This construction is covered in more detail in Lstiburek (2010) ("Rubble Foundations").

The detail uses high-density spray foam to provide insulation on the interior, which must be protected from the interior by a thermal barrier (gypsum board or intumescent paint).

Note that the risk of condensation increases if this insulation is omitted, leaving the water control layer (membrane waterproofing or air gap membrane) exposed. Condensation would occur on the upper part of the wall (in wintertime, when the exposed wall is cold) and the lower part of the wall (in spring or summertime, when exterior conditions are humid and the ground is still cold from the winter). There is a greater risk here than at the non-treated wall because the water control layer is moisture-impermeable, and thus condensation can form more readily. This risk becomes even greater if air-permeable insulation (e.g., fiberglass batt or cellulose) is used (i.e., cold surfaces will be even colder while still allowing air to contact the cold surface, causing greater risk of condensation).

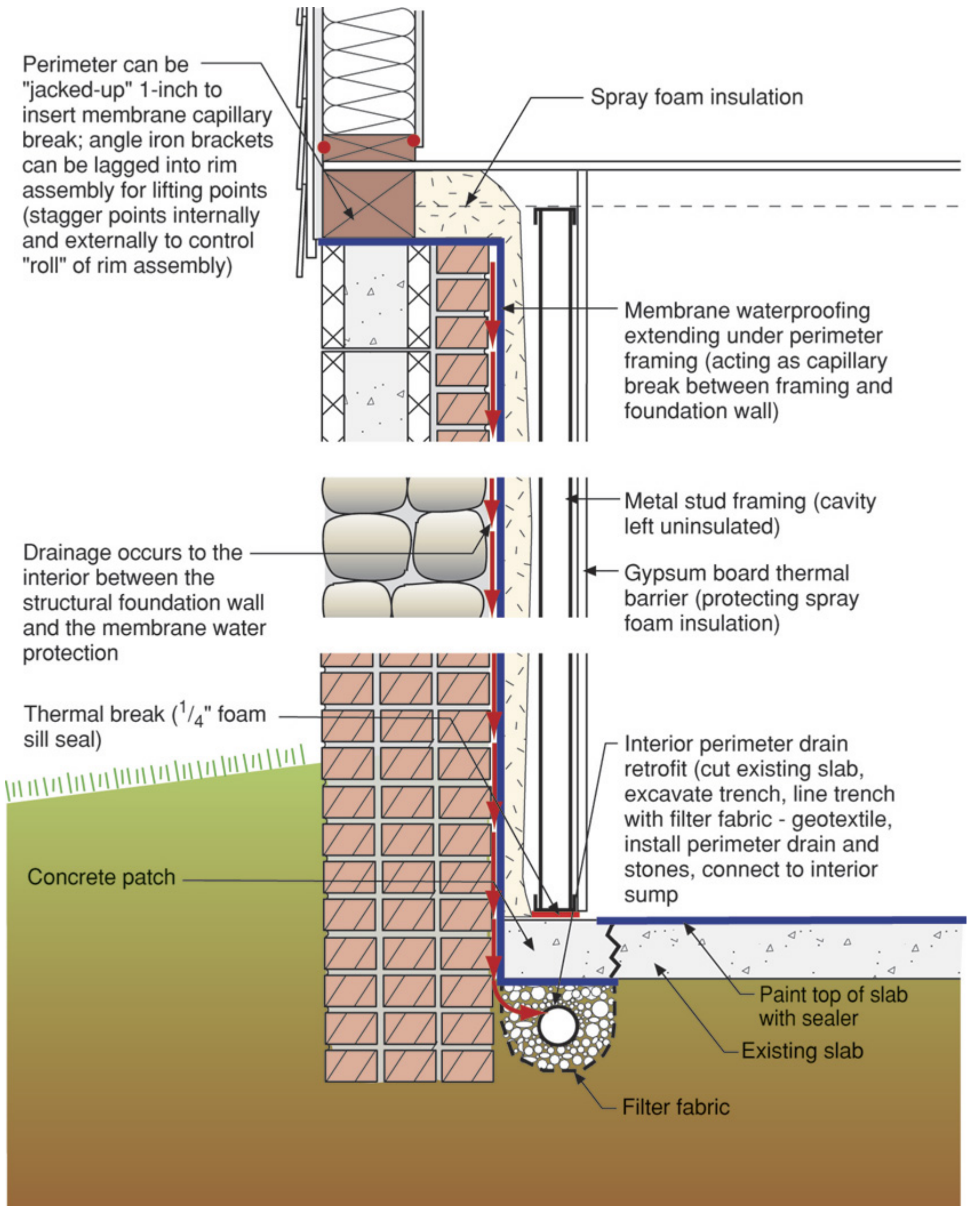

Figure 27. Interior drainage—renovation

A similar type of detail can be applied to foundation walls with a relatively even interior surface, such as cast concrete or block. In this case, a "spacer" mesh and impermeable foil-faced polyisocyanurate are attached to the wall, thus creating a cavity which is drained into the sub-slab granular fill. This drains any water that passes through the masonry wall away from the interior space. The interior rigid insulation must be gas tight (meets requirements for air barrier materials/assemblies) and vapor tight (Class I vapor control layer) relative to the interior. The foil-faced polyisocyanurate must be rated for interior exposure (acceptable flame spread and smoke developed indices), or otherwise, some type of thermal/fire protection must be added.

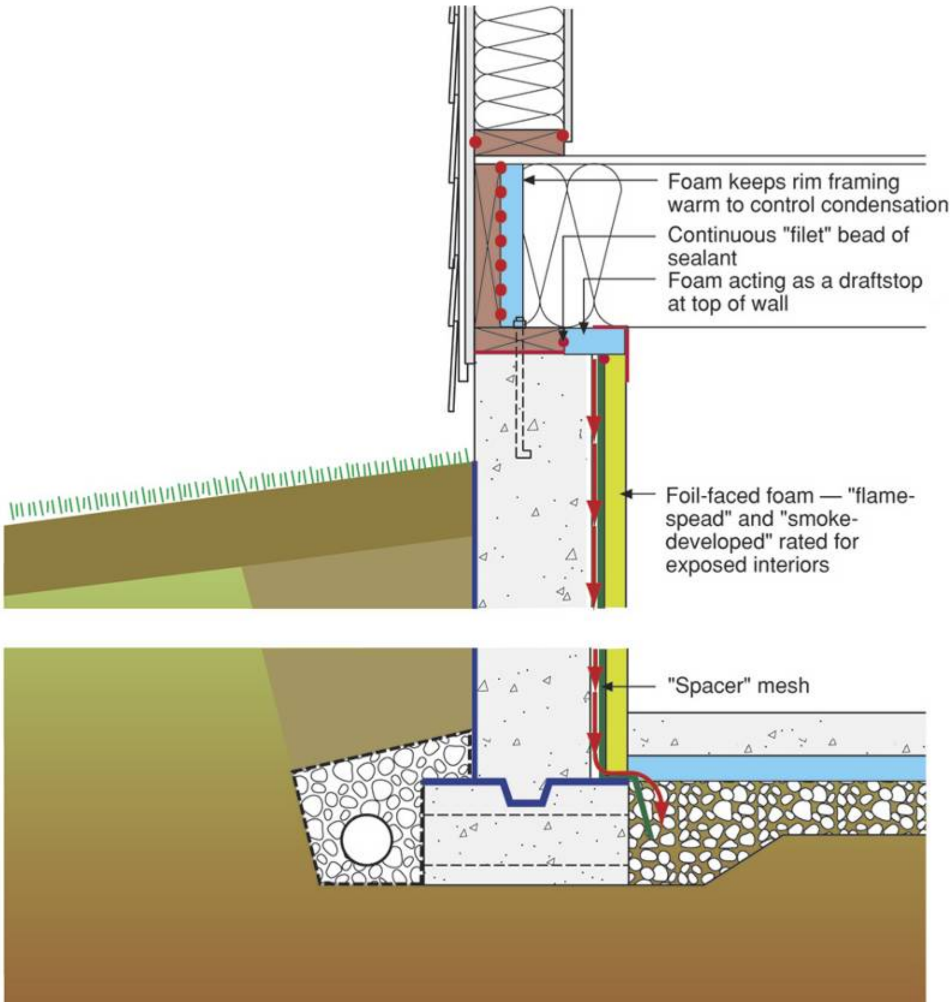

Figure 28. Interior drainage; new or retrofit construction (non-rubble walls)

Note that some foundation materials (e.g., brick) may be subject to increased risk of freeze-thaw damage due to insulation; this should be researched before applying insulation (see Lstiburek 2010, "Thick as a Brick"). However, risks of frost heaving are actually minimal due to directions of heat flow in insulated but heated buildings (see Lstiburek 2010, "Double Rubble Toil & Trouble").

Another technique is to use an exterior impermeable material to minimize rain and groundwater entering below grade spaces, commonly known as an "apron," "skirt," or "ground roof." This detail could be considered a "below grade overhang" for shedding water away from the foundation and preventing soil saturation. This method has the advantage of improving bulk water control of the foundation with minimal excavation (i.e., not down to the footings). Note that it addresses surface water issues, but does not necessarily address ground water, which would need to be dealt with separately using interior drainage systems.

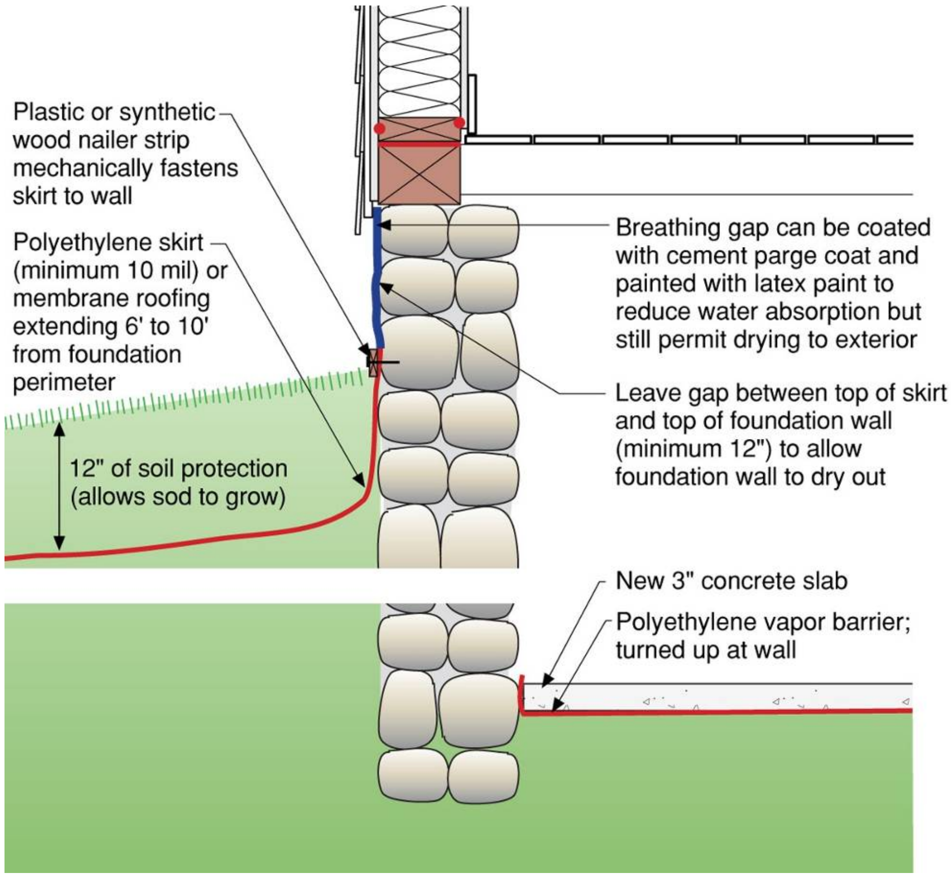

Figure 29. Using an impermeable skirt exterior to foundation

The "ground roof" can be made of polyethylene film or membrane roofing, and is mechanically fastened to the existing foundation. The outer edge can be connected to a drainage system (granular fill, perforated drainage pipe, and filter fabric) which is in turn directed to a sump, storm sewer, or daylight (see Figure 30). Use of additional drainage is of greater value in poorly draining soils.

Furthermore, during the installation, insulation can easily be retrofitted to the foundation, as shown in Figure 30. Of course, if the insulation is being extended above grade, exterior insulation finish details must be resolved (dealing with resistance to weathering, impact damage, insect infestation, and aesthetics).

Figure 30. Impermeable skirt with horizontal insulation and drainage (c/o Petersen Engineering)

3.5 Field Inspection

See previous sections.

3.6 Install Procedure

See previous sections.

3.7 Verification procedures and tests

See previous sections.

Critical Takeaways

Roof runoff must be kept away from foundations, by use of roof overhangs, gutters/eavestroughs & downspouts, and drainage swales.

Exterior grading must direct surface water away from the foundation; backfill compaction and utility trenches are critical to ensure settling does not cause a negative grade condition. Impermeable surface soils can also assist in directing water away from the foundation.

Standard foundation "dampproofing" can only withstand minimal hydrostatic head pressure; therefore, foundation wall drainage is critical. This can be done with free-draining backfills, or various synthetic drainage layers (e.g., "air gap membranes").

Footing drains collect water draining from above, and keep ground water levels from rising above the interior floor levels (e.g., basement slab). It is drained to a sump, daylight, or a storm sewer. It should be cross-connected to the sub-slab gravel field for redundancy if clogging occurs over time.

The sump pit should be well-connected to the sub-slab gravel field, to avoid the risk of hydrostatic head pushing water through the floor slab. The outflow must be directed away from the foundation to avoid "recycling" water.

A capillary break at the joint between the footing and foundation wall is required to eliminate moisture “wicking” through the bottom of the foundation wall.

In a retrofit situation, although it is ideal to intercept groundwater with an exterior perimeter drain, this may be impractical or impossible to implement. In such cases, interior perimeter drainage can be used and connected to an interior sump pump. Note that insulation interactions and condensation risks may come into play with retrofit of interior drainage materials.

Another technique is to use an exterior impermeable material to minimize rain and groundwater entering below grade spaces, commonly known as an “apron,” “skirt,” or “ground roof.” This method has the advantage of improving bulk water control of the foundation with minimal excavation (i.e., not down to the footings).Another technique to reduce

Important Definitions

Air Barrier: A term often abbreviated from Air Barrier System or Air Barrier Material. The complete air barrier system is comprised of materials and assemblies, each with their own performance requirements.

Air Barrier Material: A material that has sufficiently low air permeance and adequate strength that it can be part of an air barrier system. Recommended maximum air permeance for a material is 0.02 $l/s{\cdot}m^2$ @ 75 Pa (0.004 cfm/sf @ 0.3 IWC) when tested according to ASTM E 2178 or E 283.

Air Barrier System: Air barriers are three-dimensional systems of materials designed, constructed, and/or acting to control air flow across a building enclosure, or between a conditioned space and an unconditioned space. In multi-unit/townhouse/apartment construction an air barrier system should also separate the conditioned air from any given unit and adjacent units. The pressure boundary of the enclosure should, by definition, be coincident with the plane of a functional air barrier system.

Air Leakage: Uncontrolled and/or unintended airflow through a building enclosure or between units of occupancy. Leakage from indoors to outdoors is known as exfiltration and leakage from outdoors to indoors is known as infiltration. Air leakage can cause indoor air quality problems, condensation, excess energy use, comfort complaints, and smoke transport.

Air-Impermeable Material: An air impermeable material is an air control layer. An air-impermeable material has an air permeance equal to of less than 0.02 $l/s{\cdot}m^2$ at 75 Pa pressure differential when tested according to ASTM E 2178 or E 283.

Air-Permeable Material: An air-permeable material has an air permeance greater than 0.02 $l/s{\cdot}m^2$ at 75 Pa pressure differential when tested according to ASTM E 2178 or E 283.

Basement: That portion of a building that is partly or completely below grade (see “Story above grade”) (ICC 2009)

Basement Wall. The opaque portion of a wall that encloses one side of a basement and has an average below grade wall area that is 50 percent or more of the total opaque and non-opaque area of that enclosing side. (ICC 2009)

Below Grade: The portion of a building that is below the line of the surrounding ground level.

Building Enclosure: The system or assembly of components that provides environmental separation between the conditioned space and the exterior environment. Note: The enclosure is a special type of environmental separator. Environmental separators also exist within buildings as dividers between spaces with different environmental conditions.

Building Envelope: An outdated term for the building enclosure.

Bulk water: water in its liquid form, in this case encompassing rainwater and roof runoff, surface pooling or ponding, and groundwater.

Capillary Action/Capillarity: The movement of water within the confined spaces of a porous material or between two adjoining hydrophilic materials due to the attractive force of surface tension. Only significant in gaps of less than about 1/8" (3 mm).

Capillary Break: A hydrophobic material or non porous material (such as glass, plastic, or metal) or gap between parallel layers of material (often less than 1/16" or 1.5 mm) sufficient to stop capillary action.

Condensation: The change of state from vapor to liquid. A common factor in moisture damage. Occurs on surfaces, which must be cooler than the air containing vapor next to it. Vapor supply to the condensation surface is usually by airflow but can be by diffusion.

Drained/Drainage: A building enclosure rain control strategy (or ground water control) that accepts that some water will penetrate the outer surface (the cladding, which "screens" rain) and removes this water back to the exterior by gravity drainage over a drainage plane, through a drainage gap, and exiting via flashing and weep holes. Many wall systems (lap siding, brick veneer) and sloped roof systems (metal, asphalt shingles) employ drained strategies.

Drainscreen: An enclosure system that control rain penetration using the drained approach. See Drained.

Efflorescence: The deposition of dissolved salts in the material (such as concrete or brick) being transported within water (usually by capillary action) on a visible surface after evaporation of the water.

Foundation, Water-Managed: Systems for at or below-grade enclosure assemblies where gravity (drainage) is used to move liquid water away from the structure, relieving hydrostatic water forces.

Freeze-thaw: Damage that occurs to stone, clay, or cementitious products due to high moisture content (near saturation) combined with cycling above and below the freezing temperature. Typically manifested as spalling of the surface.

Grade Beam: A foundation wall that is cast at or just below the grade of the earth, most often associated with the deepened perimeter concrete section in slab-on-grade foundations.

Hydrostatic: A term used to describe pressures developed by a non-moving fluid (typically water, in our cases), such as the buildup of subsurface water against a foundation wall.

Joints: An interface between elements. Joints may be needed to allow for movement of different parts of a building or assembly, or may be required to make construction sequences practical. In all cases, the functional requirements of the enclosure must be maintained the same as for the body of an enclosure element, although aesthetic requirements may be relaxed.

Mold: A type of fungus that is different from plants, animals and bacteria. Molds are decomposers of dead organic material such as leaves, wood and plants. Molds sometimes can infect living plants and animals. The spores and hair-like bodies of individual mold colonies are too small for us to see without a microscope. When a lot of mold is growing on a surface, it often appears black or green. The color of mold is influenced by the nutrient source and the age of the colony. Mold growing on fabric is called mildew.

Penetration: A hole passing through the building envelope in which ducts, pipes, wires, structural elements, and windows are run between inside and outside. Windows are also a penetration.

Ponding: A condition where water stands on a roof, slab, or any other nominally horizontally surface for prolonged periods due to poor drainage and/or deflection of the surface.

Rigid Insulation: Rigid board material that provides thermal resistance. Foam plastic such as EPS, XPS, and polyisocyanurate are commonly used.

Spall: A fragment of material, such as concrete or masonry, detached from a larger mass by a physical blow, freeze-thaw, high levels of compression, or subfluorescence.

Vapor Barrier: A material that has a permeance of 0.1 perm or less. A vapor barrier is a material that is essentially vapor impermeable. A vapor barrier is a Class I vapor control layer. The test procedure for classifying vapor barriers is ASTM E-96 Test Method A—the desiccant or dry cup method.

Vapor Control Layer (or Layers): The component (or components) that is (or are) designed and installed in an assembly to control the movement of water by vapor diffusion.

Vapor Impermeable: Materials with a permeance of 0.1 perm or less (rubber membranes, polyethylene film, glass, aluminum foil). A Class I vapor control layer.

Vapor Permeable: Materials with a permeance of greater than 10 perms (housewraps, building papers).

Contractor/Homeowner Safety

[DOE] US Department of Energy (August, 2010). "Workforce Guidelines for Home Energy Upgrades." Washington, DC: US Department of Energy, 632 pp. (see section 7, page 331 is entitled "Crawl Spaces and Basements" and refers to safety procedures for workers who have to deal with those spaces)

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Appendix A: Prescriptive Measure Checklist

This checklist outlines key points for foundation bulk water control measures for basements, crawl spaces, and slabs on grade.

Table 1. Basement Measures Checklist

Strategy	Sub-Tasks/Recommendations
Above grade: roof water control	• Use roof overhangs to keep water away from foundation • Collect water from roof and flash roof into gutters/eavestroughs. • Use downspouts to carry water from gutters away from foundation. Do not percolate water into soils adjacent to foundation. • Do not connect downspouts to footing drains. • Certain roof geometries can concentrate water (valleys, roof-wall intersections). Address with this water with impermeable surfaces, additional drainage, surface swales, etc. • As an alternative to gutters, an in-ground surface drainage swale can be used around the perimeter of the building, with water drained away from foundation.
Above grade: grading and landscaping	• Slope site away from foundation; avoid negative grade conditions (water will pool against foundation) • Proper compaction around foundation is critical to ensure that negative grade conditions do not occur later due to settling of fill. Similarly, utility trenches must be addressed to avoid settling. • Consider the use of an impermeable top cap of soil to prevent soil adjacent to foundation from becoming saturated. • Keep plantings away from foundation if possible (risks of overwatering and saturation of soils; risk of hidden negative slope conditions). • Snow accumulation adjacent to the house can cause significant water loading during thawing periods. In addition, snow bank may cause a "dam" condition, trapping bulk water adjacent to the foundation.
Below grade: foundation wall drainage	• Foundation must be dampproofed (or waterproofed), as per code • Backfill with free-draining fill material AND/OR • Install synthetic drainage board against foundation, drained to footing drains (e.g., air gap membrane)
Below grade: sub-slab drainage	• Install granular drainage pad (coarse gravel, ¾", no fines) below slab, and polyethylene vapor diffusion

	retarder. • Cast slab directly onto polyethylene layer (no sand "blotter" layer)
Below grade: footing drains	• Footing drain installed at footing level, drained to sump, daylight, or storm sewer. • Footing drain is wrapped with ¾" granular fill (crushed gravel, no fines), and in turn wrapped with geotextile filter fabric (to avoid clogging of granular fill). • Install 4" diameter (minimum) perforated drain pipe; use 6" diameter pipe in highly draining soils or in cases of exceptional water loadings. • Footing drain cross-connected to granular layer below slab to provide redundant paths back to sump in case of clogging of drains.
Below grade: sump pit	• Sump pit must be well connected to sub-slab granular fill to avoid buildup of hydrostatic head. • Airtight cover is required for sump.
Below grade: capillarity through footings	• Capillary break must be installed between top of footing and foundation wall, to avoid "wicking" of water from footing to interior. • Acceptable materials include asphalt-based coatings (i.e., standard dampproofing), waterproof membranes, cementitious coatings (cement-based waterproofing, polymer modified), latex paint based waterproofing coatings, and silanes/siloxanes.

Table 2. Conditioned Crawl Space Measures Checklist

Strategy	Sub-Tasks/Recommendations
Above grade: roof water control	• Use roof overhangs to keep water away from foundation • Collect water from roof and flash roof into gutters/eavestroughs. • Use downspouts to carry water from gutters away from foundation. Do not percolate water into soils adjacent to foundation. • Do not connect downspouts to footing drains. • Certain roof geometries can concentrate water (valleys, roof-wall intersections). Address with this water with impermeable surfaces, additional drainage, surface swales, etc. • As an alternative to gutters, an in-ground surface drainage swale can be used around the perimeter of the building, with water drained away from foundation.
Above grade: grading and landscaping	• Slope site away from foundation; avoid negative grade conditions (water will pool against foundation)

	• Proper compaction around foundation is critical to ensure that negative grade conditions do not occur later due to settling of fill. Similarly, utility trenches must be addressed to avoid settling. • Consider the use of an impermeable top cap of soil to prevent soil adjacent to foundation from becoming saturated. • Keep plantings away from foundation if possible (risks of overwatering and saturation of soils; risk of hidden negative slope conditions). • Snow accumulation adjacent to the house can cause significant water loading during thawing periods. In addition, snow bank may cause a "dam" condition, trapping bulk water adjacent to the foundation.
Below grade: foundation wall drainage†	• Foundation must be dampproofed (or waterproofed), as per code • Backfill with free-draining fill material AND/OR • Install synthetic drainage board against foundation, drained to footing drains (e.g., air gap membrane)
Below grade: drainage below ground cover†	• Install granular drainage pad (coarse gravel, ¾", no fines) below polyethylene vapor diffusion retarder ground cover. • Cast slab (if used) directly onto polyethylene layer (no sand "blotter" layer)
Below grade: footing drains†	• Footing drain installed at footing level, drained to sump, daylight, or storm sewer. • Footing drain is wrapped with ¾" granular fill (crushed gravel, no fines), and in turn wrapped with geotextile filter fabric (to avoid clogging of granular fill). • Install 4" diameter (minimum) perforated drain pipe; use 6" diameter pipe in highly draining soils or in cases of exceptional water loadings. • Footing drain cross-connected to granular layer below slab to provide redundant paths back to sump in case of clogging of drains.
Below grade: sump pit†	• Sump pit must be well connected to sub-slab granular fill to avoid buildup of hydrostatic head. • Airtight cover is required for sump.
Below grade: capillarity through footings†	• Capillary break must be installed between top of footing and foundation wall, to avoid "wicking" of water from footing to interior. • Acceptable materials include asphalt-based coatings (i.e., standard dampproofing), waterproof membranes, cementitious coatings (cement-based waterproofing, polymer modified), latex paint based waterproofing

	coatings, and silanes/siloxanes.

†: To be done only if interior crawl space floor is below exterior grade. If interior is above exterior grade, these measures do not apply.

Table 3. Slab on Grade Measures Checklist

Strategy	Sub-Tasks/Recommendations
Above grade: roof water control	• Use roof overhangs to keep water away from foundation • Collect water from roof and flash roof into gutters/eavestroughs. • Use downspouts to carry water from gutters away from foundation. Do not percolate water into soils adjacent to foundation. • Do not connect downspouts to footing drains. • Certain roof geometries can concentrate water (valleys, roof-wall intersections). Address with this water with impermeable surfaces, additional drainage, surface swales, etc. • As an alternative to gutters, an in-ground surface drainage swale can be used around the perimeter of the building, with water drained away from foundation.
Above grade: grading and landscaping	• Slope site away from foundation; avoid negative grade conditions (water will pool against foundation) • Proper compaction around foundation is critical to ensure that negative grade conditions do not occur later due to settling of fill. Similarly, utility trenches must be addressed to avoid settling. • Consider the use of an impermeable top cap of soil to prevent soil adjacent to foundation from becoming saturated. • Keep plantings away from foundation if possible (risks of overwatering and saturation of soils; risk of hidden negative slope conditions). • Snow accumulation adjacent to the house can cause significant water loading during thawing periods. In addition, snow bank may cause a "dam" condition, trapping bulk water adjacent to the foundation.
Slab Details	• Install granular drainage pad (coarse gravel, ¾", no fines) below slab, and polyethylene vapor diffusion retarder. • Cast slab directly onto polyethylene layer (no sand "blotter" layer). • Polyethylene vapor barrier is extended up grade beam

	(or thickened slab edge) where it also acts as a capillary break. • Where vinyl flooring (impermeable floor covering) is installed over slabs, a low water-to-cement (w/c) ratio is recommended to reduce water content in concrete (w/c < ~0.45). • If it is known that the slab edge will see wet conditions (e.g., constant watering of plantings adjacent to the foundation), measures to reduce water uptake at slab edge are recommended (e.g., dampproofing, or cement-compatible latex paint to reduce water uptake).

Appendix B: Material Specifications

Air Barrier Specifications

Air barrier systems typically are assembled from materials incorporated in assemblies that are interconnected to create enclosures. Each of these three elements has measurable resistance to airflow. The recommended minimum resistances or air permeances for the three components are listed as follows:

- Material 0.02 $l/(s \cdot m^2)$@75 Pa
- Assembly 0.20 $l/(s \cdot m^2)$@75 Pa
- Enclosure 2.00 $l/(s \cdot m^2)$@75 Pa

Materials and assemblies that meet these performance requirements are said to be air barrier materials and air barrier assemblies. Air barrier materials incorporated in air barrier assemblies that in turn are interconnected to create enclosures are called air barrier systems.

Vapor Barrier/Retarder Specifications

Vapor Control Layer Classes are the measure of a material or assembly's ability to limit the amount of water that passes through the material or assembly by vapor diffusion. The test procedure for determining vapor control layer class is ASTM E-96 Test Method A (the desiccant or dry cup method).

- Class I: Materials that have a permeance of 0.1 perm or less. A.k.a. "vapor impermeable."
- Class II: Materials that have a permeance of 1.0 perm or less and greater than 0.1 perm
- Class III: Materials that have a permeance of 10 perms or less and greater than 1.0 perm

Appendix C: 2009 IRC Excerpts (Foundation Bulk Water Control)

CHAPTER 4 FOUNDATIONS

SECTION R401: GENERAL

R401.3 Drainage. Surface drainage shall be diverted to a storm sewer conveyance or other approved point of collection that does not create a hazard. Lots shall be graded to drain surface water away from foundation walls. The grade shall fall a minimum of 6 inches (152 mm) within the first 10 feet (3048 mm).

SECTION R403: FOOTINGS

R403.3.3 Drainage. Final grade shall be sloped in accordance with Section R401.3. In other than Group I Soils, as detailed in Table R405.1, gravel or crushed stone beneath horizontal insulation below ground shall drain to daylight or into an approved sewer system.

SECTION R405: FOUNDATION DRAINAGE

R405.1 Concrete or masonry foundations. Drains shall be provided around all concrete or masonry foundations that retain earth and enclose habitable or usable spaces located below grade. Drainage tiles, gravel or crushed stone drains, perforated pipe or other approved systems or materials shall be installed at or below the area to be protected and shall discharge by gravity or mechanical means into an approved drainage system. Gravel or crushed stone drains shall extend at least 1 foot (305 mm) beyond the outside edge of the footing and 6 inches (152 mm) above the lap of the footing and be covered with an approved filter membrane material. The top of open joints of drain tiles shall be protected with strips of building paper, and the drainage tiles or perforated pipe shall be placed on a minimum of 2 inches (51 mm) of washed gravel or crushed rock at least one sieve size larger than the tile joint opening or perforation and covered with no less than 6 inches (152 mm) of the same material.

R405.2.3. Exception: A drainage system is not required when the foundation is installed on well-drained ground or sand-gravel mixture soils according to the Unified Soil Classification System, Group I Soils, as detailed in Table R405.1.

R40S.1.1 Precast concrete foundation. Precast concrete walls that retain earth and enclose habitable or useable space located below-grade that rest on crushed stone footings shall have a perforated drainage pipe installed below the base of the wall on either the interior or exterior side of the wall, at least one foot (305 mm) beyond the edge of the wall. If the exterior drainage pipe is used, an approved filter membrane material shall cover the pipe. The drainage system shall discharge into an approved sewer system or to daylight.

R405.2.3 Drainage system. In other than Group I soils, a sump shall be provided to drain the porous layer and footings. The sump shall be at least 24 inches (610 mm) in diameter or 20 inches square (0.0129 m^2), shall extend at least 24 inches (610 mm) below the bottom of the basement floor and shall be capable of positive gravity or mechanical drainage to remove any accumulated water. The drainage system shall discharge into an approved sewer system or to daylight.

SECTION R406: FOUNDATION WATERPROOFING AND DAMPPROOFING

R406.1 Concrete and masonry foundation dampproofing. Except where required by Section R406.2 to be waterproofed, foundation walls that retain earth and enclose interior spaces and floors below grade shall be dampproofed from the top of the footing to the finished grade. [listing of acceptable materials follows]

R406.2 Concrete and masonry foundation waterproofing. In areas where a high water table or other severe soil-water conditions are known to exist, exterior foundation walls that retain earth and enclose interior spaces and floors below grade shall be waterproofed from the top of the footing to the finished grade. Walls shall be waterproofed in accordance with one of the following: [hot mopped felt, roll roofing, PVC, poly, PM asphalt, polymer cement, fiber reinforced cement, synthetic rubber]

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