PART I ONE

FOOTINGS AND FOUNDATIONS

We're going to talk about footings and foundations from a performance standpoint. We're looking to see whether they're doing their job. We are not going to figure out how to design buildings, learn to be soils engineers, or pretend we have x-ray vision.

Like all parts of a home inspection, while there's stuff we can't do, there's lots that we can. Just remember that when we're talking about footings and foundations, we typically see absolutely none of the footings and only part of the foundations.

In this Part you will learn—

- the various foundation configurations
- the different material types used for foundations
- the key components of a foundation and the basics of foundation construction
- the common problems found with foundations
- how to identify these conditions
- the causes and implications of these conditions

CHAPTER 1

AN OVERVIEW OF FOOTINGS AND FOUNDATIONS

LEARNING OBJECTIVES

By the end of this chapter you should be able to:

- list two functions of footings and foundations
- define dead loads and live loads in one sentence each
- list seven common soil types in order of strength
- describe in one sentence how frost can affect foundations
- list three common foundation configurations
- list three common slab-on-grade arrangements
- define in one sentence spread footings, pad footings, pilasters, piles, piers, and grade beams

1.1 THE FUNCTION OF FOOTINGS AND FOUNDATIONS

To put it simply, the function of a structure is to do nothing. The most successful structures stay still. That's the goal of the exercise. Getting slightly more technical, we can look at footings and foundations as having two functions:

Transfer Loads

1. To transfer the live and dead loads of the building to the soil over a large enough area so that neither the soil nor the building will move

Resist Frost

2. In areas where frost occurs, to prevent frost from moving the building

Dead loads are the weight of the building materials and the soil surrounding the foundations.

Live loads include the weight of people, furniture, snow, rain, and wind. Wind may be a vertical force downward, a horizontal force, or an uplift force.

A live load may also be exerted by water in the soil around the foundations (Figure 1.1). Wet soil exerts much more force than dry soil. Frozen soil exerts much more force than wet soil.

Direction of Loads

The weight of objects is caused by gravity and results in a vertical downward load. Wind can be in any direction, as mentioned earlier. The soil exerts forces in all directions, but foundations usually see the horizontal thrust of the soil on the outside of the foundation wall. The forces of frost are also in all directions. Most frost failures in buildings include horizontal movement (foundation walls cracking, bowing, or collapsing inward) and frost heaving (upward movement of the building as the soil under the building expands due to frost) (Figure 1.2).

FIGURE 1.1 Soil Pressure on Foundation Walls

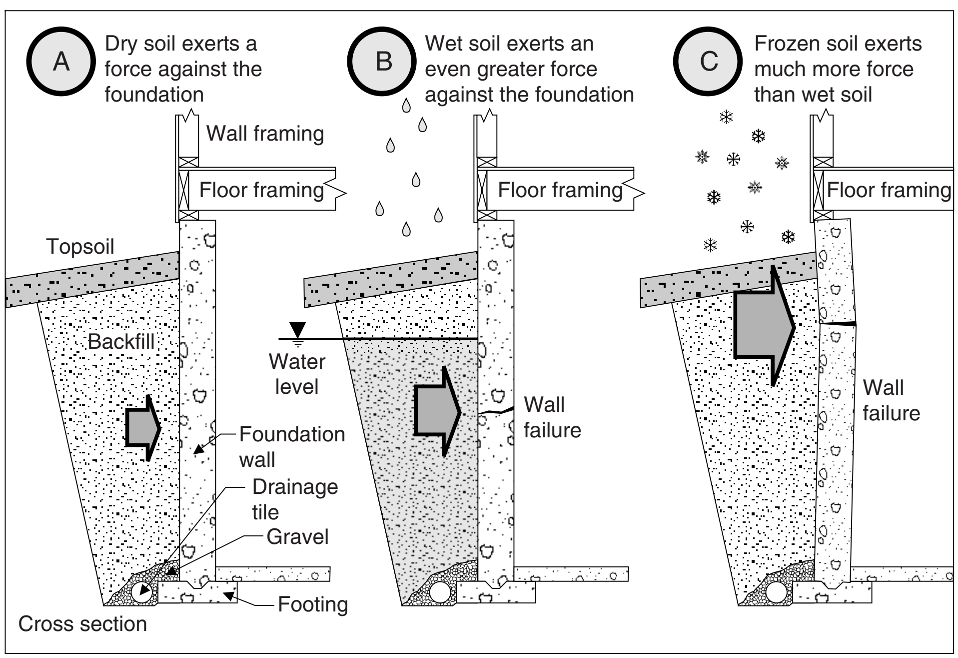
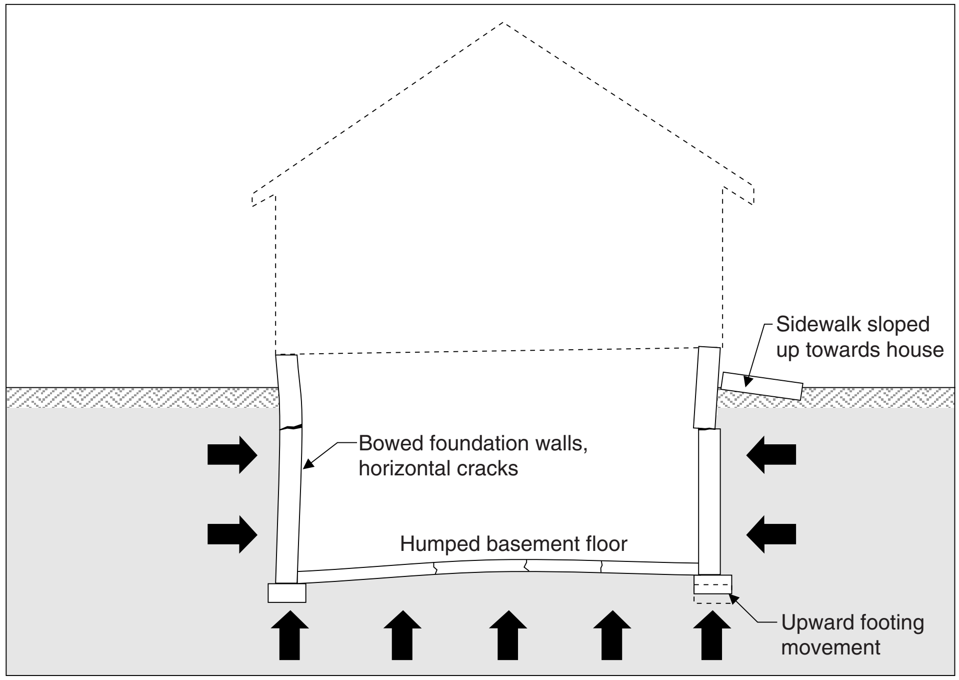


FIGURE 1.2 Evidence of Frost Heaving



1.2 SOILS

Soil Quality Is the Key

Buildings rely on the soil beneath them to stay put. If the soil under the house moves up, down, or sideways, the house is in trouble. Designers of homes may know quite a bit about the soil conditions at a site and may design the building exactly for those conditions. More commonly, soil conditions are assumed to be a certain type, and footings and foundations are designed with a margin of safety to account for adverse soil conditions, within reasonable limits. Occasionally we guess wrong and the building moves, but for an average site, it costs more to find out how good the soil is over the whole site than to design a system that will work on most soils.

Soil Types

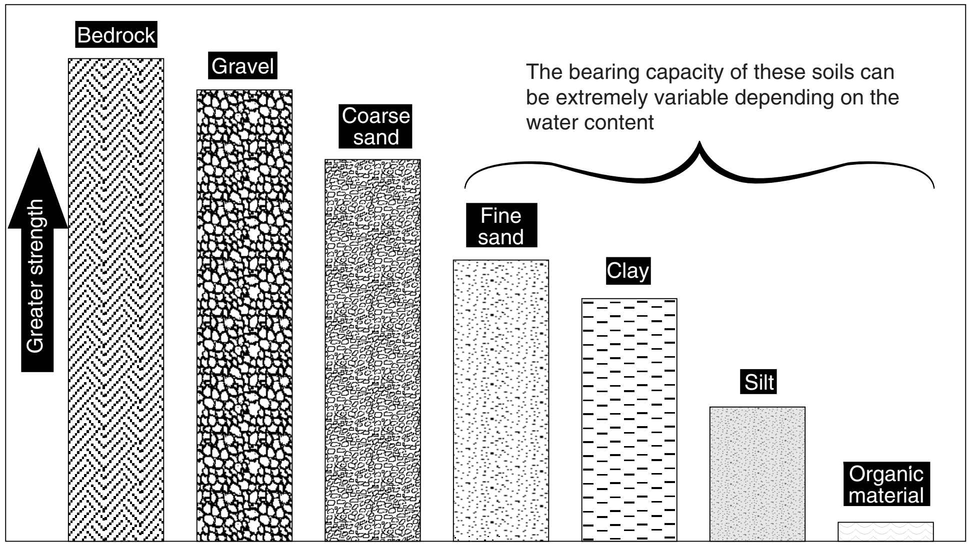
While we won't be talking about any soils engineering or geology, and we certainly don't encourage you to offer soil testing as part of your home inspection, let's just give you some very crude rules and rank **soil types** in order of their bearing capacity (Figure 1.3). You should understand that many soils are a combination of these types, and many building sites contain more than one soil type. The soil profile can change as you move across a site from side to side, and it can change as you go down into the soil. With all those qualifiers, here is a ranking of soil types from strongest to weakest.

Strong

1. Bedrock
2. Gravel
3. Coarse sand
4. Fine sand
5. Clay
6. Silt
7. Organic material

Weak

FIGURE 1.3 Bearing Strength of Soils



With the exception of organic material, all of the soil types can be built on, given appropriate consideration for the soil type.

Again, while it's beyond our scope to get specific, the soil-bearing capacity changes with moisture levels for most soil types, in some cases dramatically.

Function Depends on Location

The function of footing and foundation systems varies with location. Perimeter foundations have to resist the lateral thrust of soil outside the foundation wall. Interior foundations and footings under columns, for example, see more purely vertical loads.

1.3 FROST

The Strategy Varies

Have you ever wondered why there are basements in houses in the northern part of North America but not in the southern parts? Many of you probably know that the answer lies in one word: **frost.** Frost expands soil and exerts tremendous pressure. Frost-induced pressures can lift houses up or push foundation walls in. If you are building in the north, you have to dig down far enough to get below the *frost line*—the depth to which frost penetrates into the soil. That's where the footings should be. The foundations have to be tall enough to extend up through the soil above the grade so that we can put the house on top of the foundation. Since we have to dig a trench for the footings and foundations, we may as well create a hole and use the below-grade space. That's how basements were invented.

Basements Where There's Frost

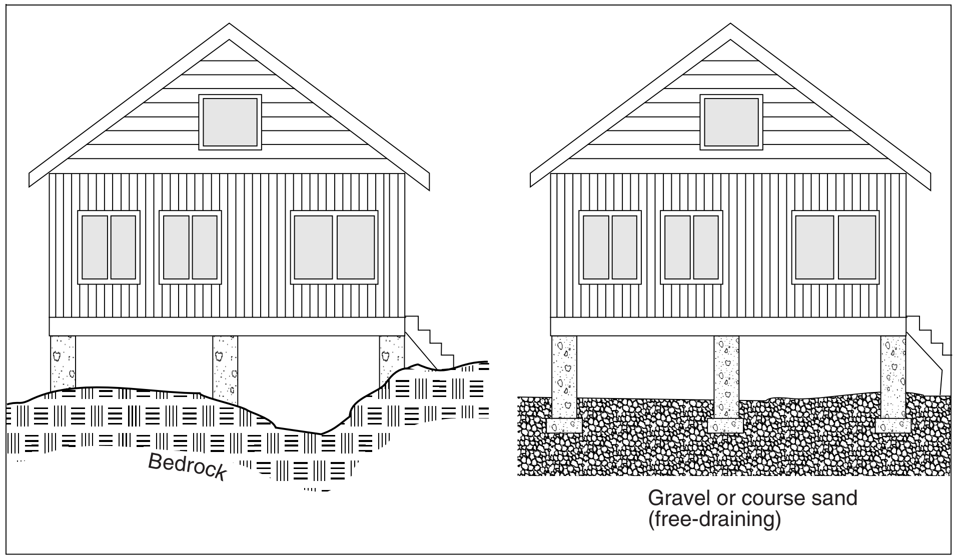
Slab-on-Grade or Crawlspaces Where There's No Frost

If the building is not likely to see frost to any great depth, there's little risk of the building heaving. As a result, the weight of the building can be spread out on footings near the surface. Adding a basement becomes quite expensive. Most of the living space is above grade in areas where frost is not an issue. Incidentally, when we build at grade level in southern climates, we remove the organic soil (topsoil) from the surface, since it is not very stable. While we might scrape off the surface, that's different from digging holes to get below the frost line.

Exceptions

Since this is home inspection, there are always exceptions to the rule (Figure 1.4). If you build on bedrock in frost areas, frost is not an issue and you don't have to put footings down below the frost line. Similarly, if you build on gravel or coarse

FIGURE 1.4 Two Situations Where Frost Heaving Is Very Unlikely



No Frost in Cold Areas

sand that is free-draining, and the water table is far enough down, frost isn't likely to be a problem. Free-draining soils allow the water from rain and melting snow to fall through very quickly, and as long as the water doesn't stick around, it doesn't matter how cold the sand and gravel gets; it won't expand if there's no water in it.

Homes with Basements Need Heat

For those of you who live in frost areas, it's important to understand that once you dig a hole and make a basement, you've got to keep the building heated. We're trying to stop the frost from getting under the building. As long as we keep the inside of the building heated, frost can't get down under the basement floor. As long as the foundations are deep enough to extend below the frost line outside, the frost can't get under the building from the outside either.

Unheated Houses Can Heave

A problem arises when we have a house with a basement that is left unheated over the winter. If the frost depth in an area penetrates 3 to 4 feet into the soil, the footings have to be at or below that depth. An unheated house allows frost to penetrate the soil 3 to 4 feet *under the basement floor*. If there is adequate moisture in the soil, it will heave, picking the whole house up with it, or more commonly, parts of the house (Figure 1.5). Very serious structural damage can result.

1.4 BASEMENTS, CRAWLSPACES, AND SLAB-ON-GRADE CONSTRUCTION

We've just been talking about **basements,** one of the common foundation configurations. **Crawlspaces** are another, which you can think of as short basements. Crawlspaces are used in areas where holes have to be dug to a slight depth to get below organic material or frost depth, but the area is not tall enough to create a basement, or basement space is not desirable. Crawlspaces may be built very similar to basements. They may have continuous perimeter foundations or they may have piers.

The third common configuration is **slab-on-grade** construction. A concrete floor slab is poured at grade level. These slabs may be supported on continuous foundations, piers or piles and grade beams, or grade beams directly on isolated

FIGURE 1.5 Frost Heaving of Unheated Houses

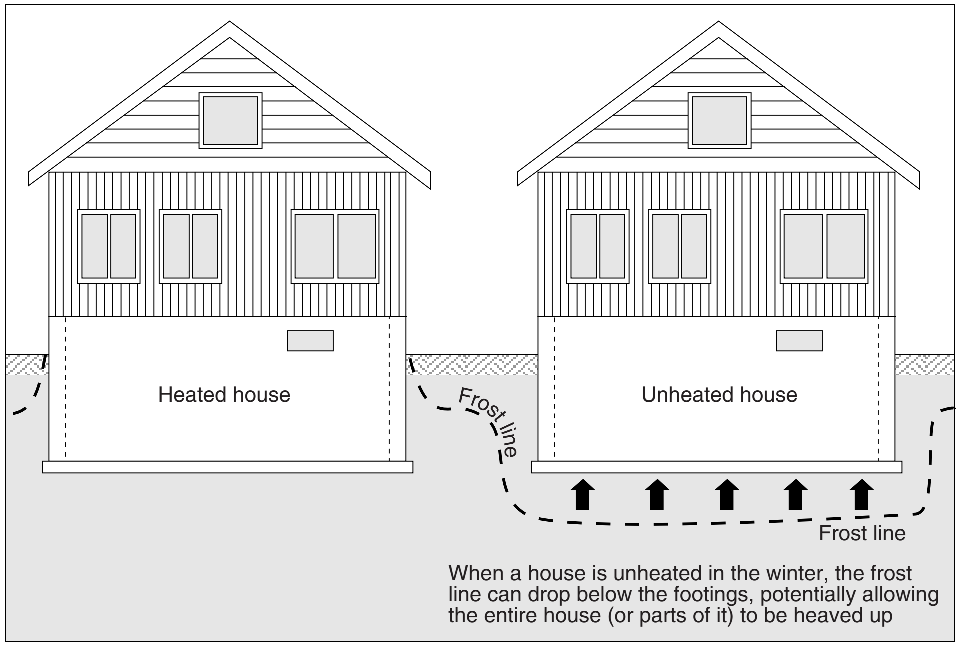
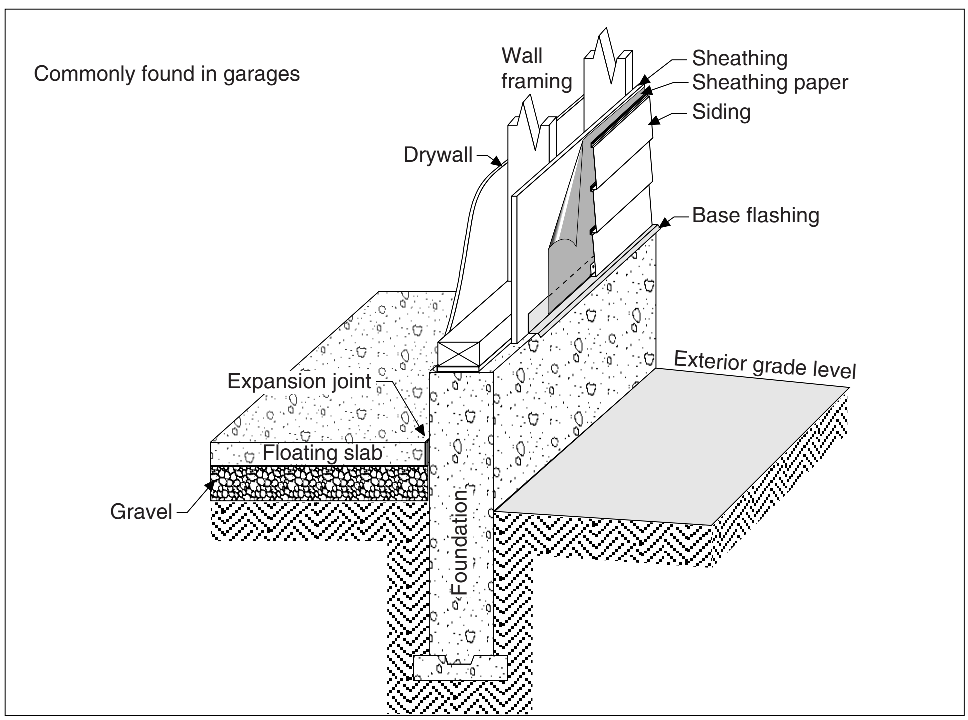


FIGURE 1.6 Slab-on-Grade—Floating Slab



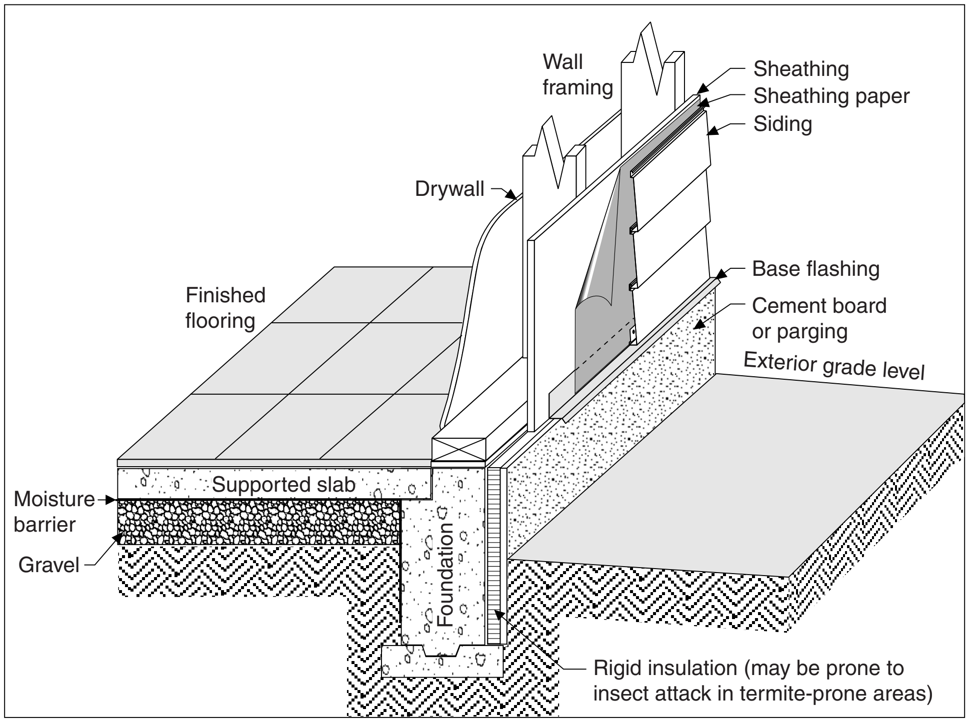
footings, for example. These foundations often serve as the building floor, as well as the support for the house loads.

Floor slabs may be—

Floating

1. Floating—supported by the ground and independent of perimeter foundations (Figure 1.6).

FIGURE 1.7 Slab-on-Grade—Supported Slab



Supported

2. Supported—with the floor slab integrated into the foundation system for the building, in which case the foundations support the slab (Figure 1.7)

Monolithic

3. Monolithic—with the slab an integral part of the footing (Figure 1.8)

Slabs are typically concrete and may be reinforced, depending on how they're built. They may be thickened, typically on the underside, to support the weight of interior load-bearing members such as columns. Alternatively, the column may go through the slab, and a separate footing may be provided for the column.

1.5 FOOTING AND FOUNDATION TYPES

Spread Footings

This leads us to the configuration of footings. Houses may have **spread footings** (strip footings) that support the perimeter walls. These footings are wide pads that are continuous around the perimeter of the house (Figure 1.9). In some cases, the pads may be widened and/or thickened to accommodate concentrated loads from fireplaces, pilasters, etc.

Pilasters

A **pilaster** is a thickening of a foundation wall. It may be thickened to receive the concentrated load of a beam resting on top of the pilaster, or it may be acting as a stiffener to prevent the foundation wall from bowing inward.

Pad Footings

Pad footings are similar to continuous footings except they are usually under a single pier or column. Pad footings spread the load out, usually in a square, with the column or pier sitting in the middle of the square. It's common for houses to have strip footings around the perimeter and pad footings on the building interior under columns.

FIGURE 1.8 Slab-on-Grade—Monolithic Slab

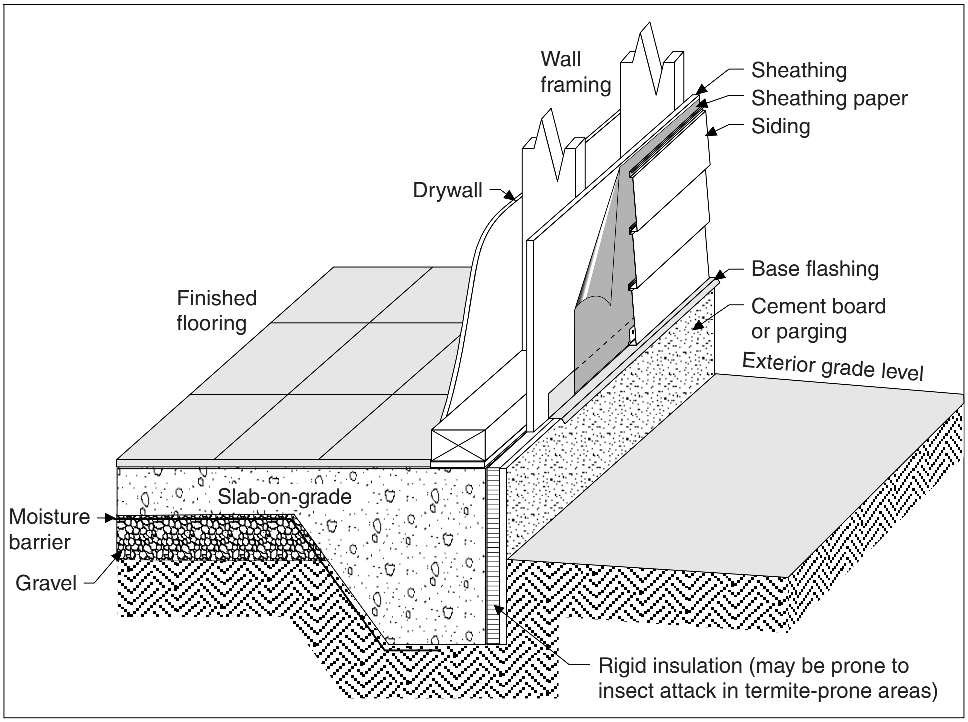
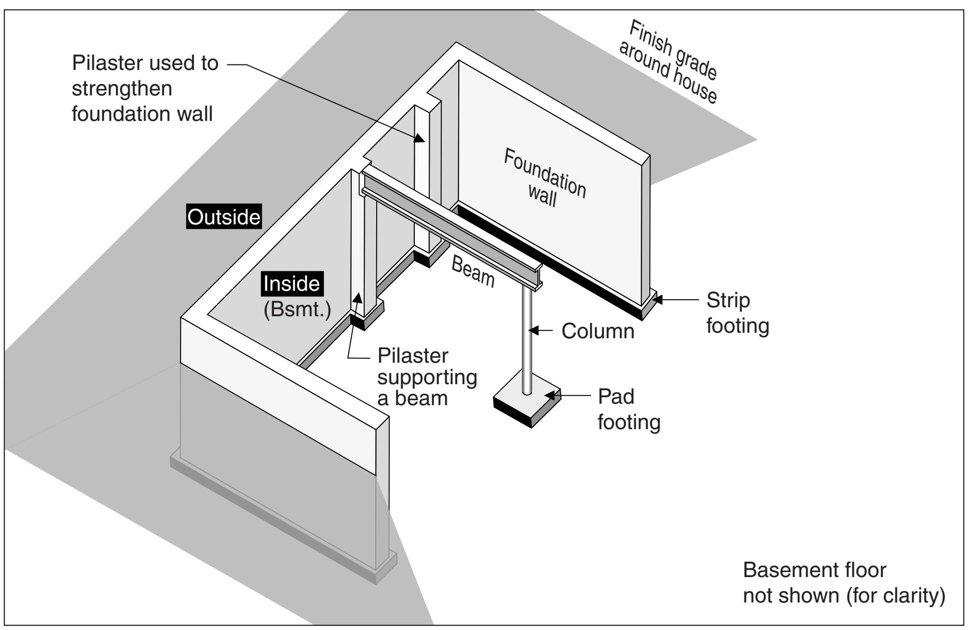


FIGURE 1.9 Spread Footings and Pad Footings



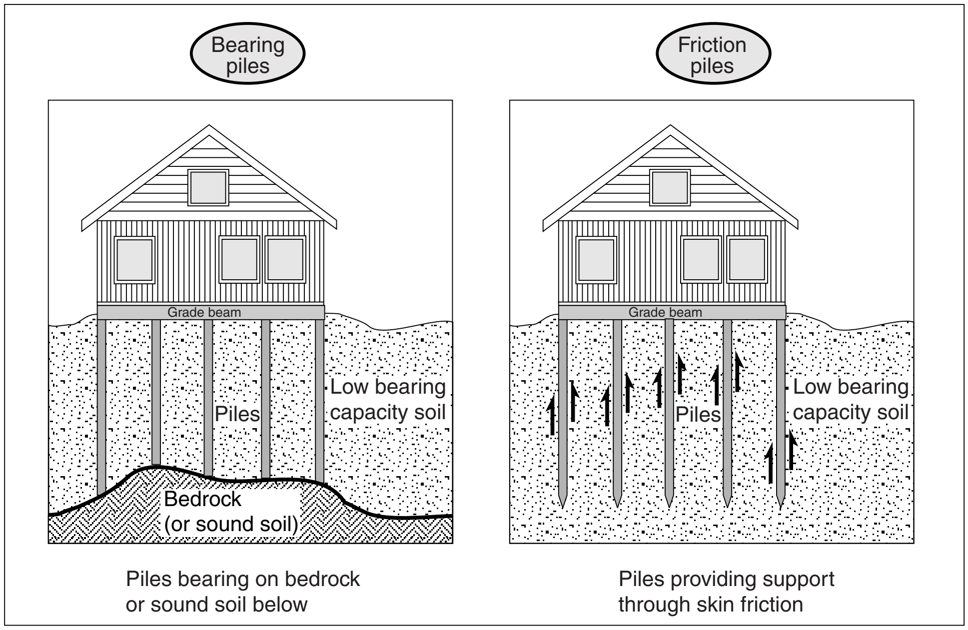
Piles

Piles are typically used instead of footings where the soil quality is poor. They are, generally speaking, more expensive to install and have to be driven into the ground with specialized equipment. They can work one of two ways (Figure 1.10):

End Bearing

1. Piles can be driven down to a point where they bear on bedrock or other sound substrate.

FIGURE 1.10 Pile Foundations



Friction

2. Piles can be driven into soil far enough that the friction of the soil against the sides of the pile is enough to resist any downward movement.

Incidentally, if a house is supported on piles, they probably won't be visible and you may not know it.

Piers

Piers are columns that may be completely concealed in the soil or may project above it. Most of you will be familiar with the piers that are commonly used to build exterior wood decks and porches. These piers may be poured concrete, often with the concrete poured into a cardboard cylinder in a hole dug in the ground. Piers usually, but not always, have footings (Figure 1.11). Piers can either be thought of as posts or columns, or can be thought of as short piles that bear on their ends.

Grade Beams

Grade beams are usually concrete beams that are supported on footings, piles, or piers and are located at grade. In some cases they extend below grade; usually they extend only slightly above grade. Grade beams transfer the loads from the building down to the footings or piles.

Caissons

Caissons are foundation systems created by drilling holes and filling them with concrete. A caisson pile is a cast-in-place pile that has a hollow tube driven into the ground. The earth is excavated from the tube, and concrete is poured into the tube. Some caisson piles are flared out at the bottom to create a larger bearing surface. These are sometimes called bell caissons.

By now it should be clear that footings and foundations are—

- important to the stability of the house
- expensive
- mostly out of sight

Materials

Footings and foundations should be strong so they can transfer loads and durable with respect to exposure from air, water, soil, and insect attack. Most modern footings are concrete (sometimes reinforced). Footings on older buildings

FIGURE 1.11 Pier Foundations

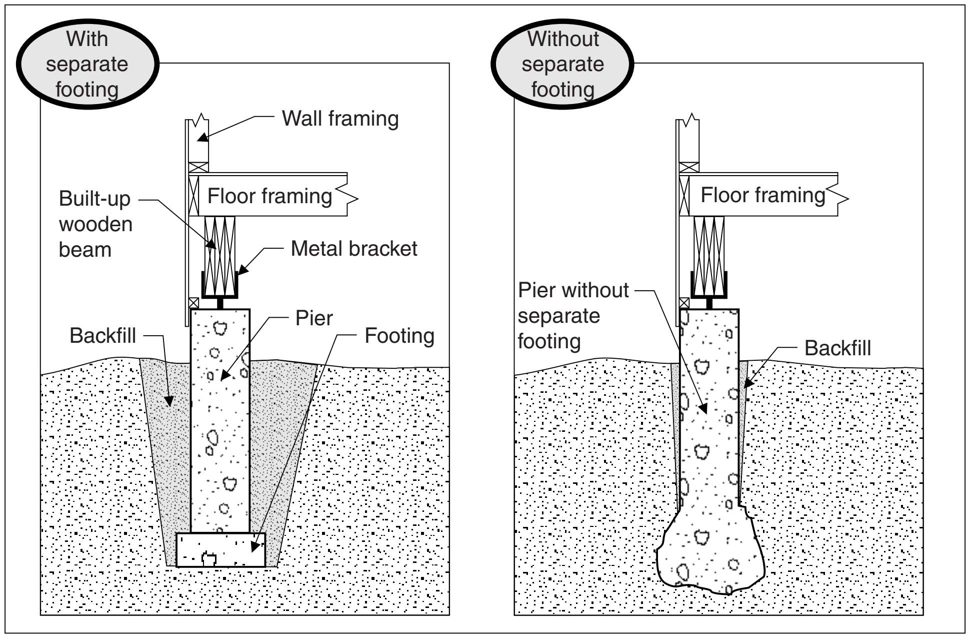
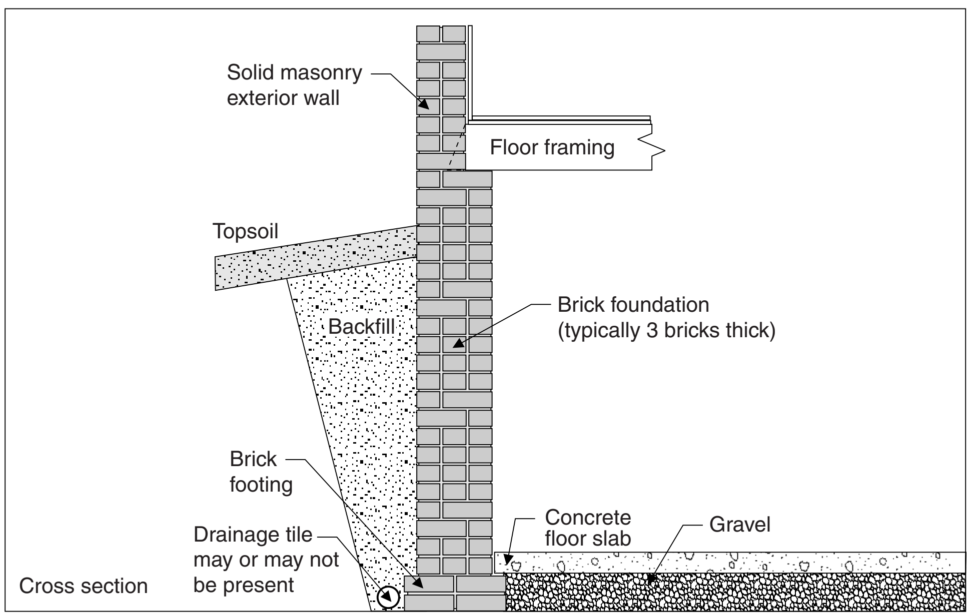


FIGURE 1.12 Brick Foundation with Masonry Exterior Walls



may be brick or stone. While we won't talk much about preserved wood foundation systems, these systems sometimes employ a wood footing.

Foundations

Foundations may be concrete, concrete block, cinder block, brick, hollow clay tile (terra cotta), stone (either dry laid or laid in mortar), or wood (see Figures 1.12–1.14). Wood was common on very old buildings and has become common again to the extent that preserved wood foundations are used.

Piles

Piles are typically concrete, steel, or wood. Again, you likely won't see these.

Piers

Piers might be wood, concrete, concrete block, brick, or stone.

FIGURE 1.13 Stone Foundation with Masonry Exterior Walls

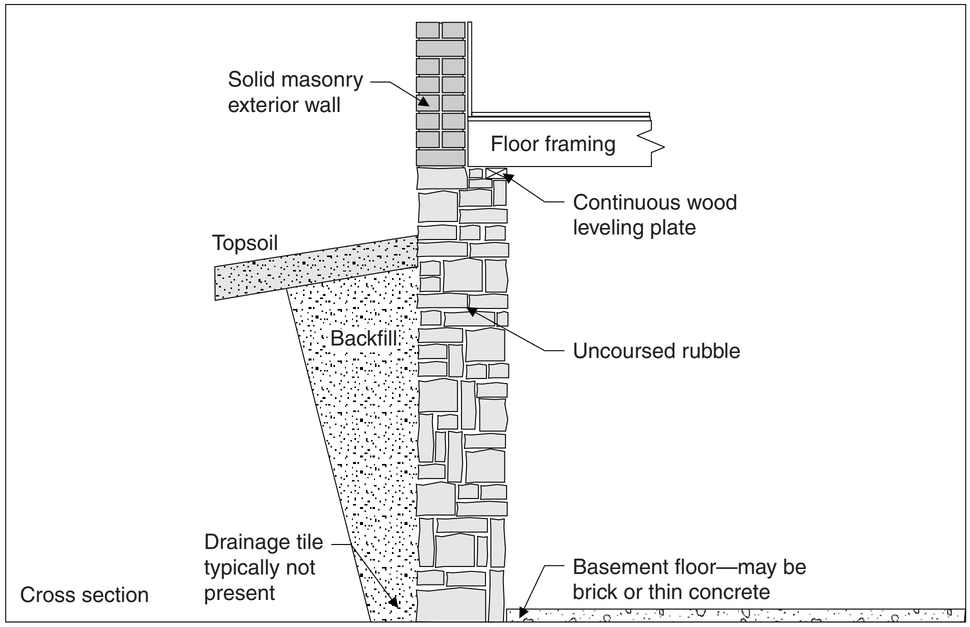
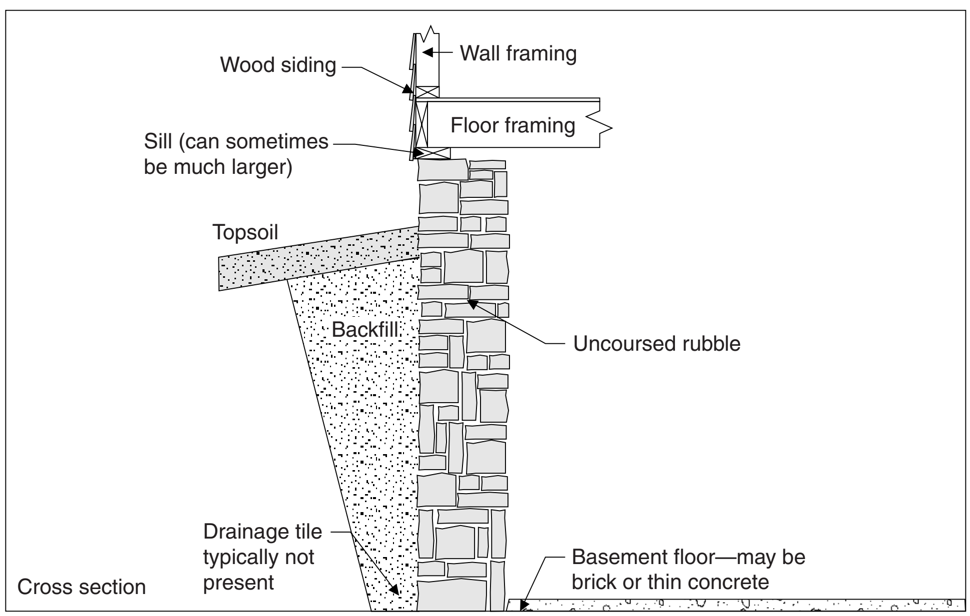


FIGURE 1.14 Stone Foundation with Wood Frame Exterior Walls



1.6 SPECIAL FOUNDATIONS

Raft or Mat Foundations

Raft or mat foundation systems are not common, and you would not usually know that is what you're looking at in the field (Figure 1.15). Their construction materials and failure modes are the same as what we will be looking at, in any case. So we won't go into more detail.

Preserved Wood Foundations

Preserved wood foundations have become popular in some areas over the last few years (Figure 1.16). Wood in a below-grade, damp soil environment has historically

FIGURE 1.15 Raft and Mat Foundations

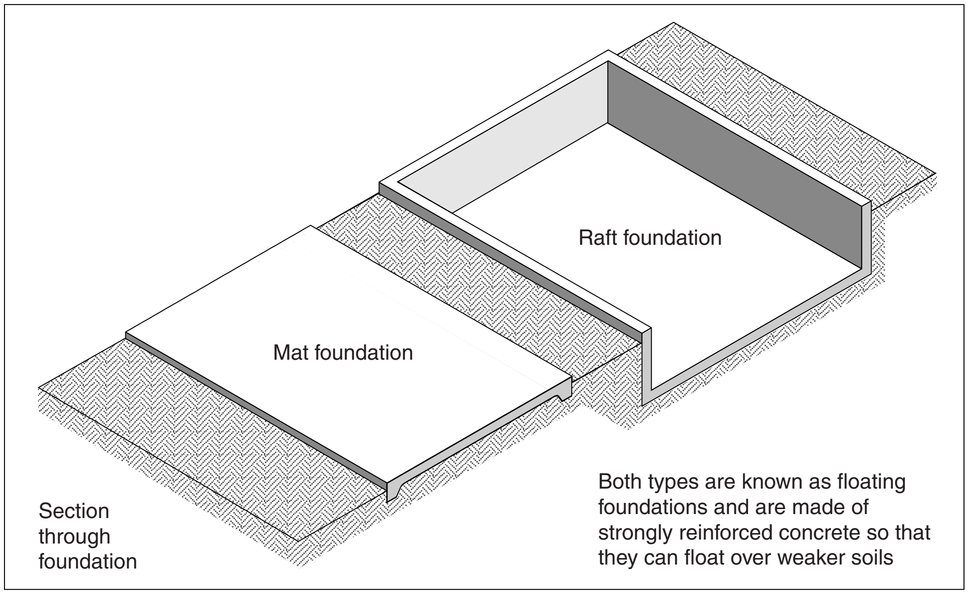
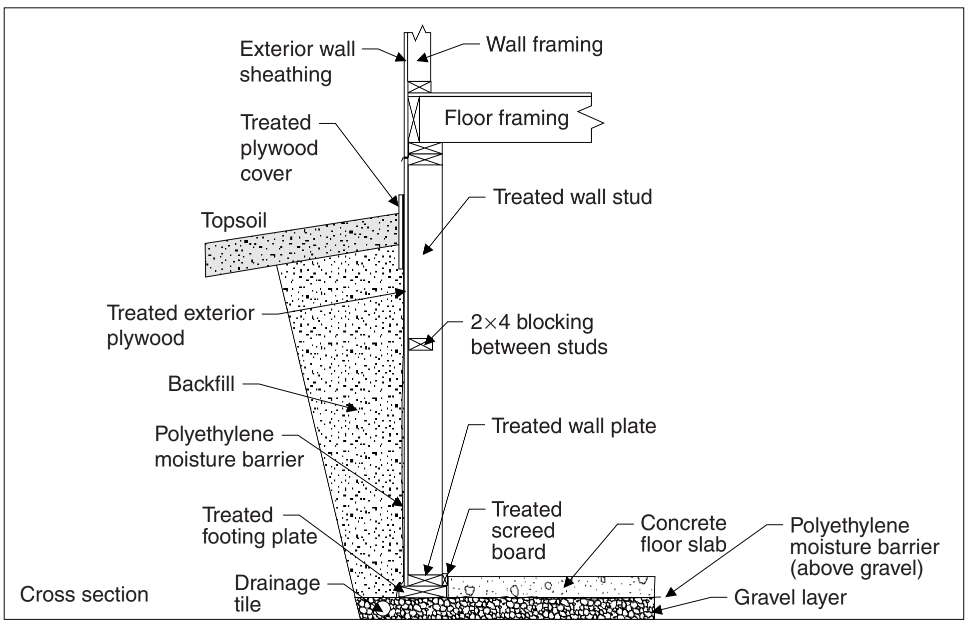


FIGURE 1.16 Preserved Wood Foundations



not had a long life, particularly as a structural member. As a result, there are several design challenges with respect to wood foundations.

Rot and Insects

They are more likely to be successful in dry soils than in wet soils. For the most part, their modes of failure will be similar to what we will look at on most other foundation systems, with a couple of exceptions. Since wood is less brittle or more flexible than concrete, for example, cracking is likely to be less common and bowing may be prevalent. Rot and insect damage are obviously possibilities with wood foundations, while these are not issues with most other foundation and footing materials.

In most cases, the interiors of preserved wood foundations are finished as living space, and it may be difficult to identify the foundation system, let alone inspect it.

Post-Tensioned Foundations

Some areas have expansive soils that make it risky to use conventional footings and foundations. A special reinforcement technique for concrete grade beams and floor slabs is sometimes used to resist the forces of the soil and to prevent differential movement of the structure.

Cables or Tendons

Post-tensioned slabs and grade beams use steel cables or tendons that are laid in place before the concrete is poured. The cables are most often surrounded by a plastic sheathing. After the concrete is poured, jacks are used to pull the cables tight, strengthening the assembly. You may be able to see the anchors and cable ends on the exterior of foundations near grade level. These post-tensioned cables sometimes snap, and in some cases they shoot out from the foundation or come up through floor slabs. Fortunately, this problem is rare, at least so far.

1.7 INSPECTION TIPS

No Access into Crawlspaces

If there is no access to a part of a house structure that you ordinarily would see, this should be a red flag. You should document the limitations to your inspection and make your client understand that you couldn't do everything you normally do. This is important because problems in living spaces or highly visible areas tend to get addressed, whereas those that are concealed tend to get ignored. If you can't get into the crawlspace, chances are no one has been in there. There may be considerable damage or distress that has developed over time. If you fail to make it clear to clients that you couldn't get into a crawlspace, which is important, you'll probably regret it eventually.

Macro and Micro

It's very important to look at the structure from far away and up close. Step back from the house and look at it from every angle. Where possible, line up the walls of the house you're looking at with adjacent houses or structures. Do the corners line up, or is one of the buildings leaning?

Look Inside and Out

You have to look at the outside and inside to complete your structure inspection. In many cases, after having looked outside, you'll see something inside. There is nothing wrong with going back outside to have a second look.

CHAPTER REVIEW QUESTIONS

Answer the following questions on a separate sheet of paper; then check your results against the answers provided in Appendix E. If you have trouble with a question, refer back to the chapter to review the relevant material.

1. What is the function of a footing? Of a foundation?
2. List the three common foundation configurations and footing types.
3. What is the difference between a spread footing and a pad footing, and where would each be used?
4. Several different materials can be used to make a foundation. List as many as you can.

5. As long as the footing is below the frost line, it is not a problem to let the temperature in the basement go below freezing.

   True False

6. Why is it critical to document how the crawlspace was inspected?
7. Explain the difference between a live load and a dead load. Give examples.
8. What is the difference between a pilaster and a pier?
9. When a foundation is supported on piles, are the piles typically visible for inspection?

KEY TERMS

transfer loads
live load
dead load
frost
soil types
basement
crawlspace
slab-on-grade
spread footing
pilaster
pad footing
piles
piers
grade beams
caissons
raft foundation
mat foundation
preserved wood foundation
post-tensioned slabs