Avoiding Foundation Failures

by Robert Marshall

Soil tests and good drainage are the best protection against settlement and frost heave

Liability and repair costs for foundation failures can wipe out a builder's business. As an expert litigation witness and job-site trouble shooter for the Ontario New Home Warranty Program, I've seen cases where the cost of a single claim exceeded the total cost of the home.

Most builders fail to recognize that the soil surrounding a foundation is responsible for the majority of foundation failures. Even foundations built with good materials and first-rate workmanship will fail if poor soil conditions are not considered.

The five leading causes of foundation callbacks, listed in order from the most to the least frequent, are

1. Frost-related damage
2. Settlement problems
3. High water-table problems
4. Leaky basements
5. Soil contaminant problems

Preventing Frost-Damaged Foundations

Water expands in volume by about 10% when it freezes, and can exert pressures of up to 80,000 pounds per square foot as it expands. If wet soil below a footing is allowed to freeze, significant heaving will occur, causing damage to the structure above.

For frost heave to take place, three conditions must be present: a frost-susceptible soil, a source of water, and freezing temperatures. Eliminate any one of these conditions and you'll eliminate frostheave.

To avoid frost heave in colder climates, footings are placed below the frostline. But this alone doesn't prevent frost problems altogether.

Adfreezing

Severe damage to the foundation wall can result from *adfreezing*, or side grip, of the soil to the wall (see Figure 1, next page). This phenomenon happens much more frequently

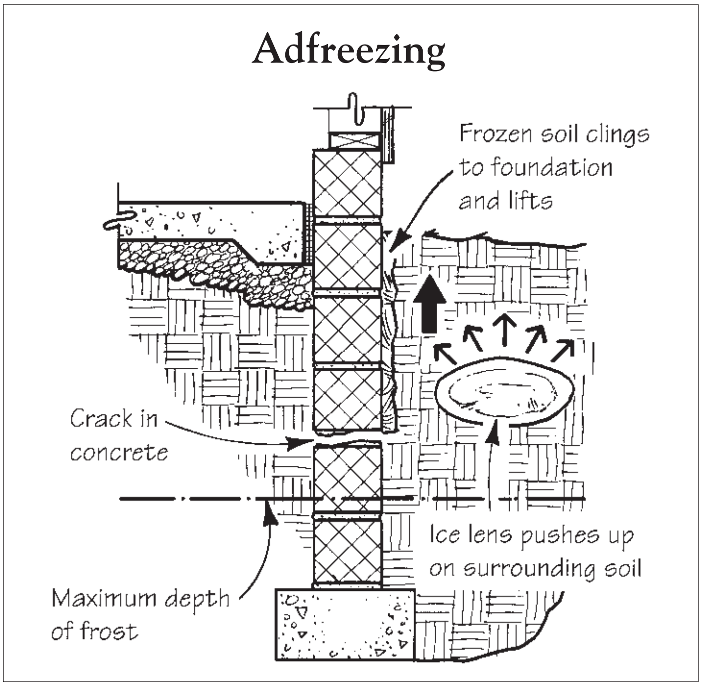


Figure 1. *As the soil around an unheated building freezes and expands, it can "grip" the foundation and lift the wall apart (left). Although block walls are particularly susceptible, poured concrete walls can also be damaged (above).*

in unheated buildings, like garages (Figure 2). As the soil surrounding the wall freezes and expands, it exerts an upward thrust on the foundation walls, which can result in costly damage.

Since soils such as clay, fine sands, tills, and silts are susceptible to frost action, they should not be used to backfill around unheated structures.

A practical method that prevents adfreezing is to provide a "slip plane" at the surface of the foundation wall. Many builders create this slip plane by placing two or more layers of 6-mil construction-grade polyethylene between the soil and the surface of the wall. The durability of polyethylene has improved dramatically over the past few years, and the builders I've talked to have reported good results.

Pier or sonotube foundations are a cheaper alternative for seasonal homes in my area. Since these foundations are even more susceptible to adfreezing, it's critical that a slip plane be provided.

Uninsulated basements will leak enough heat to keep the surrounding soil from freezing. However, placing insulation on the interior of basement walls may prevent this heat leakage and contribute to adfreezing. The only instances of this full basement adfreezing that I've observed have occurred where concrete block walls were used. Again, two layers of 6-mil poly on the exterior of interior-insulated foundation walls will prevent this type of adfreezing from occurring.

Other frost-related problems can occur when improper winter construction methods are used. If a foundation is built in subfreezing weather and the soil below the footings (or surrounding the walls) freezes, frost heave can effectively destroy the foundation. If you can't avoid building during winter conditions, be sure to protect the foundation and keep the temperature in the basement above 40°F.

Figure 2. *Unheated garages are prone to damage from adfreezing (left). Two layers of 6-mil polyethylene placed on both sides of the foundation wall provides a slip plane that prevents freezing soils from bonding to the foundation wall (right).*

Preventing Settlement Problems

Most settlement problems are caused by "problem" soils — soils that do not have the bearing capacity to carry structural loads without specialized engineering design (Figure 3). These soils are typically soft clays, including volatile, expansive, and leda clays.

If there are *any* doubts about the suitability of the soils where you intend to build, make a call to a geotechnical consultant. These experts are often aware of "problem pockets" in the region and can advise you how to proceed with a soils investigation. The Soil Conservation Service is another source for soils information.

Soft clays can often be recognized by probing with a piece of rebar: If soft clay is present, the rod will penetrate the soil easily. Builders should also note any unusual soil profiles or signs of soft clay uncovered during excavation. Keep in mind that in some cases the soil observed in the excavation may be adequate, while the underlying soil may be a soft clay or contain some other buried monster.

If a problem soil is discovered or suspected during excavation, have a soils engineer dig an auger test hole to check the underlying soil within the house excavation. A possible alternative to the auger test hole is to have a backhoe excavate outside the house foundation area. These tests can determine soil strength, which is critical for the proper design of your foundation.

Once the soil strength is determined, engineered footings and the foundation can be designed. Solutions may include a raft or pile foundation, preloading of the site to consolidate weaker soils, or the use of engineered fill.

These measures may add $4,000 to $5,000 to the cost of the foundation, but I consider that a good buy. I've seen situations where it cost more than $60,000 to repair improperly built foundations on problem soils.

Figure 3. *The foundation of this factory home (left) was built on unstable soil. Settlement caused extensive foundation damage (middle), which required complete excavation and engineered underpinnings (bottom).*

Poorly Compacted Fill

Seventeen percent of the foundation problems our organization has been involved with were due to improperly compacted fill material. Soil that is too wet or too dry will not compact properly. Builders should bring in a qualified engineer who will advise (and document) proper compaction techniques.

Be aware that when a foundation hole is "overdug" and excavated soil is returned to the foundation hole to raise the final level, the same compaction rules apply. Whenever possible, avoid using excavated material to raise the level of a foundation hole. By pouring thicker footings or building taller foundation walls, an engineered solution can sometimes be avoided.

High Water Tables

A high water table may result in insufficient foundation support. Excavations below the water table will create a wet hole, which will lead to poor-quality concrete in the footings. If gravel fill is used, the migration of fines will cause foundation settlement.

To avoid the problem, check the local groundwater levels and always build above the groundwater table. If disturbance does occur in the foundation soil, do not dig deeper, as additional hydrostatic pressures will occur, causing further loosening of soil. In these cases, consult a geotechnical engineer.

Some areas have a seasonal water table that is highest in the spring and lowest in late summer. In these areas, it's important to establish an "average" water table, and base building decisions on that.

Soil Contaminant Problems

Radon is a carcinogenic soil gas that must be considered when designing a foundation. Builders in areas with high radon levels may have to change construction methods to guard against this troublesome gas. If you're unsure about the radon levels in your area, check with the EPA to find out what zone the home you're building is in.

Building Leakproof Basements

Building a dry basement starts with an adequate foundation drain system and ends with proper site grading, and there are many important details in between. Builders who fail to pay attention to these details run the risk of an expensive callback if the basement leaks.

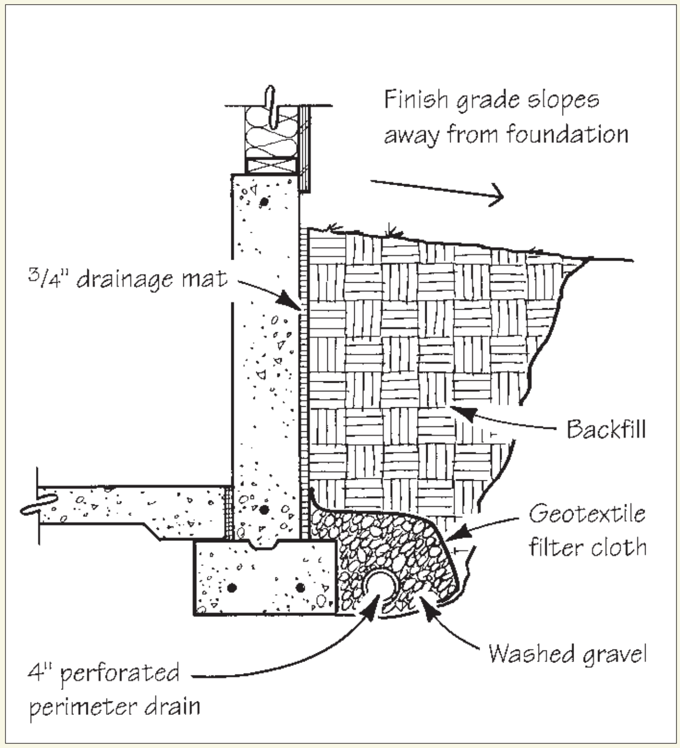
Perimeter foundation drain. No house should be without one. The drain should be covered with at least 6 inches of washed stone and protected with a geotextile filter cloth to prevent the drainpipe from becoming plugged with silts in the soil.

Foundation wall treatment. Applying a waterproofing treatment to the foundation wall or a drainage layer at the wall surface is a must in any areas that have poorly draining soils. This drainage layer can be a 3/4-inch layer of mineral fiber insulation (see photo, below), an air gap membrane, or a free-draining backfill material, such as gravel. This establishes a "path of least resistance" that directs water to the drain system rather than towards the interior of the basement. In areas with a high water table, foundation waterproofing requires an engineered design that will resist hydrostatic pressure.

Proper backfilling technique. Heavy machinery should keep its distance from the foundation wall when backfilling, and safe backfill heights should not be exceeded. Failure to observe these rules can result in overloading the foundation wall, causing it to crack (a difficult detail to waterproof). Basement window wells should have a 4-inch drainpipe tied into the perimeter foundation drain.

Final grading. Surface grades should be directed away from the house, with a minimum drop of 6 inches for the first 10 feet. Sites with steep slopes should have drainage swales "cut in" to direct surface water around the house.

— *R.M.*



Always install a foundation drain, covered with a minimum of 6 inches of washed gravel, and followed by a filter fabric. A waterproofing treatment or drainage layer (left) should be applied to the foundation wall, and a clay "cap" should top off the backfilled area. To direct any runoff away from the house, perimeter grading should have a minimum slope of 6 inches in 10 feet.

Radon abatement measures typically include a perforated piping system placed in a sub-slab gravel layer and a vent stack rough-in. If radon levels are too high after the house is finished, the piping and exhaust venting are completed and a fan installed to depressurize the sub-slab area.

Other contamination sources tend to be regionally specific. Builders should educate themselves about the potential problems that exist in their building region.

In my area, deposits of methane-producing peat are occasionally encountered that can generate explosive levels of the gas. Alkaline soils sometimes require a sulfate-resistant cement to be used during construction.

Get Accurate Information

The best no-cost measure for preventing foundation problems is to look at any available soils maps and to check with municipal planning/building departments before starting the job. On larger projects, seek out any geotechnical reports that may have been provided by the developer. The soil type and water table levels are usually analyzed before a subdivision goes in. Geotechnical consultants often have a database of local soils, including known problem areas and radon pockets. Look for a proven track record from the consultant and make sure he or she has liability insurance.

Make sure all geotechnical reports and foundation inspections are certified by a geotechnical engineer and in compliance with local codes. This can be valuable information to present to the home buyer.

In the absence of expert information (or in addition to it), local well drillers and — in more rural areas — farmers have a wealth of knowledge about local water table levels and soil types. The important point is to collect this information as early as possible in the building design process to avoid costly problems or delays. ■

Rob Marshall is a civil engineer and building science specialist in Ontario, Canada. Photos courtesy of Ontario New Home Warranty Program.