FAILED FOOTINGS & BUCKLED WALLS

by William Rose

Know thy dirt — lest it spring any unpleasant surprises

During dry spells, expansive clay soils shrink and pull away from the foundation wall.

Soil is the universal building material; every building has some. Some soil is good, some is bad. My apologies to builders who have to blast foundations out of granite and to those who have to use houseboat technology for shifting soils. The emphasis here is on basements and crawl-space foundations in dirt.

There are two building problems associated with soil that are prevalent in our area (central Illinois) and deserve to be mentioned: crawl-space additions, and basement wall buckling.

Crawl-Space Additions

Crawl spaces attached to basement homes can have a strange but substantial form of failure. Home inspectors in this area have learned to look for it. It goes like this: If water from the downspouts tends to deposit directly at the foundation, *and* if there is a discrete place for the water to go, such as a footing drain, then the water will take the straightest, lowest path between the two points (see Figure 1.) That path is the underside of the footing. In many cases, we've seen sections of crawlspace footings hanging in midair because soil beneath had eroded by this process. Solution: Direct the rain discharge well away from the crawl-space foundation and slope the backfill to provide good drainage away from the foundation at grade.

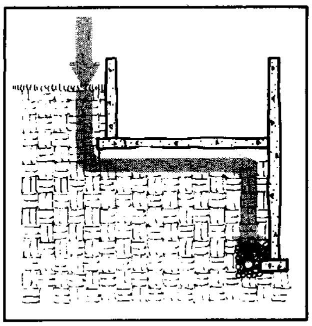


Figure 1. *Water takes the path of least resistance. In this case, the path was under the crawl-space footing to the lower footing drain. This process has undermined many crawl-space footings and left them sitting on air.*

Know Your Dirt

What does a builder do when confronted with a new site? To read the CABO building code, you'd think that live and dead loads just stop once they get to the footing. Of course, residential loads are small compared to those for tall buildings. Still, the loads go somewhere. The soil characteristics that are important and desirable for building foundations are workability and non-compressibility. The soil should also resist erosion, frost heaving, and swelling. Plus, permeable soils permit the use of septic tanks.

Soils are confusing not only because they are inherently varied and complex, but soil scientists didn't accept a Uniform Soil Classification until 1952, and some of the old classification methods still linger. It used to be that "silts" referred to soil particles greater than .005 mm and "clay" particles were any smaller than .005 mm. Now silts and clays are the same size, but with different dry *strength* and *plasticity* (see glossary).

The principal soil classification distinguishes among gravel (G) sand (S), silt (M), clay (C) and organic (O). These distinctions are the best determinants of the engineering properties of soils.

Old government documents explain one method for distinguishing between sands, silts, and clays. It's the "teeth test" *(Engineering Soil Classification for Residential Developments,* Federal Housing Administration, August 1959, honest!) The test "consists of biting a portion of the sample between the teeth. Sand feels gritty whereas silt and clay do not; clay tends to stick to the teeth while silt does not."

The method adopted by ASTM (American Society for Testing and Materials) is still pretty low-tech. but more hygienic. Gravels are rock particles which do not pass through a sieve with 4.75 mm openings. Sand will pass through bit will be retained by a .075 mm sieve. Whatever passes through the .075 mm sieve is called "fines" – either silt or clay. Basically silt is like flour and clay is like putty.

Two methods are used to distinguish silts from clay – dry strength and plasticity. To test dry strength, oven dry a sugar-cube size sample in an oven, and see what pressure it takes to make it crumble. Silt crumbles easily after drying while clay remains hard and tough. The plasticity test is more fun. Add water to the sample and try to roll the sample into a "snake" 1/8 inch in thickness. Silt won't roll, wet or dry. If you manage to roll out a good snake, but then find that you can't reconsolidate the sample, it's a lean day (CL); if you can mush it back up and reroll, the clay is fat (CH).

Officially, a plasticity index is assigned to the sample based on its snakeability and that result is used together with a liquid-limit test (a grooved sample in a mechanical spoon is tapped until the groove closes) and plotted on a chart.

Gravel and sand are superb building foundation materials. They are workable and incompressible. They are also extremely permeable, which helps drainage and septic tank performance. However, permeable soils may also be more permeable to radon.

Silts can be quite troublesome. They are often found in wind-blown (aeolean) loess. Dry, loose silts (rock flour) can be unworkable and undependable, and may flow like a liquid when wet. One poor homeowner near a high water table installed a sump pump without filter fabric to dewater his basement and very cheaply excavated four tons of silt from directly beneath his footings. Silt deposits are the soil's most susceptible to frost heaving. Erosion, too, can be a major problem with silts. A tilting silt stratum can sheer and take everything above it on a ride downhill. Pure silts are hard to find; they often occur with some clay which acts as a binder.

Clays can be troublesome as well. If the moisture content in the soil remains about constant, then they can be stable, moderately incompressible and workable. But if the moisture content changes and goes through fluctuations from wet to dry, then clays can put a foundation through its paces. Certain clays expand when they are wetted, and this can exert enormous forces – lateral and upward – for which residences are not designed.

Organic soil is usually detected by smell and color. If the soil is brown, then the sample should be heated to see if an "organic" odor is given off. Of course, the soil layer that is of concern here is the subsoil, the soil beneath the topsoil.

Classifying soil is a little like classifying movies. Gravel and sand (GW, GP, GM, GC, SW, SP, SM, SC) are fine for general consumption; low compressibility silts and clays (ML, CL) may need a little supervision; organics and highly compressible silts and clays (OL, OH, MH, CH) should have restricted use – they could do violence or expose parts of the house; and peats and mucks – the real raw stuff – is x-rated material.

Soil classification is only a starting point for site analysis. Height of the water table, site drainage and infrastructure of the soil are every bit as important as particle size,

On all sites you should control the moisture content with proper drainage and downspouts. Anticipate soil movement and bearing strength. Get to know your soil (and don't forget to brush your teeth).

Glossary

clay: fine soil with high dry-strength and high plasticity

compressibility: a soil characteristic usually determined by measuring its deflection under a load over time

dry strength: ability of a soil to remain consolidated (stuck together) when dried

gravel: broken rock particles which are retained in a 4.75 mm sieve

horizons: upper layers of soil

loess: soil deposited in place by wind

permeability: ability of a soil to drain liquid water, measured with percolation tests

plasticity: ability of a soil to remain cohesive when deformed (can be formed into snakes)

sand: soil particles retained in a .075 mm sieve

silt: fine soil with low dry-strength and low plasticity.

Basement Wall Buckling

A common form of basement damage in our area is wall buckling. A horizontal crack forms about a foot beneath the soil grade, often at the level of the bottoms of the windows (see Figure 2). Near the corners of the room the crack takes a stepped jag up or down or both, since the wall cannot buckle here. The crack is the sign that the wall has bowed inward, and the amount of bowing can be checked with a straightedge.

We knew that the buckling was related to the clay soils in the area. But to say that the clay soil caused the inward buckling is a little like saying sex causes babies – we're describing the conditions without describing the mechanism. Or what to do about it.

So to better understand the mechanisms involved we excavated the soil around a few basements that were collapsing inward. We found that the soil in direct contact with the foundation wall contained a different composition and color than the soil 2 inches away. The soil against the wall appeared identical to the upper 3-inch layer of soil. This top layer of soil appeared to dip down in a 1/2-inch-deep band along the foundation wall for about 2 feet (see Figure 2). This finding helped us understand how and why the bulging occurs, and what to do about it.

Here's how the mechanism operates. In a dry spell the soil shrinks. It shrinks away from the foundation wall, forming a vertical crack all the way around the

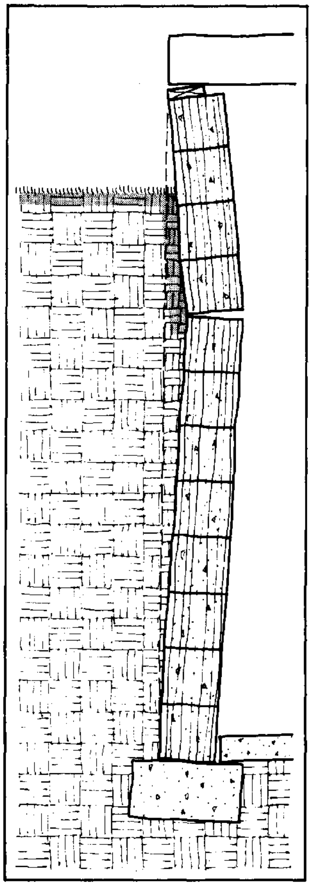
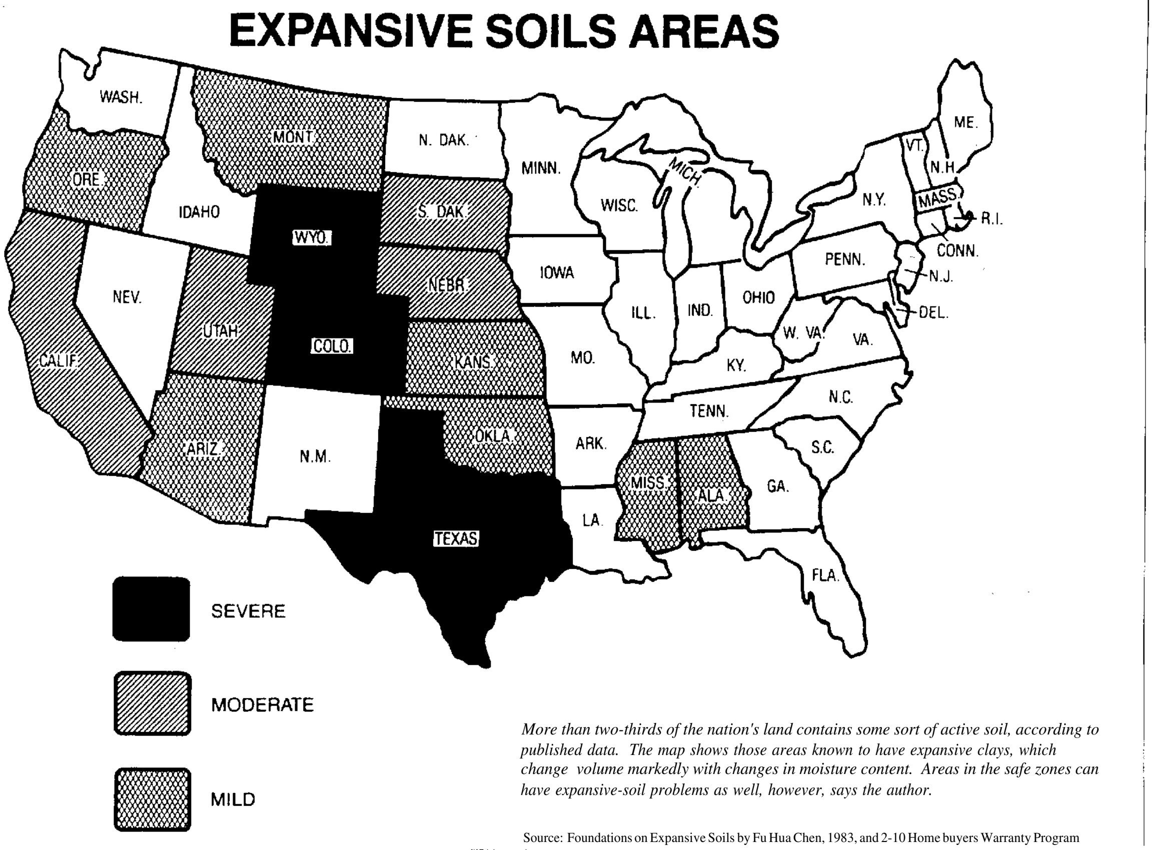


Figure 2. Unreinforced block walls retaining over 4 feet of backfill are prone to problems– particularly in expansive or frost-susceptible soils. The foundation shown above is pushed in by expansive clay. First, the soil shrinks away from the foundation and the gap is filled with topsoil and whatever else blows in. When the soil re-expands, the wall buckles.

Check the amount of bowing with a straightedge. If the amount of deflection is one-third the thickness of the wall, then part of the wall is in tension, and the wall will be structurally unstable.



More than two-thirds of the nation's land contains some sort of active soil, according to published data. The map shows those areas known to have expansive clays, which change volume markedly with changes in moisture content. Areas in the safe zones can have expansive-soil problems as well, however, says the author.

Source: Foundations on Expansive Soils by Fu Hua Chen, 1983, and 2-10 Home buyers Warranty Program

house. That crack lasts as long as the dry spell lasts. During that time, the wind blows just about any old thing into the crack, including topsoil. Then the rains come. The soil swells back to its original dimension–plus the volume of the compressed accumulated crud. It is helpful to understand that clay soil not only expands–it grows, by accumulation. As the clay soil goes through cycles of extreme dryness to extreme wetness, the walls are ratcheted inward. There are no measurements available of the magnitude of the lateral forces involved.

From my vantage point of central Illinois, it is difficult to reckon how common this problem is across the U.S. The local soil contains montmorillonite, an active clay, almost as active as bentonite. But the concentrations of the clay are variable, and there are often enough silts mixed in to reduce the moisture activity of the clay. On national maps of potential danger from expansive clays, central Illinois is in the safe zone. If our basements are deflecting inward, we have to presume that those areas marked as active on the maps must have a substantially greater problem. Other things can make walls bulge inward, of course—driveway surcharge is a common problem. Tree roots, however, are overrated for their ability to push walls inward.

Wall construction. Most buckled walls we see are built of 8-inch unreinforced block retaining 7 feet or so of fill. Such walls were considered acceptable during the 1950s, but since that time codes have limited the allowable height of unbalanced fill to 4 feet on such walls. These walls are not only weak against lateral soil forces, but they are not resilient either—they don't bounce back into place once the force is removed. Some experts believe that older block walls with soft mortar can recover from deformations. Cast-in-place concrete, reinforced masonry, and 12-inch block, all seem to resist lateral soil pressures rather well.

Soil moisture. No matter how expansive a clay is, it won't budge as long as the moisture content in the soil remains constant. One obvious method for controlling the effects of expansive clay is to reduce the swings in moisture content in the soil next to the foundation. The factors that allow soil to dry out are sun exposure and lack of ground cover. The factors that allow soil to saturate are poor site drainage and poor rainwater discharge.

Compressible interfaces. A lot of work is going on right now in building labs around the country to try to develop proper foundation insulation and drainage materials. The materials are expected to last a long time, to provide a water channel down to the footing drains, and to insulate well. I would like to add a further criterion—that these products be compressible. Imagine—if the interface material is compressed, it will spring back without allowing a crack to form. I expect that foundation treatments that work against heat loss, water buildup, *and* lateral buckling will become commonplace in the near future.

Other treatments. The swelling of clay is an ionic phenomenon and the effect can be reduced by mixing an alkali such as lime in the soil. The key word here is "mixing." Clay is not easy to mix. I encountered one buckling site where the proposed solution to the lateral soil pressures was to cut a trench around the house so that pressures would not build up. Of course, they had to fill the trench, so they filled it with *bentonite*—a highly expansive clay! ■

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