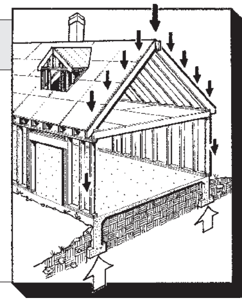

# Preventing Frost Heaves

by Harris Hyman, P.E.

It's the middle of summer, and probably the last thing on your mind is freezing weather. But as you build those decks and porches, sinking pressure-treated posts or sonotubes into the ground, you'd better think about next winter — and what frost might do.

Frost heaving is extremely difficult to control and also generally misunderstood. Those of us in the northern tier of the U.S. know the demonstrations of frost all too well: The earth bulges and carries buildings and roads with it. The bulges are uneven, lifting one or two posts on the porch, a single corner of a building, a patch of roadway, or a small section of an exposed slab. The results of frost heaves are unsightly, destructive, and drive us crazy.

There are several techniques used to try to control frost action: deep anchoring into the earth, fine crushed stone fills, wrapping posts with plastic so that the bulging earth will slip on by, heating the foundation during the frost season, or placing rigid foam insulation around the foundation to hold in the earth's heat. Some of these methods may work some of the time, but they mainly ignore the real problem.

## Understanding the Problem

As an engineer, I want to understand a little about the problem before I recommend corrective measures. Research work on frost heaving is somewhat limited, but there is a theory. Around the end of winter in cold regions, the earth develops a characteristic temperature profile: At the surface, the earth takes on the day's temperature. But a couple of inches below, the ground temperature cools to approximately the February average temperature of the region. As we go deeper into the earth, the temperature rises, until several feet deep it reaches the annual mean temperature of the area.

The soil usually reaches its coldest temperature in March, when the freezing point reaches down to the region's frost line. Below this depth, the soil and groundwater almost never freeze. But at the frost line — the 32°F point — the groundwater freezes, forming a thin sheet of ice. In soils that are porous enough to allow moisture to move, more groundwater touches this ice. The groundwater accumulates, freezes, and builds up into a bulge called an *ice lens*, which might be anywhere from several inches to a few feet across. The bulging ice lens pushes the earth above up into a frost heave. Aggravating the effect is surface melting, which also occurs at the end of March. The snow melt water moves through the ground, touches the ice lens, and adds to the bulge.

This is why, every spring, rural roads up North develop sinuous dips and dives. The ice lenses form during the winter, pushing up spots on the asphalt surface. When the weather warms sufficiently to melt the ice lenses, the unsupported asphalt sags and leaves low spots and potholes. On major highways, which cost a lot more to build, the base layer is sufficiently permeable to carry away groundwater, so heaves are rare.

## Beat Frost the Easy Way: Drainage

Ice is fierce stuff. While most substances expand as they become warmer, ice actually expands as it gets *colder*, with the maximum expansion at about 28°F. When ice is confined, it can exert pressures from 20,000 to 80,000 pounds per square foot. There is almost no way to contain pressures like this; other solutions must be found.

The theory about ice lenses corresponds pretty well with the experience of engineers and excavating contractors. The most interesting implication is that heaving needs *two* things: cold *and* water.

This fact gives us our solution: Remove the water. Drainage is the one solution to heaving that does work most of the time. With post construction, this means allowing the water that collects in the postholes to have a way to get out of the holes before it freezes. This usually means cutting a trench along the line of holes, which tends to defeat the conceptually easy construction of digging postholes, but it does do the job. What a pain!

Likewise, with full basement or slab foundations, we have to get rid of water. If a slab is placed on a good base with perimeter drainage to remove all the water, the slab stays flat and doesn't bulge up in spots. A good deal of construction that has been done in Alaska shows the effectiveness of well-drained slabs. Likewise, if there is a layer of drain rock placed in back of a retaining wall, and weep holes for groundwater to move through the wall, the wall doesn't progressively disintegrate year by year. If the backfill beside full basement walls is well drained, the walls don't get pushed

### Soil Pressure Against a Post

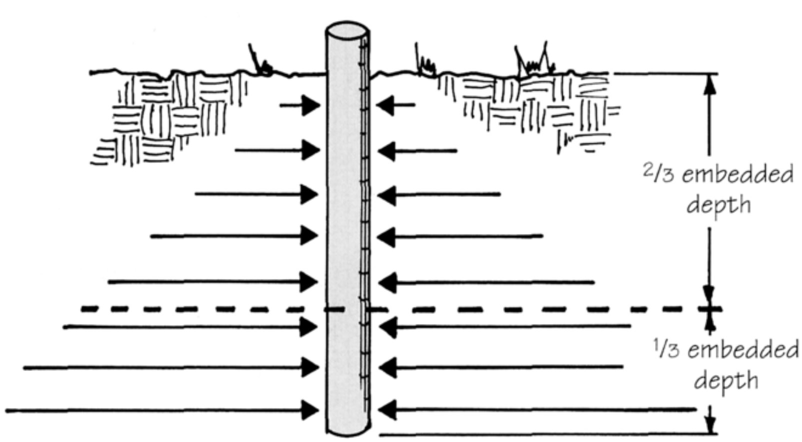


**Figure 1.** *The pressure of the earth against an embedded post increases as the post goes deeper. According to the Coulomb theory, the pressure against the bottom third of the post equals the pressure against the top two-thirds.*

## Preventing Frost From Lifting a Post

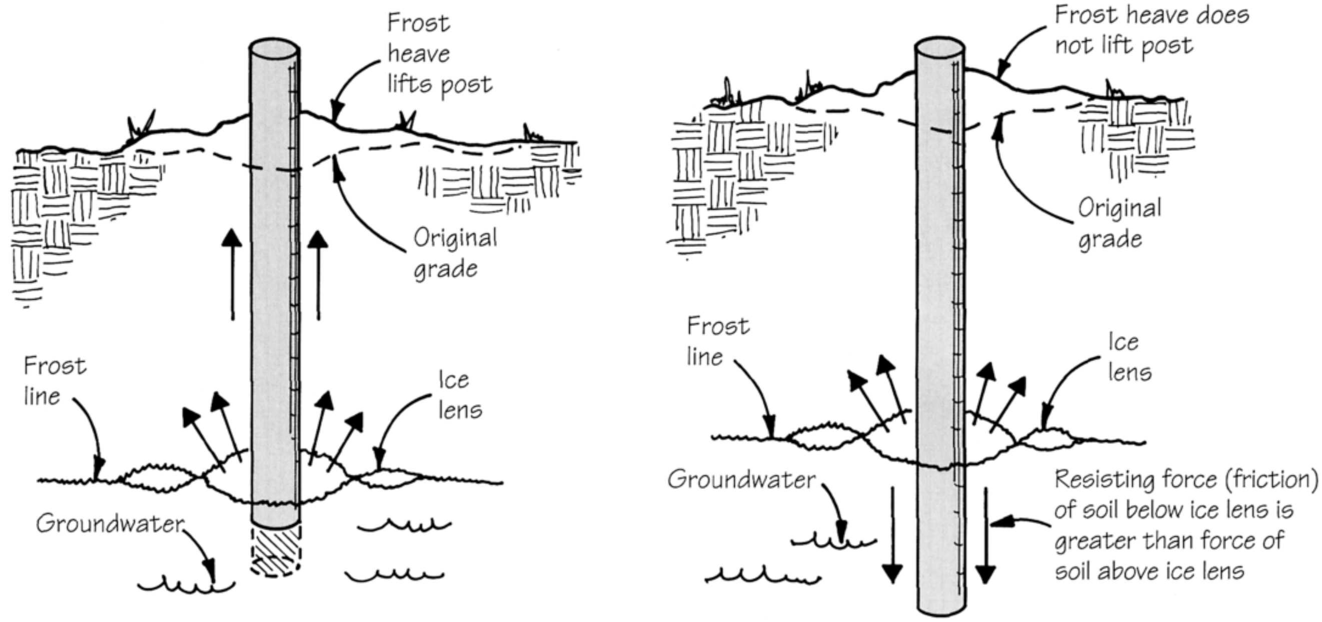


**Figure 2.** *Frost can heave a foundation post that is not embedded well below the frost line. As an ice lens forms, it pushes up the earth above it. Because the earth pressure around the post holds it firmly by friction, the post rises with the earth (left). If more than one-third the embedded depth of the post is below the frost line, however, the frost heave cannot lift the post because the pressure of the earth below the ice lens is greater than that above it. As the ice pushes up, the soil above the lens lets go and the post stays in place (right).*

in each spring. It's almost too simple to believe.

### Other Solutions

There is another way to fight frost heaving — the hard way. This involves anchoring the structure into the earth, such that it grabs on and fights the earth. The model codes support this approach, requiring the perimeter of a slab to be turned down into the earth to a point below the frost line. Personally, I believe that this is both costly and ineffective; proper drainage works and is a whole lot cheaper.

Another method used by builders of small porches and additions on posts is to try to anchor the post to an oversized footing. The notion is that the weight of the earth above the footing will hold the post down. If the footing is sufficiently deep, or there are no heaving conditions, this may work, but it is hardly a sure thing.

There is another option that may have more promise for post construction: Forget the footing, but put the post in deep enough to resist lifting by the friction of the earth. The earth exerts a lateral — sideways — force against the surface of a wood post or sonotube (see Figure 1, page 84). Friction between the earth and the post causes the post to move with the earth. As the post goes deeper, the lateral force of the earth increases, creating greater and greater friction against the sides of the post and holding it in the ground.

The Coulomb theory of earth pressures shows that the friction against the bottom third of the underground portion of an embedded post is equal to the friction against the top two-thirds. By this reasoning, if the post is not to move, the bottom one-third (or a little more) must be below the frost line (Figure 2). With a 4-foot frost line, a 6-foot or deeper post depth is needed, so that at least 2 feet, or one-third, of the embedded part of the post is below the frost line.

### Some Methods That Don't Work

Another method for dealing with frost involves wrapping posts with plastic, so that the ice slips when it heaves. I suspect that this will work for a year or two — maybe — but eventually deterioration of the plastic will bring the whole dream to an end. It seems that filling postholes with uniformly graded $1^1/_2$-inch crushed stone might work a little better. However, I do admit never having worked with plastic wrap and look forward to hearing about your experiences.

Another technique is using rigid foam insulation to protect walls. This is useful for heat retention, not for frost protection. It should be supplemented with a drain rock backfill.

The two worst methods for dealing with frost heaving are the heated foundation and the locking bar. I call the heated foundation "structural use of energy" — burning irreplaceable fuel, warming the soil around the building, to prevent frost damage and hold a building together. This is both extremely expensive over a long period of time and socially undesirable. Even though it cuts down initial construction costs, it should not be encouraged.

The locking bar is a bit of foolishness that seems to keep appearing on construction sites. This is a cross-bar nailed or lag-screwed to a post, usually about 2 feet below grade. Apparently the builders think that this helps hold the post down, but it is usually above the ice lens and actually helps *lift* the post.

So the best way to beat frost is just to let it freeze — but get rid of the water first. ■

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