

Floating Slabs for Unheated Buildings

A slab on a gravel bed can make an economical and durable foundation for a garage, workshop, or vacation home.

by Fredrick E. Crory

During the past year, I've had several inquiries about designing foundations for unheated or partially heated buildings in northern New England. One was for an unheated, three-car garage, another was for a small cottage that was to be heated only occasionally, and a third was for a warehouse that was to be heated continuously, but only to 40 to 50 degrees. The major concern in each case was how to prevent damage from

frost action.

One sure way to protect a structure from frost heaving is to elevate it on piers or piles. But this is not always practical, particularly for garages, workshops, and other buildings that carry motor vehicles, machinery, or other heavy loads. Slab-on-grade foundations, on the other hand, are well suited to heavy loads. Concrete slabs can also tolerate the snowmelt and road salt tracked into garages by cars and trucks.

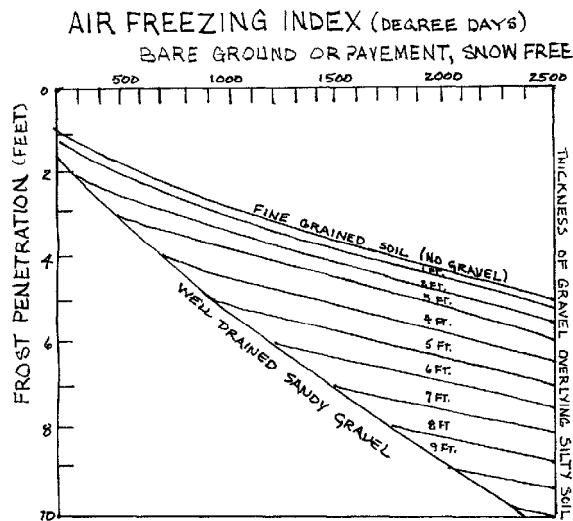
Unheated slabs on grade should be engineered essentially the same way as roads and airfields. Buildings, however, can usually tolerate less frost heaving than airfields can. So designers must know how deep frost may penetrate at a building site, and how frost-susceptible the soils are.

A Gravel Bed

Slabs on grade—as well as roads and airfields—can be protected from frost

damage by putting a layer of well-drained, clean gravel or crushed stone below the slab. The gravel limits the penetration of frost into the soil below. For structural reasons, the gravel must be well compacted.

How much gravel you need depends on the use of the building, how frost-susceptible the soil is, and how wet it will get; the more water in the soil, the more it can heave.



How Gravel Fill Affects Frost Depth

Table 1 summarizes the relative frost heaving of soils using the Unified Soil Classification System.

The Table clearly shows that silts and clays heave more than sands and gravels. Clean sands and gravels, with almost no material finer than 0.02 mm, are virtually free of frost effects. Dirty sands and gravels, including glacial tills, can have medium-to-high frost susceptibility. Thus, the first step is to identify

Figure 1 (at left) shows how far frost will penetrate through gravel into silty, frost-susceptible soil below. A deep enough gravel bed can keep the frost out of the underlying natural soil. Seventy of climate is measured by base-32°F degree-days, culled the air-freezing index.

Table 1. Soil Types and Properties

Division	Symbols	Soil Description	Frost Action	Drainage	Value as a Foundation Material
	Letter				
Gravel and Gravelly Soils	GW	Well-graded gravel, or gravel-sand mixture, little or no fines	None	Excellent	Excellent
	GP	Poorly graded gravel, or gravel-sand mixtures, little or no fines	None	Excellent	Good
	GM	Silty gravels, gravel-sand-silt mixtures	Slight	Poor	Good
	GC	Clayey-gravels, gravel-clay-sand mixtures	Slight	Poor	Good
Sand and Sandy Soils	SW	Well-graded sands, or gravelly sands, little or no fines	None	Excellent	Good
	SP	Poorly graded sands, or gravelly sands, little or no fines	None	Excellent	Fair
	SM	Silty sands, sand-silt mixtures	Slight	Fair	Fair
	SC	Clayey sands, sand-clay mixtures	Medium	Poor	Fair
Sils and Clays 50	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity	Very high	Poor	Fair
	CL	Inorganic silts of low to medium plasticity, gravelly sands, silty clays, lean clays	Very high	Impervious	Fair
	OL	Organic silt-clays of low plasticity	High	Impervious	Poor
Sils and Clays 50	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Very high	Poor	Poor
	CH	Inorganic clays of high plasticity, fat clays	Medium	Impervious	Very poor
	OH	Organic clays of medium to high plasticity, organic silts	Medium	Impervious	Very poor
Highly Organic soils	PT	Peat and other highly organic soils	Slight	Poor	Not suitable

Source: Smith, Hinchman & Grylls Assoc.

the existing soils and the fill material that will be used.

You must next establish the frost depth. Normally, the local building code defines a frost line that all footings must be below. Such depths are often based on long-term observations from ditchdiggers with water and sewer departments. But records seldom define soil conditions, whether the frost depth was a maximum, whether there was snow cover—or other parameters.

Engineers prefer to calculate frost depths based on weather data, soil, and building conditions. One of the best references for such calculations is the U.S. Army's *Arctic and Subarctic Construction manual* (TMS-852-6, available from the Government Printing Office).

Figure 1, which is reproduced from the manual, demonstrates how different soils affect frost penetration, and how a gravel layer affects frost penetration below. Assuming an air-freezing index of 1,000 degree-days, we see that, without any gravel, frost would penetrate to just under three feet. If you replaced three feet of the fine-grained soil with three feet of gravel, we can see from the fourth curve on the graph that the frost penetration would be just under four feet. Thus, all of the gravel and about one foot of the soil beneath would be frozen. About five feet of gravel would be required to prevent any frost in the underlying silt.

Figure 1 also shows that frost penetration is much less in wet, fine-grained soils than in well-drained sandy soils. This is due to the latent heat that is released when water freezes in the wet soil.

The air-freezing index is calculated like heating degree-days, except that it is based on temperatures below freezing rather than below 65°F. The air-freezing indices for New Hampshire and Vermont vary from about 500 degree-days in the southern areas to about 1,500 along the Canadian border. For design purposes, the average index is usually increased by a third. ■

—F.E.C.

Ideally, the gravel bed should be deep enough to keep the subgrade entirely free of frost. (See sidebar.) When the gravel supply is limited or expensive, however, you can use less gravel and permit some frost penetration in the subgrade—particularly with garages and outbuildings. Houses, though, should get the full depth of gravel—or equivalent insulation—because they can tolerate less frost heaving than outbuildings can.

A rule of thumb for garages and similar structures is that well-drained gravel should replace the native soil to 50 to 75 percent of the frost depth of the native soil (50 percent for moderately frost-susceptible soils, 75 percent for highly frost-prone soils).

Attached Garages

The foundation walls of unheated garages that are attached to a heated dwelling usually have a perimeter wall that extends down to or below the frost line. These foundations usually escape frost damage if they have well-draining backfill and footing drains that work. The slab, however, is still vulnerable, and should be placed over a gravel bed as prescribed above.

Pay particular attention to the door side of garages and any ramps or concrete aprons that are at driveway grade. These areas are prone to frost damage, and should have the same gravel base and good drainage afforded the foundation.

Outbuildings

Unheated, detached garages and outbuildings often are not required by code to have foundations below the frost line. These are commonly built on concrete slabs with thickened edges (Figure 1). The thickened edges, which are continuous around the perimeter of the slab, act as grade beams and support the load of the building. As grade beams, they should be reinforced with rebar near both the base and the top, with the upper rebar tied to the wire mesh of the slab proper.

To promote greater continuity between the slab and grade beams, the inner sides of the beams should be tapered rather than left vertical. This requires careful hand-shoveling and grading of the fill. Only an outside form board is needed for pouring the floor.

With a thickened-edge slab, structural integrity depends upon the slab staying intact. It's therefore critical that you make the compacted gravel layer thick enough. Slabs that are built on a sloping grade are particularly vulnerable since a thin layer of fill on the high side and a thick layer on the low side can lead to uneven frost heaving. This situation is also common on the door side of garages. It's often easier to raise the floor elevation and driveway grade than to make a deeper excavation.

Good Drainage

In a thickened-edge slab—and in other foundation types as well—the crushed-stone backfill should extend beyond the foundation perimeter to catch meltwater from the roof eaves. The gravel bed should drain to daylight, either naturally or through perimeter drains.

I prefer to leave the crushed stone or gravel backfill exposed at grade, but if planting is desired, put a filter fabric under the topsoil. Otherwise, the frost-susceptible topsoil will contaminate the clean gravel fill and make it vulnerable to frost heaving.

If floor drains are used in the slab,

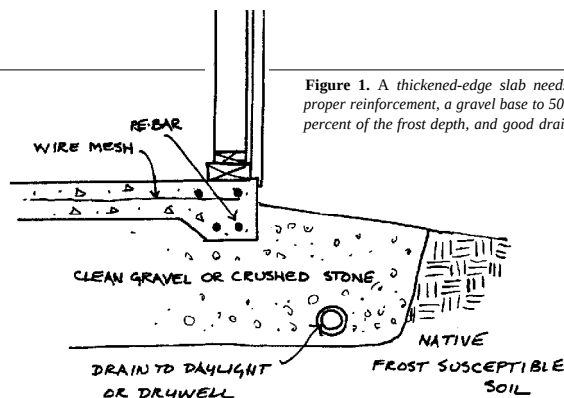


Figure 1. A thickened-edge slab needs proper reinforcement, a gravel base to 50 to 75 percent of the frost depth, and good drainage.

make sure they drain downward to below the anticipated frost depth, then out at a slight slope to a dry well or daylight. Don't discharge the floor drain directly into the gravel fill beneath the slab.

Cottages

Cottages or workshops that will be heated only intermittently can be built on slabs, but should be designed for the possibility that they will be unheated all winter.

If the structure has more than one story and many interior partitions, it will tolerate less differential movement than an open garage or workshop. Cracked plaster and stuck doors can

that are two or more inches thick can reduce the depth of gravel needed by a foot or more. Place the insulation on the prepared subgrade, preferably sloping it slightly to promote good drainage (Figure 2). The insulation should extend four or more feet out from the foundation to protect the sensitive perimeter areas of the slab and to drain water away from the foundation. Normally, at least a foot of sand or gravel should go on top of the insulation to protect it from being crushed by heavy equipment.

Be very careful when you fill on top of the insulation to avoid shifting or cracking the insulation boards. For small jobs, shovel by hand initially to

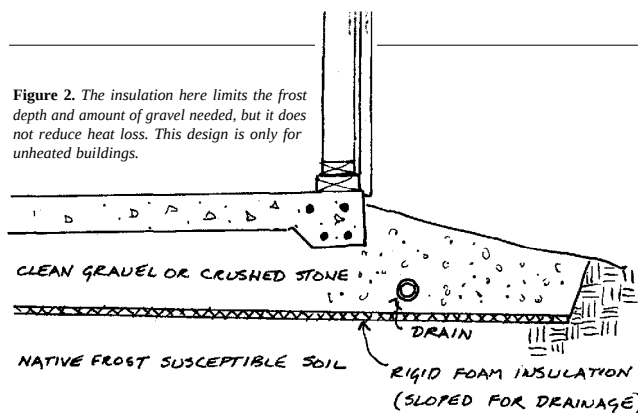


Figure 2. The insulation here limits the frost depth and amount of gravel needed, but it does not reduce heat loss. This design is only for unheated buildings.

result. Therefore, be sure you assess the frost-heaving potential, use enough gravel fill, and drain meltwater from the roof.

Passive-solar design can help by keeping the house and slab above the outdoor temperature, thereby lowering the effective freezing index at the slab. Although an exposed floor will give you the best passive-solar performance, you'll probably want wood flooring or carpeting for comfort.

Insulation Instead of Gravel

If gravel is scarce or expensive, you can use foam insulation to reduce the amount of gravel needed. Foam boards

keep the boards in place, or hold them in place by driving wooden stakes or skewers through them into the soil.

Many Scandinavian houses are built on shallow slab-on-grade foundations similar to the ones described in this article. They typically have both under-floor and perimeter insulation. Because the homes are continuously heated, they face no risk of frost heaves beneath the slab. The under-slab insulation serves primarily to reduce heat loss through the floor. ■

Fredrick E. Crory is a research civil engineer at the U.S. Army Cold Regions and Engineering Laboratory in Hanover, N.H.