# Frost-Heave Resistant Structures for Maine

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**Frost heave requires three simulations events:** 1) frost susceptible soil, 2) freezing temperatures, and 3) a supply of water. As soon as the soil temperature falls below 32°F, the moisture in the soil tends to form lens-like ice structures as shown in Fig. 1. The surrounding moisture will tend to migrate to the lens and form a larger and larger ice body within the soil. The mechanics of frost heave is more complicated than the mere nine-percent volume increase associated with the phase change from water to ice. The formation of ice lenses pulls water from warmer underlying sections of the soil into the freezing zone. This constant drawing of water from the non-freezing zone into the freezing zone and the consequent growth of ice lens accounts for the damaging frost action. Not all soils are frost susceptible. Coarse sand does not have the small pore size required to promote capillary migration of water; heavy clays are too tight to permit moisture migration. Silt-like material has the required pore size for both capillary action and moisture migration. Buildings constructed on these silty soils can be subjected to frost heave.

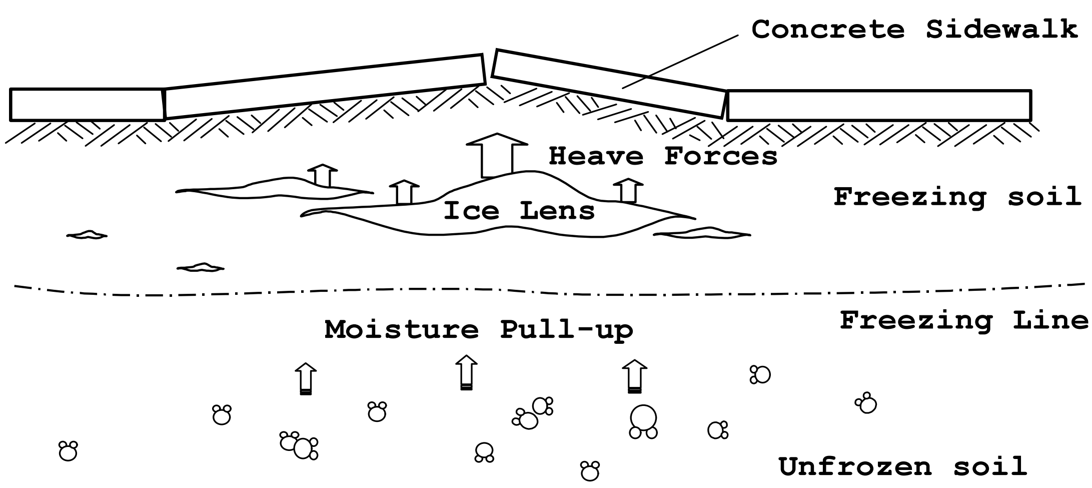


Fig.1 Mechanics of Sidewalk Frost Heave

Fig. 1 indicates the mechanism for concrete sidewalk frost heave. The extent of heaving in a frost susceptible soil is dependent on the thermal conductivity of the soil, the thermal exposure (snow cover, solar exposure, night radiation protection, etc.), and the availability of water. A woodshed that rises with frost heave in the winter and settles back with the spring thaw is not a serious matter. But that never happens. One corner of the shed, due to either exposure or soil condition, lifts more than the other corners. Each season the shed is wracked by differential lifting of the corners and is eventually destroyed.

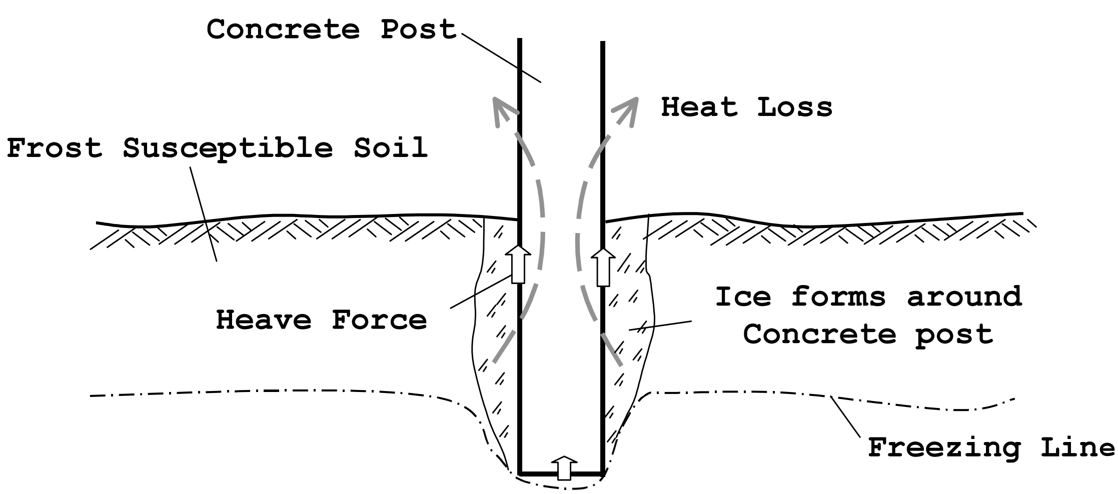


**Fig.2 Mechanics of Post Heave**

**Protecting a post from frost heave** presents a special problem. Fig. 2 indicates the difficulties associated with placing a concrete column in the ground with a large aboveground exposure. Placing the bottom of the post "below frost" may not help. The frost line goes much deeper around the post then in the surrounding soil. There are three reasons for this: 1) The concrete aboveground exposure will provide a large surface for heat transfer from the concrete to the surrounding air. 2) Concrete is a good conductor of heat. 3) The phase change from moisture to ice requires much heat transfer. The combination of these events forces the problem of "adfreeze". Moisture in the soil tends to move from areas of higher temperature to areas of lower temperature. The result: a cylinder of ice will form on the column. Additional ice-lens formation can lift the entire column—even if the bottom of the column is "below frost". If the concrete column were replaced with a four-by-four pressure treated wood post the chance of frost heave would be greatly decreased. Wood has about the same thermal conductivity as the soil; hence the adfreeze problem would be less. If the post were wrapped in plastic, frost forces could not “grab” the post and frost heave would be minimized.

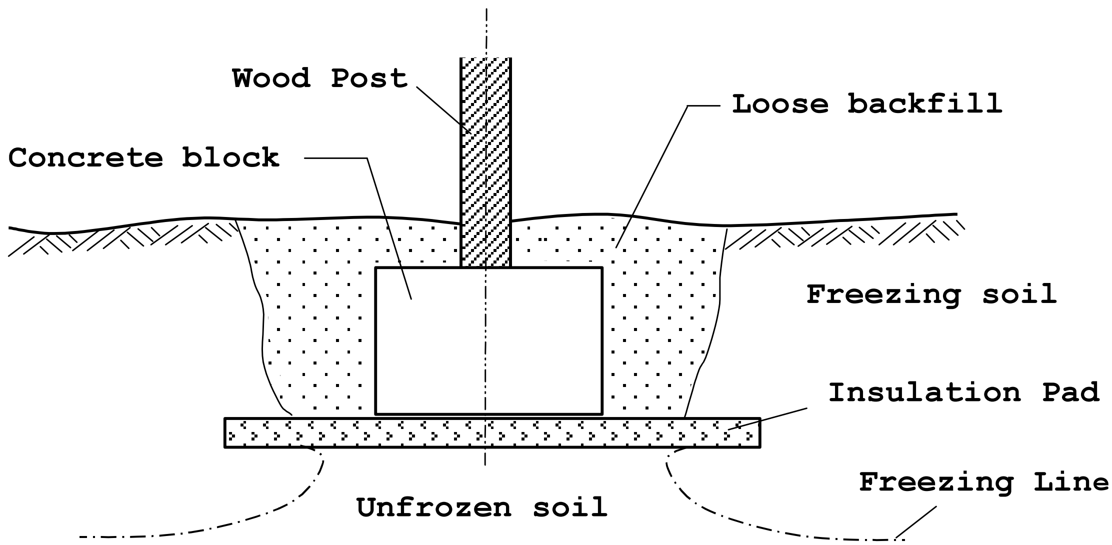


**Fig.3 Post with Frost Protection**

An alternative column support system is shown in Fig. 3. The question: How thick is the insulation pad, and what is the extension of the pad beyond the footprint of the concrete peer? Again, this is a difficult call. If the structure is a woodshed the designer will recommend a twelve-inch concrete block, with filled cores, on a two-inch thick, two-foot square pad of extruded polystyrene (Styrofoam). Crushing force is over two tons per square foot. The only excavation required would be to remove the topsoil. This will be a frost-stable support structure for, perhaps, 99 years out of one hundred. If the designer is asked to devise the post support system for, say, a two million dollar stadium; then an eight-foot square, two-foot thick concrete pad will be placed ten feet below grade and a concrete column will be placed on that pad. Pad and column will have a freight-car load of reinforcing steel (we exaggerate) such that any adfreeze force must lift the entire pad and the weight of the earth resting on top of the pad. The back fill will be non-frost susceptible material with good drainage. The design of a multimillion-dollar stadium will force criteria not applied when designing a woodshed.

The design of the post system to support a porch attached to a house presents a more difficult problem than the post system to support a camp or a wood shed. Any frost movement of the porch support will represent a difficult-to-fix connection between the porch and the dwelling. A two-inch thick foam pad that is four feet square would be appropriate. (The use of one-inch thick foam in two layers with staggered joints works better.) This may be an over-design, but given the potential variables in weather, soil thermal conductivity, soil water content etc., precise design specifications are difficult to formulate.

**Frost protection for a slab on grade** is shown in Fig 4. Geotechnical Special Publication no. 73, published by the American Society of Civil Engineers, provides design data for such a structure. For the very worst freezing condition in Maine (freeze index of 2,500), the design criteria call for an R value of 6.7 on the vertical portion of the wall and only 1.7 on the wing insulation. The wing insulation should be increased to 4.9 at the corners. Fig. 4 (a) shows the plan view. The following dimensions are called for A: 12 inches; B 24 inches; C: 40 inches and D: 16 inches. The foam insulation used in these applications (extruded polystyrene) has an R-value of about five per inch of thickness. The recommendation of Publication 73 hinges on the assumption that the temperature at point "Q" in Fig. 4 (b) will not fall below freezing. The analysis assumes a heated building with constant heat flow from the dwelling into the subgrade as shown by arrow P-Q. The design implies that this heat flow overwhelms the heat flow (arrow Q-R) to the outside. We emphasize that this recommendation represents minimum requirements for frost protection. The use of two-inch thick foam (R 10) throughout would be a more realistic design. If foam insulation were placed under the entire floor (to help keep the floors warm), the heat flow represented by arrow P-Q will decrease and temperatures below 32°F may occur under the footing. The heat flow represented by arrow P-Q would also decrease if the building were closed for the winter.

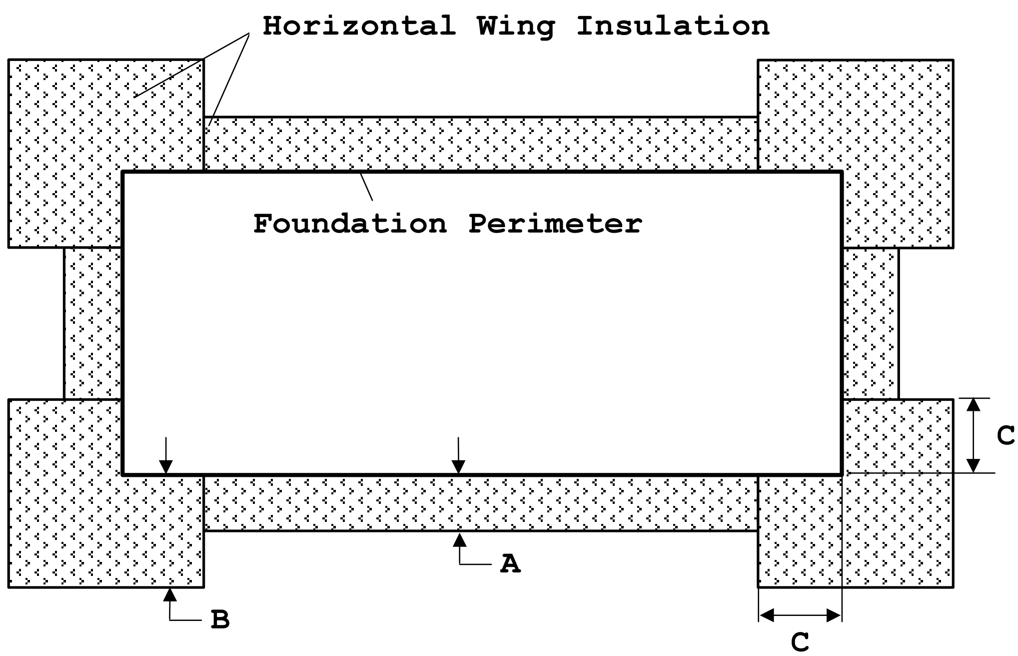


Fig.4(a) Heated Building Plan View

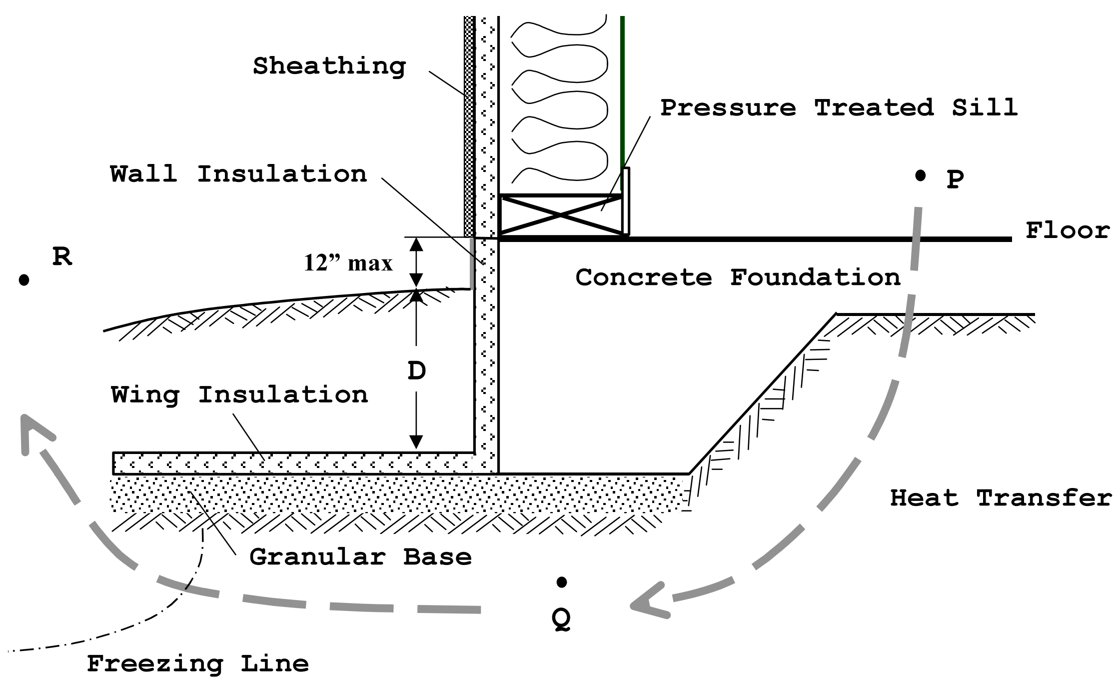


Fig.4(b) Heated Building: Cross Section

If frost protection is demanded of an exposed slab (a shuffleboard court for example), the under-slab insulation must rely on the summer-winter heat capacity of the soil and the very small (about .06 watts per square meter) geothermal heat. A 1973 paper by Bobinsky and Bespflug (Univ. of Toronto) suggests the design shown in Fig. 5. The dimension E is recommended at seven feet! The insulation thickness is recommended at four inches!

The difference between the insulation required in Fig. 4 and Fig 5. is dramatic. The presence of a heated building on the slab makes all the difference.

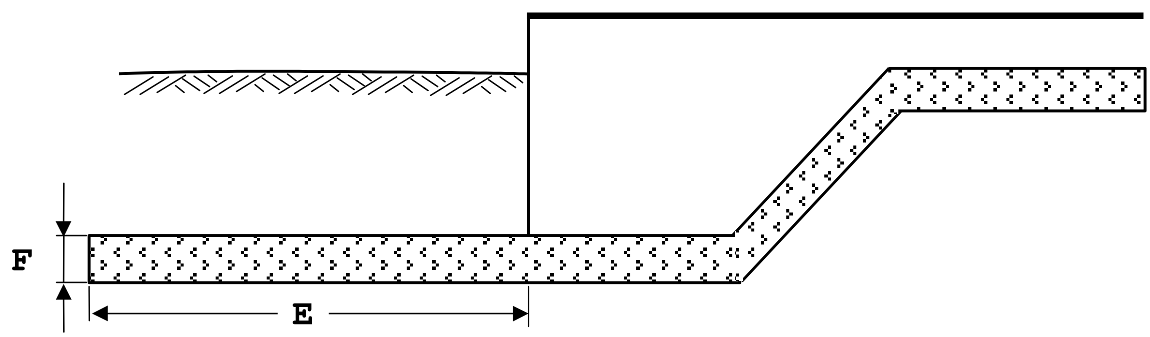


**Fig.5 Unheated Building: Cross-section**

**The civil engineering design of highways** requires three things: 1) place coarse (non frost susceptible) material under the road surface; 2) construct deep ditches to provide drainage for this coarse material; and 3) place a geotextile (filter fabric) between the coarse material and the sub-grade. Without this barrier the migration of frost susceptible fine material into the coarse road base may result in a frost susceptible material under the road.

Many successful slab-on-grade structures (stand-alone garages, for example) have stood-the-test-of-time in Maine using the highway design scheme without insulation.

It's a gamble: the cost of initial construction vs. the cost of a failure.