PREVENTION OF DETRIMENTAL FROST HEAVE IN SWEDEN

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Various measures are used in preventing detrimental frost heave in Sweden depending on the type of pavement construction. The damage may be caused by either or both of the two stages of the subsoil freezing-thawing process, heaving during freezing and softening on thawing. During the freezing period an excess of water is drawn from below to the frost level, where it freezes and causes an upheaval. This water is set free on melting and will then diminish the stability of the subsoil, in extreme cases making it a liquid. This condition is known as the frost boil and results in deformation and breakage of the road surface and pavement.

The different surface layers and pavements behave quite differently and may be placed into four main groups as follows:

1. No damage by frost heave. Damage by frost-boil condition, which may be corrected by blade maintenance. This group comprises the gravel roads.

2. Little damage by frost heave because of flexibility of surface. Great damage by frost-boil condition. To this group belong most bituminous surfaces and stone and brick pavements.

3. Rupture caused by nonuniform frost heave because of high rigidity. No damage by frost boil because of sufficient bear ing capacity even on very soft substratum. This group includes the cement concretes of high quality.

4. Damage by both nonuniform frost heave and frost-boil conditions. In this group fall the thin or weak cement concretes and the thin or weak bituminous surfaces containing very rigid bitumen.

This classification emphasizes the importance of differentiating between the frost heave and the frost boil, a distinction which is not always made.

PREVENTIVE MEASURES

Preventive measures against frost damage may be grouped as follows:

1. Excavation of the soil subject to frost heave and replacement with a material not affected by freezing.

2. Application of a layer with low heat conductivity, impeding the entrance of frost to underlying layers.

3. Application of a layer which will prevent capillary conduction. This layer may consist of a coarse porous material or an impermeable membrane.

4. Lowering the ground water by deep drainage.

5. Chemical treatment to lower the frost-heaving rate of soil.

To these measures may be added some others of minor importance which do not influence frost heave but which may diminish the damage caused by the frost boils. These include arrangements for carrying away excess water through superficial drains, boring holes through the frozen ground, etc.

The principal measures used in Sweden may be considered in two groups, insulation and deep drainage.

The following materials are used in insulating layers:

1. Coarse sand, sandy gravel, ashes, or slag.
2. Porous organic material with high resistance to decay, such as straw, moss, and certain needle brushwood.

All of these materials act according to the excavation and water cutoff principles. The organic materials, as well as ash and some slags, are also heat insulators.

Figure 1 shows typical cross sections

in which insulation and cutoff layers have been used. It is important to place the layer deep enough to get considerable thickness between the layer and the surface. For cutting off the flow of capillary water the layer may be as thin as is practicable, since this effect is independent of the thickness. For heat insulation the effect is proportional to water depth and rate of frost heaving has been the object of particular investigations by the author. Some practical illustrations are given in Figures 4 to 6. The rate of heaving is approximately inversely proportional to the distance to the ground water. Thus, increasing the distance from surface to ground water through drainage from 20 in. to 40 in.

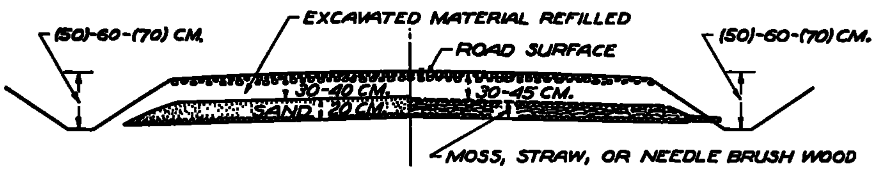

Figure 1. Insulation against Frost Damage. Figure shows excavation filled with original frost-heaving soil above the insulation layer. This is cheap construction and satisfactory for gravel roads of minor importance. On more important highways where a bituminous surface is used, a more satisfactory soil or a stone foundation is used above the insulation layer.

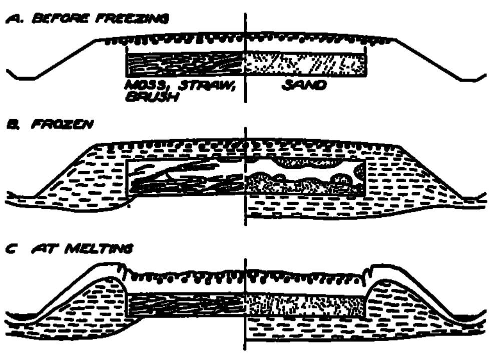

Figure 2. How Not to Construct Insulation Layer

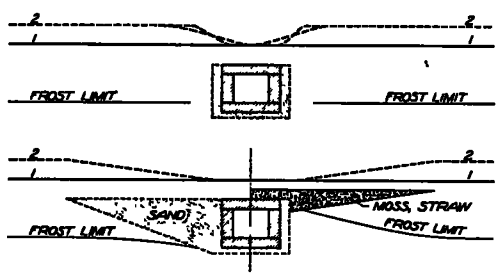

Figure 3. Wedge-shaped Insulation at Culverts Placed in Soils Subject to Frost Heave. Line 1 is road surface before freezing. Line 2 is road surface after freezing.

the thickness. Heat insulation beds can be laid near the surface, but in such cases they must be made rather thick, provided the frost penetration is great. The dimensions and depths are a matter of economics and may vary with the importance of the road and the type of surfacing to be protected.

The preventive action of deep drainage results from lowering the ground water level before and during the freezing process. The relation between ground will normally reduce the frost heaving by half.

This reduction in heaving also means that the amount of water drawn up from below during the process will be reduced, in many cases, in an amount sufficient to prevent the formation of frost boils. It has been demonstrated by hundreds of cases that if deep drains are effective to a depth of 67 in. for very dangerous soils and to a depth of 59 in. for moderately dangerous soils they are sure measures against frost boils, the type of damage which is of greatest importance in Sweden. Frost heave is reduced only in amount by newly constructed concrete roads in Germany which are liable to frost heave but not to frost boil, the experience

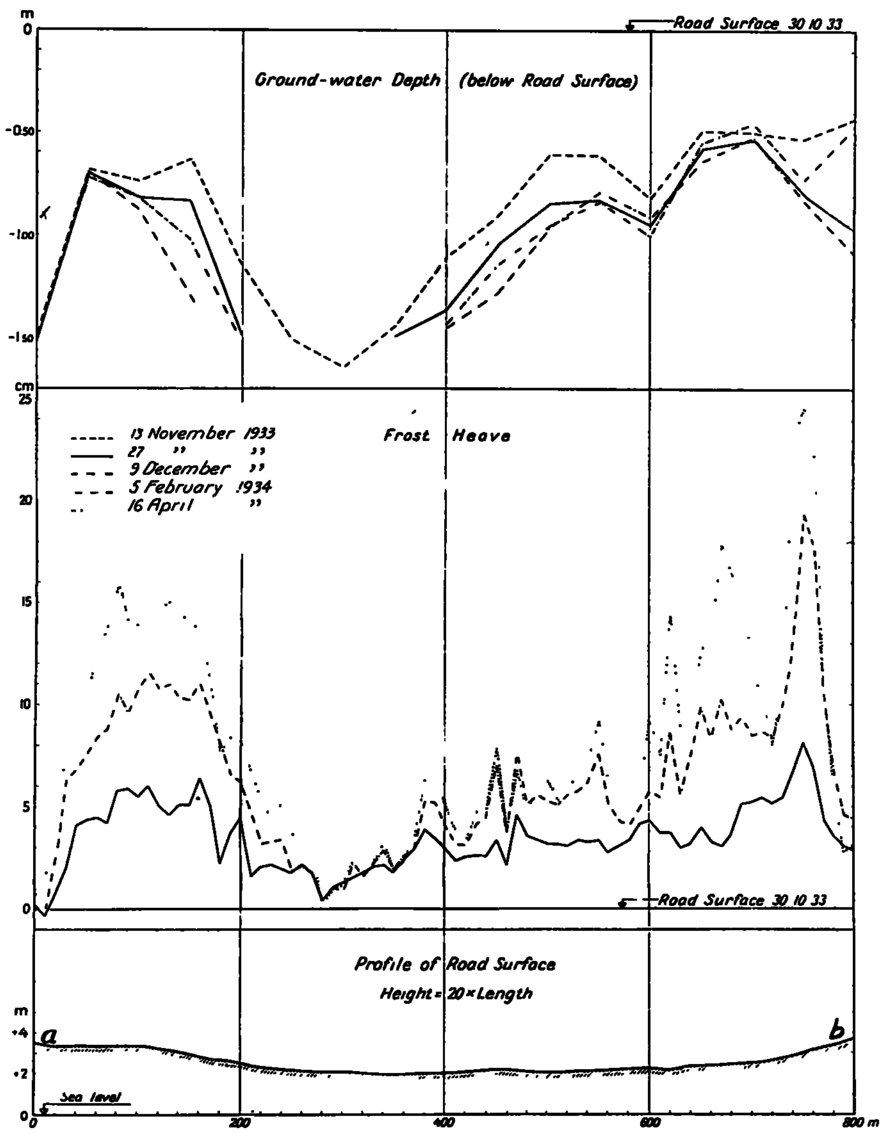

Figure 4. An Illustration of the Relation between Frost Heave and Ground Water Elevation. This illustrates that the greater the depth to ground water, the smaller will be the heave. Deep drainage would be effective in this location. Soil is a uniform loamy silt.

deep drainage. Only under special conditions can drains be placed at sufficient depth to prevent heaving. On many with deep drainage as a preventive measure has been very unfavorable. (Cf. L. Casagrande, 1938.)

The choice between insulation and deep drainage depends largely on the terrain and on whether the object is a finished road. In the case of new construction insulation is preferable; in the case of old roads deep drainage has its grand chance at saving the old road.

The author has found experimentally that the addition of chemicals which diminish the thickness of the water films around particles diminishes the rate of frost heaving. According to information from German colleagues, this principle has been applied practically in cutting away heaving tops by salt injections.

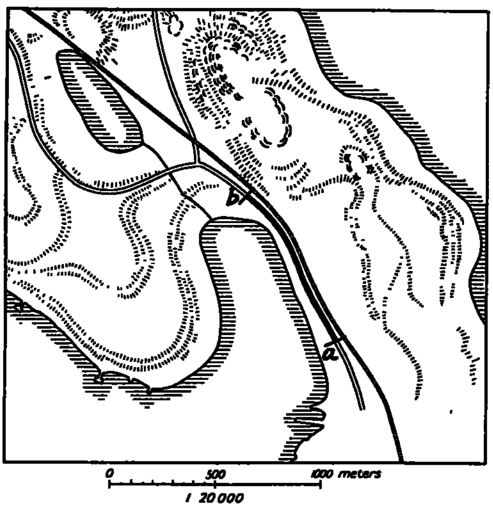

Figure 5. Location of Road from Which Data Shown in Figure 4 Was Collected

TESTING METHODS

The number of soil types in Sweden is far more limited than in the United States. Geologically the whole country belongs to the area of lost glaciation. Climatologically it belongs to the cold-intermedial temperate moist zone. The soils are of fresh glacial and post glacial origin but slightly influenced by weathering. They correspond to the soils of the New England and Great Lakes States. The rocks all over the country are Archean and are mainly of granitic origin. Thus the chemical-petrographical composition of the soils is very uniform. For these reasons a more simplified testing system can be used in Sweden than in the United States.

The inorganic soils belong to two series: (1) the sediments, mostly well sorted, and (2) the moraine soils, mostly well graded.

Sieve analyses and/or capillary tests are made to determine the susceptibility of soils to frost heaving. The limits in Table 1 have been established for soils which are not subject to frost heaving:

TABLE 1

	Passing the No. 200 sieve	Capillarity
	%	in.
Well sorted sediments	Less than 40	Less than 40
Graded moraine soils (determined on passing the No. 10 sieve).........	Less than 19	Less than 40

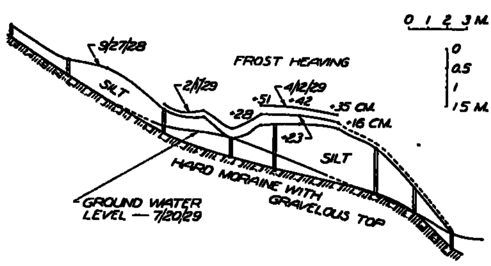

Figure 6. Another Example of the Relation between Frost Heave and Ground Water Depth. Heaved surface is slanting because of strongly inclined ground water level.

When the figures exceed these limits, the soil is usually classified as frost-heaving, although those near the limits in reality belong to a rather complicated border zone. These soils, which may or may not be frost heaving under low pressure, are tested in special cases with "freezing analysis." (Beskow, 1935, pp. 228-232, Fig. 36-49; and Beskow, 1936, pp. 48-49.)

The group of frost-heaving soils is divided into two subgroups, moderately dangerous and highly dangerous. The former comprise graded, ordinary moraine soils and plastic clays, the second, well sorted silts and loams. The Atterberg plasticity tests are used for determination of the limit between highly dangerous silts and loams, which are subject to extreme frost heaving as well as being inclined to flow when wet, and the moderately dangerous plastic clays.

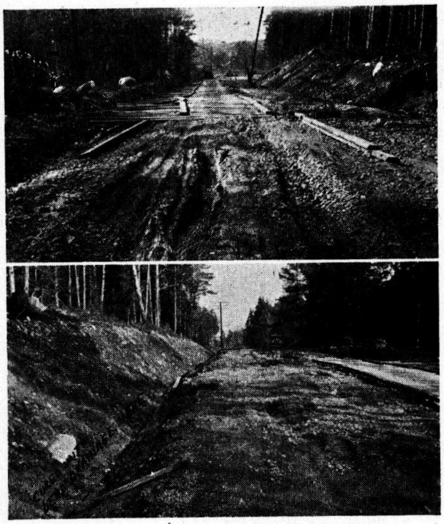

Figure 7. Newly Constructed Highway in the Neighborhood of Stockholm Destroyed by Frost Boils in the Spring of 1930. Deep drainage (1.8 m.) was installed as indicated by arrow the following summer and since that time no damage has been observed.

When the soil is determined by test to belong to one of the three groups, the water conditions are considered, especially the depth to ground water in the freezing period. The product of soil character and ground water conditions gives the "specific frost danger" of the road section in question. The choice of the preventive measure depends upon the specific frost danger, the type of road surface, and the importance of the road.

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