7. Slate, F. O., "Permanence of Calcium Chloride in Subgrade and Stabilized Bases and Its Effectiveness on Base Course Densities," Report to Highway Research Board Committee on Frost Heave and Frost Action in Soil, Purdue University Bulletin No. 14, pp. 6-8, 1948.
8. Perry, T. R., Assistant Maintenance Engineer, Iowa State Highway Commission, Personal Correspondence, 1950.

CONTROLLING THE EFFECTS OF FROST ACTION IN MICHIGAN

O. L. Stokstad, Engineer of Soils, Michigan State Highway Department

The development of frost-action control in Michigan is the result of an evolutionary process. The problem became serious at about the same time that snow removal was adapted as standard practice on the trunkline system. Excavation into heaves while frost was still in the ground indicated the heaves were caused by layers of clear ice in the soil. Further study showed this condition to be limited to silt deposits. Early efforts at control, therefore, consisted of excavating silt where it occurred in the subgrade within frost range.

Frost-Action Control in the Surface

The effect of frost action on highway pavements is first controlled by selecting construction materials least effected by freezing and thawing. Further control is gained by the use of a highway cross section crowned to drain freely and maintained in such manner that this built-in characteristic is retained. Gravel maintenance avoids the development of secondary ditches along the edge of the metal. Snow banks are not permitted on the shoulder because of the drainage problem. Figures 1 and 2 show winter and spring scenes in the North country which illustrate the difficulties of following good maintenance practice. Note especially the pitting damage to the gravel surface where traffic has had to travel through water ponded by hard snow banks left on the shoulders.

Freezing-and-thawing is one of the strong environmental factors considered when specifying materials to be used in building a highway wearing course. The amount and quality of clay binder to use in stabilized gravel and the character of aggregates to be used in bituminous and portland-cement concretes are studied carefully in an attempt to keep the destructive effect of frost action to a minimum.

Frost-Heave Control

Soil materials capable of causing frost heaving of sufficient magnitude to be destructive of pavements and dangerous to traffic is removed from the highway subgrade. The bottom width of the excavation is 4 ft. wider than the width of the overlying highway surface. The depth of excavation varies from 2-1/2 to 3 ft. in the gray-brown Podzolic soils and from 3 to 4 ft. in the Podzol soils. These depths are measured from the bottom of the proposed surfacing structure. They do not indicate maximum frost penetration but approximate average penetration. Damage resulting from frost penetration beyond the depth of frost heave excavation has been found to be negligible. Figure 3 is the standard section for frost-heave excavation.

Frost-heave excavations are backfilled with soil materials similar to the material surrounding the frost heave pocket. If the normal soil texture is sand and gravel the excavation is backfilled with sand and gravel. If the normal texture is clay the excavation is backfilled with clay up to the bottom of the granular subbase. The reason for this procedure is to avoid creating a "bath tub" in the grade which if present would require tile edge drain to drain excavation.

When frost-heaving textures occur in thin seams or small pockets their detrimental

Figure 1. Snow Banks on the Highway Shoulder Indicating Drainage Problems to Come.

Figure 2. Snow Banks Preventing Proper Surface Drainage of Cross Section.

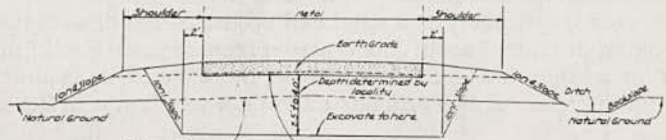

Figure 3. Section of Frost Heave Excavation.

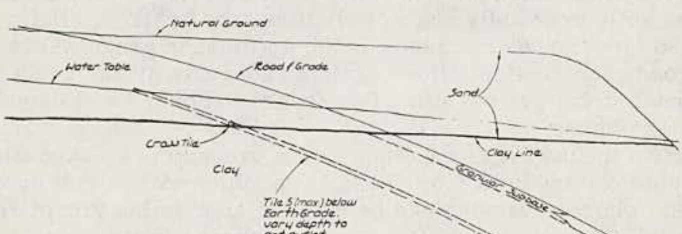

Figure 4. Drainage of Wet Sand Over Clay, Berrien Soils.

influence may be destroyed by a mixing operation. This work is usually done with a carry-all scraper in a manner which requires double handling for only half the quantities involved. Overhaul of material from some selected borrow is thus eliminated. The mixing technique is also used to eliminate sudden changes in subgrade soil textures which so often characterize morainic deposits. Crossing old embankments at grade or cutting through the weathered portion of soil profiles are examples of other causes of foundation inequalities eliminated in the same manner.

Studies and recommendations for frost-heave treatment are made sufficiently early during construction operations so that any necessary excavation can be done while excavating equipment is working in the immediate area. Frost-heaving textures may then be used for filling in the lower portions of embankments under construction. Such materials should not be used within the frost-penetration range. Depths and widths for mixing are the same as for excavating frost-heaving materials.

Bad drainage may also be the cause of frost heaving. Free water flowing through the subgrade within the range of frost penetration can be quite destructive of road surfaces. Wherever possible the elevation of watertables and springy areas are made available to the design engineer so that an adequate grade height above water can be provided for whenever other factors permit. Drainage pipe is a poor substitute for an adequate grade height, largely because of the difficulty experienced in maintaining a free outlet. On the other hand, there are times when the engineer has no choice in the matter. Springy areas encountered in cut sections for instance usually require edge drains. When underground drainage structures are necessary they should be placed 5 ft. below the roadway grade and carried far enough to outlet into a drainageway sufficiently deep to provide a foot outfall at the outlet. Detailed specifications cover the installation of edge drains. Figure 4 is a sketch showing a typical drainage problem presented by a sand-over-clay type of soil. Figure 5 illustrates outlet blocking resulting from inadequate maintenance and poor outlet design.

Small cross culverts improperly installed can be the cause of serious "summer heaves." In the region of podzol soils these structures require a minimum of 2 ft. of cover between the top of the pipe and the bottom of the pavement. Otherwise frost will gradually lift the pipe out of the ground, causing a bad bump in the roadway surface.

Rock cuts present another special drainage problem. These are undercut one foot from ditch bottom to ditch bottom, crowned so as to drain to the sides and then backfilled with granular material. Sand and gravel subbases wherever used likewise are built through the shoulder from ditch to ditch so as to provide subgrade drainage by what has been called a continuous bleeder. To obtain this effect it is important that the subbase material have free-draining characteristics.

Spring Breakup Control

Spring breakup is most commonly experienced on flexible land-access roads. Good farm land involves soils especially susceptible to spring breakup. Unfortunately, therefore, the need for land-access roads is the greatest in areas where the soils are the poorest for road construction. Here again an adequate grade height is the best solution wherever other factors permit. Two feet of fill over level clay farm lands is preferable to tile or ditches.

The most effective means for controlling spring breakup is an adequate granular subbase. Most subbases are built from 12 to 18 in. thick except that an 8-in. depth is sometimes used where advantage can be taken of an existing gravel road. The material used for this purpose is the best sand or gravel most readily available. Pit-run material is used, and if this cannot be made available through selective grading, the state buys granular borrow, which is placed by the contractor at his regular contract price for earth excavation. Figure 6 illustrates the subbase section most commonly used.

Figure 5. Tile Outlet Without Proper Outfall.

Condition Survey

Obviously all the land-access roads of a state cannot be rebuilt to modern standards at once. A long range program is necessary which to be practical must take advantage of every local resource. The ultimate objective is to bring these roads all to a level of excellence necessary to carry their normal traffic load without failure throughout the entire year. As a first step in this program, a speedometer survey of the main secondary road system is made showing soils, road conditions during the spring breakup, and such landmarks as may be necessary for location in later use of the map in the field. An attempt is made to bring this map up-to-date each

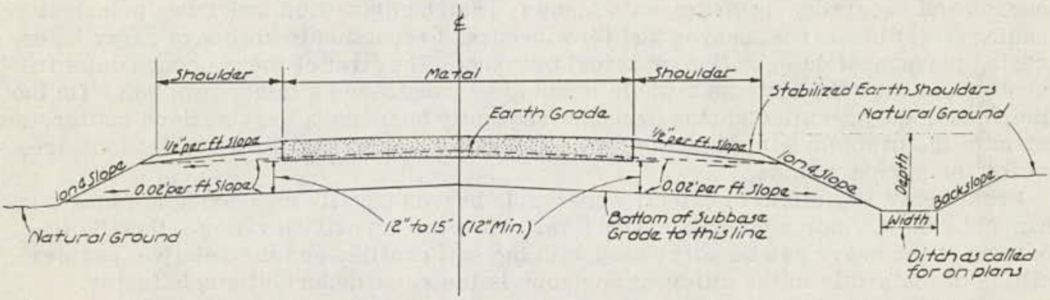

Figure 6. Section of Granular Subbase.

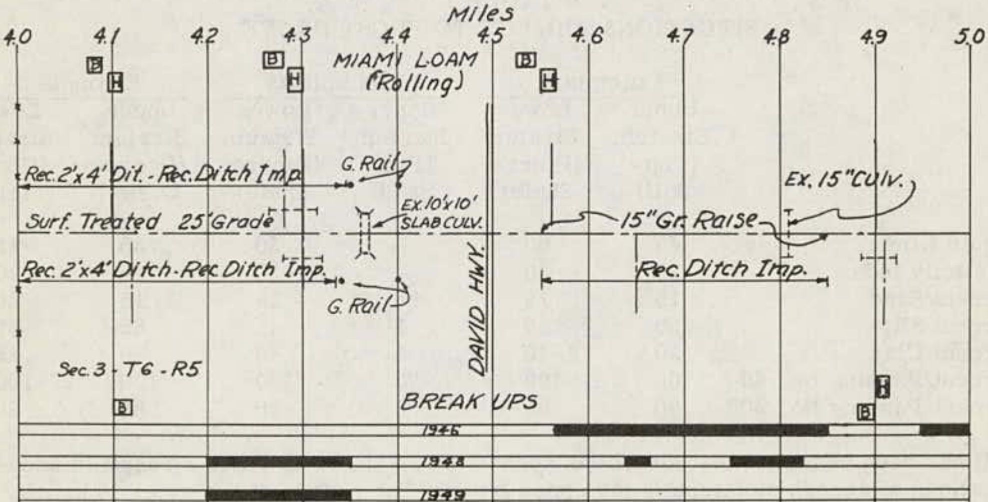

Figure 7. Soil Survey, Project 34-41, Ionia County, M-166 from Portland to Lyons, April 1948. Remarks. Height of Grade, Good, Average Ditch, 1-ft. Valley. Recommendations: Ditch Improvement at 4.00 to 4.35 R and L, Ditch Improvement at 4.55 to 4.85 R; Raise Grade 15 in. at 4.55 to 4.85.

year, so when money is available for reconstruction or betterment, plans may be based on a fairly comprehensive service record. At this stage a report is submitted with the map by the district soil engineer. In this report he makes design recommendations for correcting inadequate foundations. Included also is information on the location and character of needed construction materials available in the neighborhood. Figure 7 is a typical sample of condition map. The spring breakup records over a 3-year period are shown. In making his soil survey and in generally gathering data on which to base his report and recommendations, the soil engineer works closely with highway staff members concerned with the project. This is done so he may profit by their knowledge of the project and they may know more intimately some of the background for the report. A more sympathetic execution of the recommendations is thus assured.

REMEDIES AND TREATMENTS FOR THE FROST PROBLEM IN NEBRASKA

O. L. Lund, Soils Engineer, Nebraska Department of Roads and Irrigation

The damaging effects resulting from the freezing and thawing of base and subbase courses and subgrades on Nebraska's highways can be classified under two principal headings: (1) local frost heaves and (2) widespread reduction in ability to carry loads, causing permanent deformation or actual breakup. The first of these occurs quite frequently, yet over the state as a whole it would be considered a minor problem. On the other hand, the so-called spring breakup frequently becomes a very serious matter, the extent of the problem sometimes becoming so great that special load restrictions are set for the spring months.

Frost heave is limited in extent, observable heaves usually measuring not longer than 40 or 50 ft., nor higher than 4 or 5 in. above the normal elevation. Usually the location of the heave can be correlated with the soil profile, and the relative permeabilities of materials in the different horizons is the most important single factor. The following table indicates the wide diversity of materials in which frost heave may occur if the soil layer in question is underlain with a more impervious horizon.

TABLE 1
SITUATIONS SUBJECT TO FROST HEAVE

	Example 1		Example 2		Example 3	
	Upper Stratum (Top-Soil)	Lower Stratum (Pierre Shale)	Upper Stratum (Fine Sand)	Lower Stratum (Pierre Shale)	Upper Stratum (Peorian Loess)	Lower Stratum (Glacial Till)
Liquid Limit	45	60	-	60	35	45
Plasticity Index	20	30	-	30	15	20
Percent Sand	15	15	98	15	15	20
Percent Silt	55	45	1	45	65	55
Percent Clay	30	40	1	40	20	25
Percent Passing No. 40	100	100	70	100	100	100
Percent Passing No. 200	90	90	5	90	98	90

It has been observed that situations such as those shown in Table 1 result in accumulations of excess moisture in the upper layer. The source of the water is usually from the precipitation on the adjacent shoulders, side slopes, ditches, and backslopes, though in some cases the seepage moves underground from considerable distances. This latter situation is illustrated in Example 2, which represents a region where fine sands overlie the impervious Pierre Shale over large areas. In these areas, free water fills all of the pore space in the lower 2 to 7 ft. of fine sand immediately over the