REMEDIES AND TREATMENTS

CALCIUM CHLORIDE TREATMENT OF FROST ACTION

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Chemical treatment of soils to correct damaging effects from frost action has been used for several years. An early report of this type treatment described a method of incorporating calcium chloride into the subgrade soil through holes drilled in the road which were back-filled with two parts pea gravel and one part chloride (1). During the past several years, much additional data have been accumulated, both on the effects of chemical treatment on frost action and on theories of frost action itself. This paper, however, describes methods of controlling the detrimental damage from frost action through various types of treatments from experience gained from field projects and laboratory research.

Chemical treatment of soils or soil aggregate for frost control has been accomplished by various types of applications, depending upon the particular problem encountered. These can be grouped in three classifications: (1) treatment to prevent freezing of subgrade soil or foundations during cold weather construction; (2) treatment to permit the drainage of melt water trapped above frozen ground; and (3) treatment to minimize frost action and controlling the loss of subgrade support during the spring melting period.

The low freezing property of a calcium chloride solution is no doubt the major factor in its successful application for the above uses. F. O. Slate described the antifreeze property in relation to frost control (2). The presence of calcium chloride in the soil lowers the freezing point so that a lower temperature is required to produce the ice lenses that cause frost heave. The freezing point of pure water is lowered from 32 F. to 23 F. by the addition of 10 percent of chloride. Any fraction or multiple of this percentage will lower the freezing point a corresponding amount, that is, the freezing point lowering is directly proportional to the amount of chemical present. However, a soil containing 10 percent solution will have a freezing point well below 23 F. because soil itself begins to freeze at lower temperatures than pure water (3).

It should be noted that just below its freezing point, water freezes solid. For example, if pure water is held at 30 F. for some time, it will become completely solid. However, a solution of calcium chloride does not freeze solid at, or just below, its freezing point, only a few crystals of ice are formed. This ice is composed of nearly pure water, which upon being frozen, releases its calcium chloride. The extra chloride is added to the remaining solution making it more concentrated and thus lowering its freezing point. (Because of this mechanism, a 10 percent solution does not freeze solid until a temperature of -1.5 F. is reached.)

This low solid-freezing point permits the use of relative small percentages to be effective in minimizing frost damage. When calcium chloride is used as an admixture for moisture control and compaction aid in densely graded aggregate bases and subbases, it serves a double purpose, in minimizing voids through increased density and by giving antifreeze properties to the soil moisture. Even a very small increase in density represents a substantial reduction in the total voids or moisture absorbing capacity of soil (4).

Prevention of Freezing of Subgrade During Cold-Weather Construction

Most construction is planned for completion during favorable weather conditions. This is not always possible, however, and in the northern climates, contractors are often forced to continue construction during below-freezing temperatures. Calcium

Figure 1.

Figure 2.

chloride has proven effective for treating newly prepared foundations and subgrades to prevent freezing during the period of grading and placing of the construction material. This was especially true for airport construction during World War II. Specifications covering this use are of a general nature permitting the contractor to use judgement as to method and quantity of material, depending upon the weather and construction conditions. An example is a paragraph taken from the United States Army Engineers' Specification on the Lockbourne Air Base, Columbus, Ohio.

> "The contractor is cautioned that frozen material is not permitted for use in subbase, nor is it permitted that concrete be placed upon frozen subbase. When freezing weather threatens, the contractor shall take measures to prevent freezing of the subbase by covering it with straw or other acceptable methods. The use of calcium chloride mixed with the subbase for the purpose of preventing freezing is permitted providing the quantity does not exceed one (1) pound per square yard per inch of depth and that it is bladed and mixed uniformly throughout the portion of the subbase so treated."

The method now recommended to permit uninterrupted paving is to apply 1-1/2 to 2 lb. calcium chloride per sq. yd. bladed or mixed into the top 2 to 3 in. of subgrade material. This provides protection for the normal period between grading and paving at minimum temperatures of 10 to 15 F. For periods of longer duration (48 hr.) or lower temperatures and added protection of straw or marsh grass hay is recommended.

Treatment of Frost Heave Areas

Maximum frost penetration is the depth to which the frost has penetrated during the winter season and the range is 3 to 6 ft. in the northern half of the United States. At this depth, and with gradually rising temperatures, the frost ceases to penetrate and starts to recede. At this same time, the frost at the surface also starts to melt, this melting action gradually penetrating down into the soil. This period of change is a critical one since the load-carrying capacity of the road is greatly reduced.

During the surface-melting action, there is an intermediate layer of frozen soil through which the free moisture above cannot drain. Thus, this moisture along with other surface moisture from melting snow, etc. is trapped above the still frozen soil layer.

In areas where this condition is severe, a method of treatment using vertical drains back-filled with gravel and calcium chloride has proven successful. The chloride keeps the drains from freezing and permits the drainage of the melt water through the frozen zone.

This type of treatment, used by the Iowa State Highway Commission (8), consists of placing the vertical drains at 5-ft. intervals, the holes are 7 in. in diameter and 6 ft. in depth. The holes are drilled with a power drill at the rate of 40 to 60 per hr., depending on the conditions. Each hole is filled with clean sandy gravel to which is added 3-1/2 gallons of solution composed of 100 lb. of calcium chloride and 30 gallons of water. The gravel is then consolidated in each hole with a vibrator. The cost of the work complete was reported about $1 per hole or $1 per lineal ft. of roadway where five lines of holes are placed.

A similar method (5) was reported in Ionia County, Michigan, and consisted of placing vertical drains at the edge of the roadway on 15-ft. centers. The holes are dug with post hole diggers to a depth of 4 ft. and back-filled with clean gravel and calcium chloride. Calcium chloride in the amount of 25 lb. was mixed with the gravel for each hole.

Figure 3.

Minimization of Frost Action and Loss of Subgrade Support During Spring Melting

It is recognized that problems of frost action are of two distinct types: (1) differential frost heave associated with certain water and soil conditions, and (2) critical reduction of subbase and subgrade support during the spring melting period (6). The latter type is not generally recognized as frost action, since there is no visible differential heaving. It infers a more uniform type of frost action which does not result in pavement failure during the freezing period, but is evident in the form of subgrade distress only during and after the melting period.

Observations of treated stabilized aggregate bases have shown definite beneficial effects in maintaining higher stability than adjacent similar untreated bases during the spring breakup period. Laboratory research has confirmed that relative small percentages of calcium chloride in soil mixtures will protect the soil from damaging frost heave. As a general average, it can be said that protection from frost heave in silt is afforded by 2 percent chloride, in clay by 1 percent and in graded mixes 1/2-percent (2). Permanency tests of chloride-treated aggregate base projects showed that after a period of 5 to 10 years, one-third to one-half of the chemical originally placed still remained. Almost all the loss occurred during the first five years (7).

Deliquescent chemicals have been used for years as a compactive aid in various types of graded aggregate bases and subbases but very little thought has been given to its value for controlling the loss of load-bearing value during the spring-melting period. Field tests on base projects have shown that calcium chloride contained in stabilized bases with bituminous wearing surface has gradually migrated downward into the more impermeable subgrade soil. It is evident that the small percentage of chemical used in the construction of flexible bases has also been effective to some degree in minimizing this critical loss of load-carrying capacity during the spring breakup period.

Application of Chemical

The procedure for treatment of the subbase or subgrade is relatively simple. The basic idea is incorporating the chemical into the top portion of material immediately below the base course, consisting of densely graded aggregate (subbase) or finely grained soil (subgrade). Since calcium chloride will gradually migrate downward in soil covered with an impervious wearing surface, it need only be incorporated into the upper portion of the section to be treated. When the subbase or subgrade has been prepared, it is recommended that the required amount of chloride be spread over the surface and bladed or scarified into the material to a depth of 3 or 4 in. and compacted as required.

Recommended range of depth for estimated treatement is 6 to 12 in. Observations have shown the area near the surface of the subgrade is the critical zone during the spring-melting period.

Quantity of Chemical

Recommended quantity is one percent by weight of the soil for minimum temperatures of zero or below and 1/2-percent for minimum temperature of zero or above. Assuming compacted soil to have a density of 100 lb. per cu. ft., these quantities represent the following amount on a square-yard basis:

Treatment	Depth of Treatment	Calcium Chloride per sq. yd.
Percent	in.	lb.
1/2	6	2.25
1/2	12	4.5
1	6	4.5
1	12	9.0

This treatment is considered as an added factor of safety in the design of flexible bases: bases designed for sufficient load-carrying capacity may fail entirely or be damaged severely due to critical loss of bearing value during the short period of the melting action. The value of the chemical in the subbase has a dual purpose as a compactive aid and a frost-action control.

Field projects and laboratory research, sponsored by the Calcium Chloride Association, is now under investigation in measuring the loss of load-bearing capacity due to frost action and the effective control of calcium-chloride treatments, which should be of value for consideration in the design of flexible bases in frost-affected areas.

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CONTROLLING THE EFFECTS OF FROST ACTION IN MICHIGAN

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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