Frost Considerations in Highway Pavement Design: Eastern United States

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•AN up-to-date assessment of knowledge pertaining to frost action in soils was presented in "Highway Pavement Design in Frost Areas, A Symposium: Part 1. Basic Considerations" (HRB Bull. 225, 1959). The papers covered such interrelated factors as soil type, moisture, and temperature penetration, and also the mechanism of frost heaving.

Various state highway departments, as well as other agencies responsible for design and maintenance of pavement structures, have accumulated a vast wealth of empirical knowledge which they use to design pavements to withstand the effects of frost as well as other environmental factors and use.

This paper includes a summary and discussion of the design practices of 16 highway departments in the Eastern United States (Zone 1). The area involved extends from the Atlantic coastline inland for 200 to 400 miles, from Maine to Georgia. These states offer an extremely wide diversity of climate, soil and other factors that influence the severity of frost action. As a matter of fact, such states as New York, New Hampshire and Maine have significant variations in freezing conditions from south to north or from the coastline inland within their boundaries. The following paragraphs describe in a general way the type of surface soils that are prevalent in the area and also present information on freezing air temperatures and rainfall.

SURFACE SOILS IN ZONE 1

Figure 1 has been adapted from a soils map of the United States prepared by Donald J. Belcher. For the purpose of this paper, the surface soils have been grouped into four major groups: glacial, coastal plain, residual, and non-soil areas.

Glacial

The predominant soil type in the glaciated area is glacial till. The character of glacial till varies widely and is directly related to its parent material. In the crystalline bedrock areas of New England, till is generally a heterogeneous well-graded soil with all grain sizes from clay to large boulders. The material can, however, range from a boulder clay to a slightly plastic silty till. Where the parent materials are interbedded shales or sandstones, the derived till is generally a clayey sand or gravel with few cobbles and boulders. Clayey sand or clayey gravel tills are found overlying the red sedimentary shales and sandstones of Connecticut and Newark Triassic troughs. They also overlie large areas in central New York and northwestern Pennsylvania. Although the glacial till soils have a high bearing capacity for the support of buildings and bridges, they range from moderate to high in frost susceptibility.

Waterlain granular soils are the next most common soil type found in glaciated areas. These materials were deposited by meltwater streams flowing from the main glacial terminus or from detached and melting blocks of ice. They generally consist of stratified silts, sands and gravels.

Although deposits of glacial clay, both fresh water and marine, have attained notoriety because of construction problems they engender, they are actually the least abundant of the glacial deposits. Most fresh water clay deposits are confined to areas once occupied by a few large glacial lakes, notably Lake Hartford and Lake Albany.

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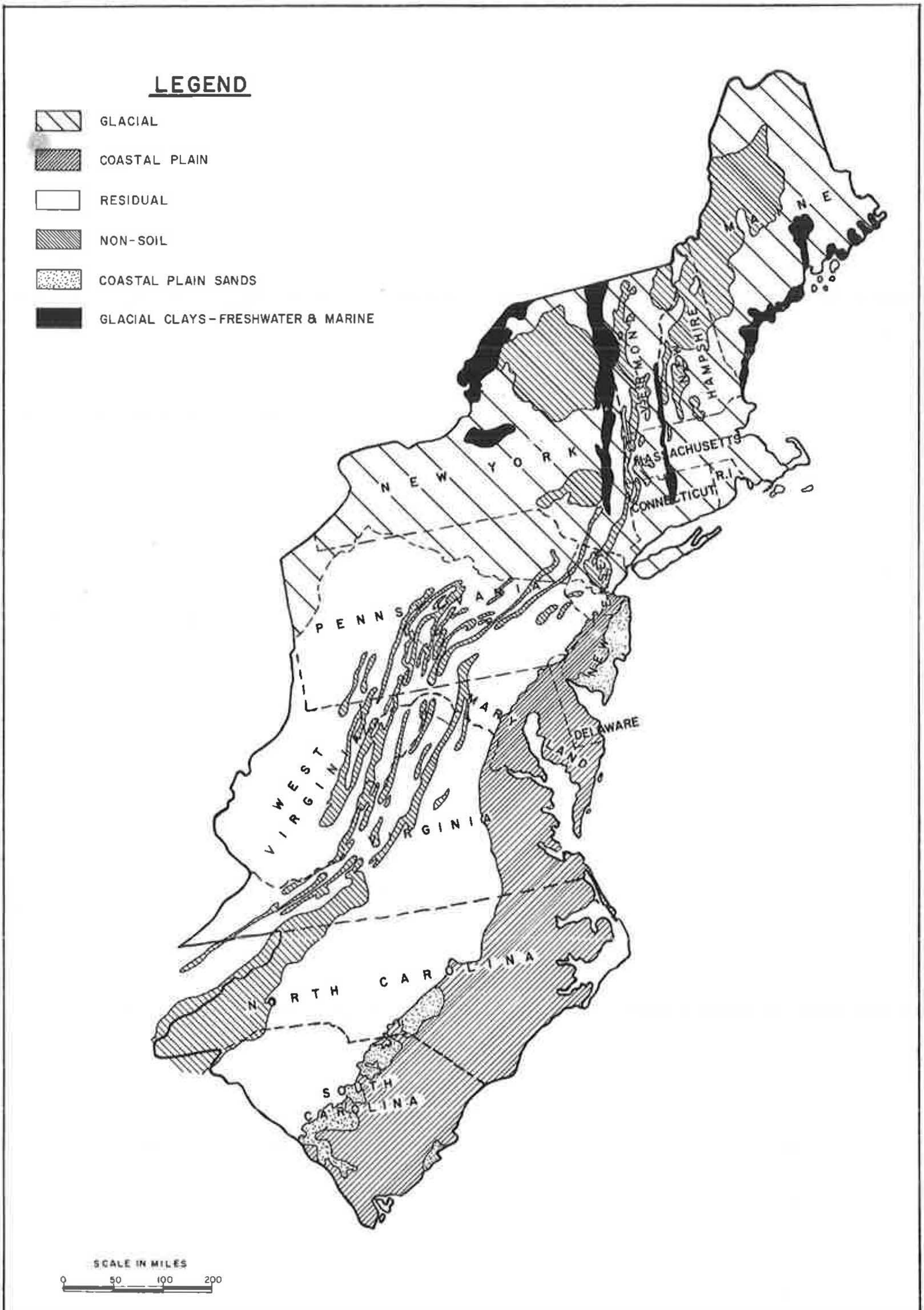

Figure 1. Soils map, Zone 1.

Minor deposits appear throughout the glaciated area, however, in small glacial lake sequences. Fresh water clays are usually varved; that is, they consist of a rhythmic alternation of clay and silt.

Marine glacial clays are not varved and are generally found interbedded with silt and sand. For the most part they are found immediately adjacent to the existing coast. However, in the Champlain Valley Lowland an immediate post-glacial incursion of the sea resulted in the deposition of large deposits of glacial marine clays in an area now quite distant from the sea.

Organic silts, clays, and peat, of both fresh water and marine origin, are found in the glaciated area. Because of their low strength and high compressibility, these soils are usually removed in highway construction, at least for the full depth of frost penetration. Therefore, they have no significance in the frost design problem.

Although glaciated areas in the East are not generally thought of as containing much loess, there are in fact large areas overlain by this material. These windblown, very fine sands and inorganic silts occur in relatively thin surface deposits compared to the great thicknesses found in some western and midwestern states. Eastern loessial deposits average 2 to 3 ft and rarely exceed 6 ft in thickness. As loess is a surface deposit, the topsoil (which may vary from a few inches to as much as 2 ft) is developed in this material and the thin horizon of loess remaining is not generally recognized as such. In addition, because most thin loessial deposits are well within the zone of frost action, gravel, cobbles and boulders have worked their way up into the loess from the underlying soils by frost action.

For the most part, the sand and gravel deposits found in the glaciated area contain materials that are non-frost susceptible or only slightly frost susceptible. These materials offer ideal subgrade conditions and serve as sources for base and subbase courses in highway construction. On the other hand, fresh water and marine glacial clays and inorganic silts are highly frost susceptible. These soils exhibit high frost heaving characteristics and severe loss in strength during frost melting periods.

In the subgrade of highway cuts, the transition zone between non-frost-susceptible and highly frost-susceptible soils, is critical from the standpoint of differential heaving. The occurrence of pockets or zones of inorganic silt within an otherwise non-frost-susceptible sand or gravel subgrade is commonly a source of abrupt changes in the pavement surface profile.

Coastal Plain

The soils in the coastal plain group form a complex assemblage of marine and terrigenous deposits. The complexity arises from their having been deposited during a period of continuing fluctuating sea levels ranging from the Cretaceous to the present. Fluvial sands and gravels were reworked by advances of the sea and intermixed or interbedded with marine clays and silts. These deposits were in turn eroded, reworked and redeposited by rivers during the retreat of the sea. The engineering properties of these soils may be expected to change rapidly both laterally and vertically.

Large areas of the coastal plain are overlain by sand. Large sand deposits occur adjacent to the coast along the fall line in Virginia and the Carolinas. They are the principal surface deposits in the coastal plain of New Jersey.

A number of geologic processes are responsible for the various sand deposits. Those in New Jersey are primarily glacial outwash, whereas coastal sands are essentially marine. Some of the fall-line sands are of marine origin; others are residual sands and have been reworked by the wind, for example, the Congaree sand hills of South Carolina.

Residual

In Zone 1, these soils are confined exclusively to the Piedmont and Appalachian plateau provinces of the Appalachian highland. These products of the chemical and mechanical weathering of rocks accumulate in relatively level or gently rolling bedrock areas. Since the climatic variation in the zone where residual soils are found is not great, the character of the parent bedrock material is the decisive variable that influences the following types of residual soils.

1. Sandy topsoils underlain by sandy clays are the characteristic soils derived from the crystalline rocks (granite, gneiss and gneissoid schist) in the Piedmont province.
2. The soluble carbonates of limestone rocks tend to dissolve and leach away leaving insoluble iron oxide and hydrous silicates. The resulting soils are reddish clays, which contain fragments of more or less unaltered limestone.
3. Micaceous schist generally weathers to friable sand soils, but the properties may vary from sand to clay dependent on the quantity and type of other minerals, particularly feldspar and quartz, in the parent material and on the degree of weathering.
4. Because shales are composed chiefly of relatively stable clay minerals, weathering can produce little change in their mineral composition. However, it can break the strong bonds produced by consolidation so that shales readily revert to soft clay soils.

The residual soils are for the most part frost susceptible.

Non-Soil Areas

In mountainous areas where stream gradients and topography are steep and erosion active, residual soils and the products of mechanical weathering are removed nearly as fast as they are formed and the bedrock is exposed at the surface. It should not be inferred that the area denoted as non-soil in Figure 1 is one vast bedrock outcrop. Within this area are stream valleys and their associate alluvial deposits which often attain a considerable thickness. In glaciated areas there are thin patches of till and high level kame deposits. High in the Appalachians, are small, relatively level meadow lands in which residual soils have accumulated. In general, however, the area is one in which there is little or no soil cover.

CLIMATE

The contours of air freezing index for the coldest year in 10 are shown in Figure 2. For example, the freezing index in Maine is ten times that which occurs in Virginia. Figure 3 shows the contours of freezing index for the coldest year in 30. Figure 4 shows the estimated depth of frost penetration into clean granular soils beneath pavements kept free of snow and ice for the coldest year in 10. Figure 4 was prepared from an empirical relationship between air freezing index and frost penetration by the Corps of Engineers (Fig. 5).

Average annual precipitation is shown in Figure 6. The amount of rainfall within this zone does not vary widely, the mean generally varying from about 35 to 50 in. per year. In the western portion of the Carolinas, however, a mean annual rainfall of up to 80 in. is recorded in a small area.

SURVEY OF DESIGN PRACTICE

A questionnaire (basically the same as prepared by Erickson for the western survey) was sent to each state highway department in Zone 1. Table 1 abstracts and summarizes the replies.

Frost is considered in the design of highway pavements in all states north of New Jersey. In some of these states, the variation in freezing conditions is appreciable. For example, there is approximately 2 ft greater frost penetration in northern New Hampshire and Vermont than in the southern parts of these states. The variation is somewhat greater in Maine. Delaware considers frost in Kent and New Castle counties only. Maryland considers frost only in Garrett and Alleghany counties (approximately 12% of the total state area with approximately 6% of the state routes). In North Carolina, the only areas where frost is considered a factor in the design of pavements are mountainous areas above approximate 2,500-ft elevation. South Carolina reports negligible frost effects. Georgia experiences only a few cycles of freezing; the maximum penetration into base course materials is a few inches. By emphasizing a free-draining base in the northern two-thirds of the state, the minor frost problem has been virtually eliminated.

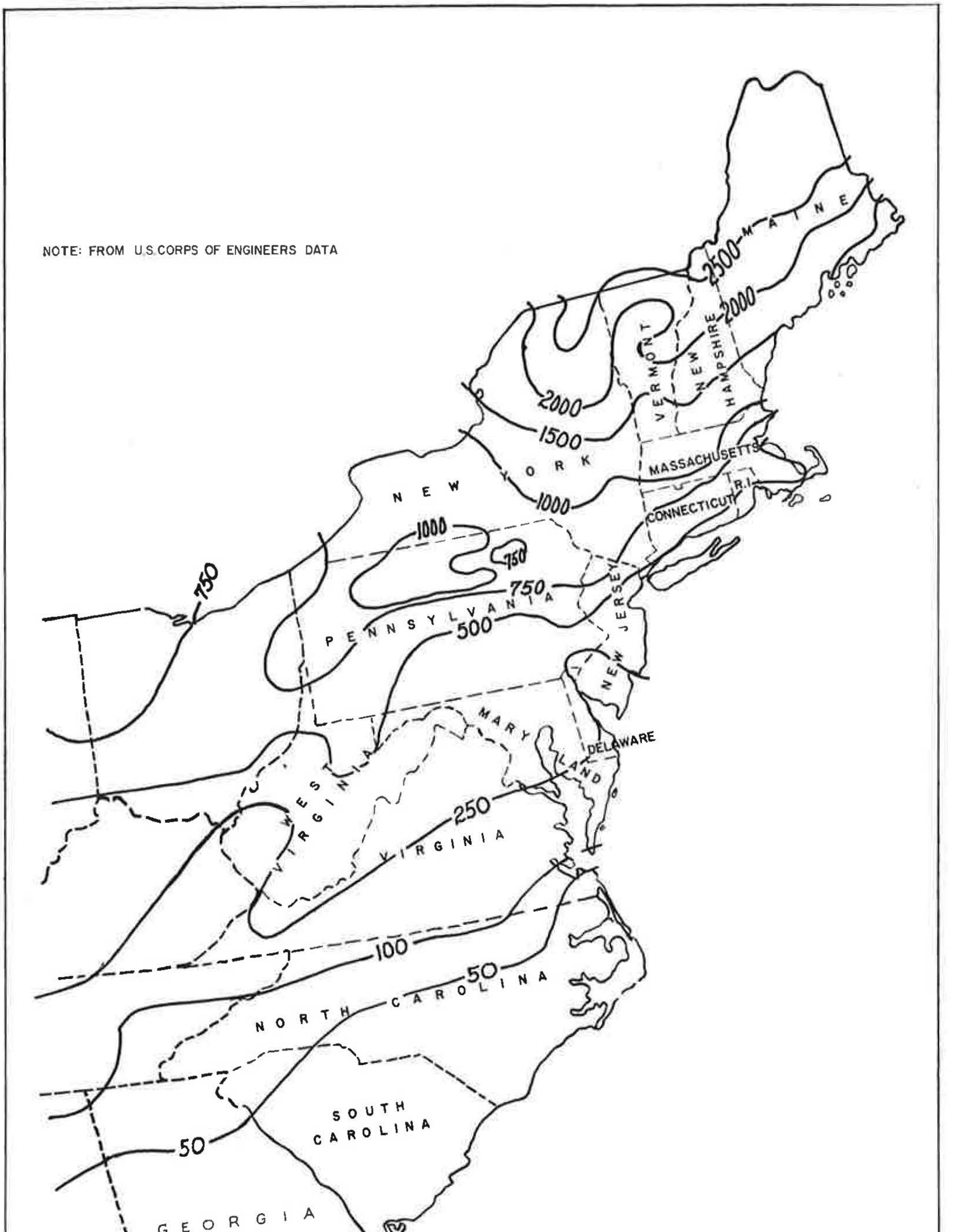

Figure 2. Air freezing index, coldest year in 10.

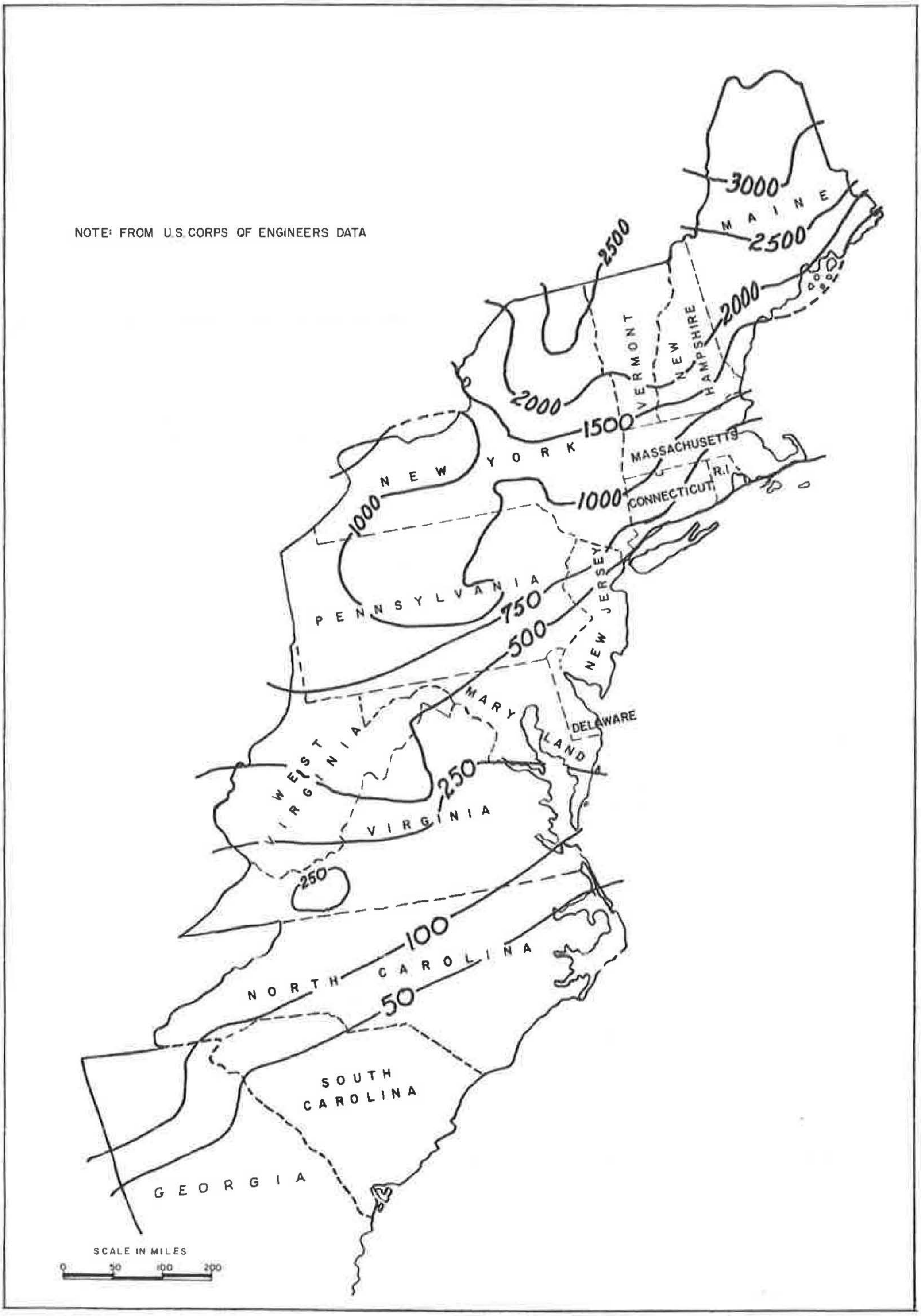

Figure 3. Air freezing index, coldest year in 30.

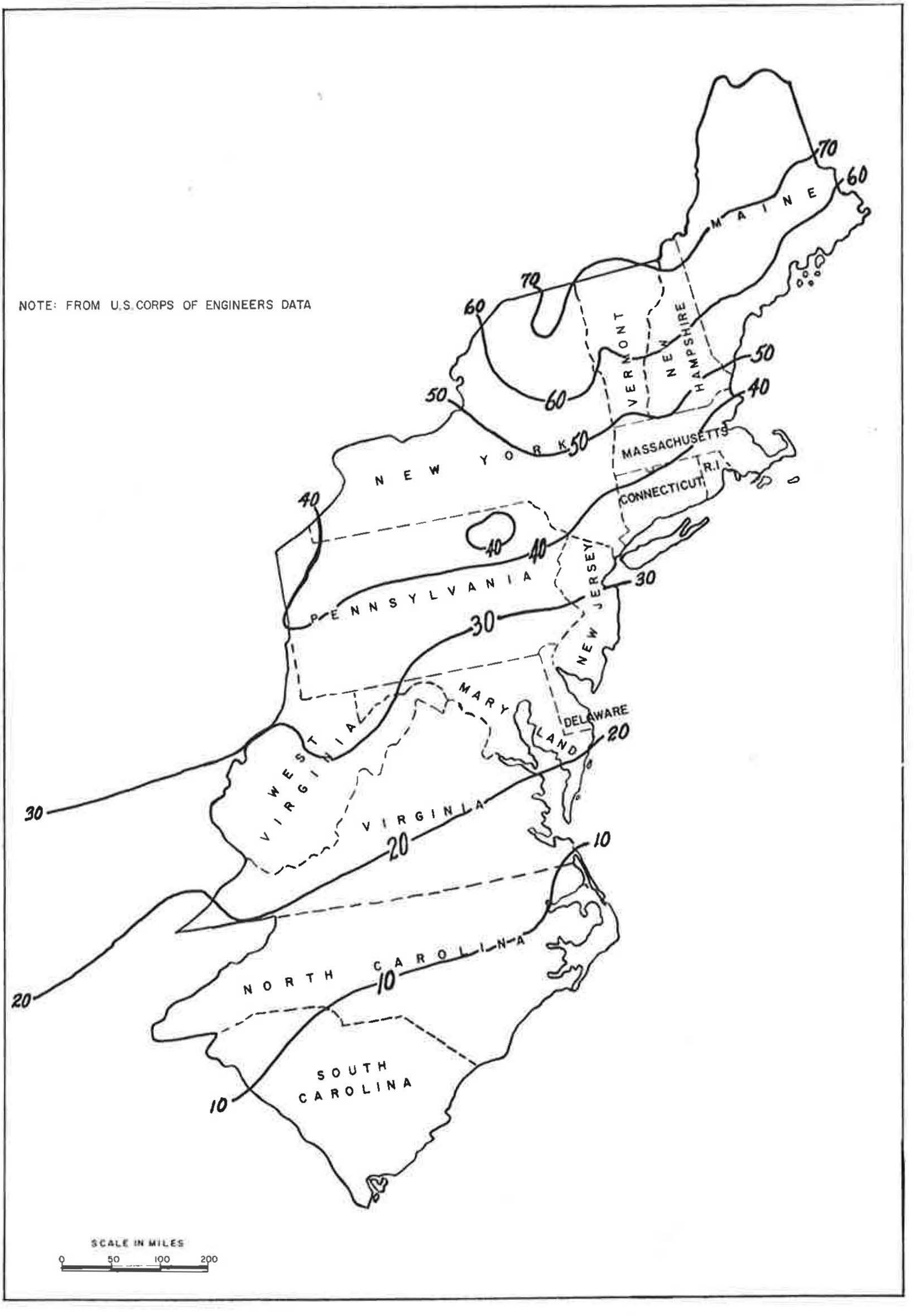

Figure 4. Frost penetration (in.) into clean, granular soils beneath pavements kept free of snow and ice.

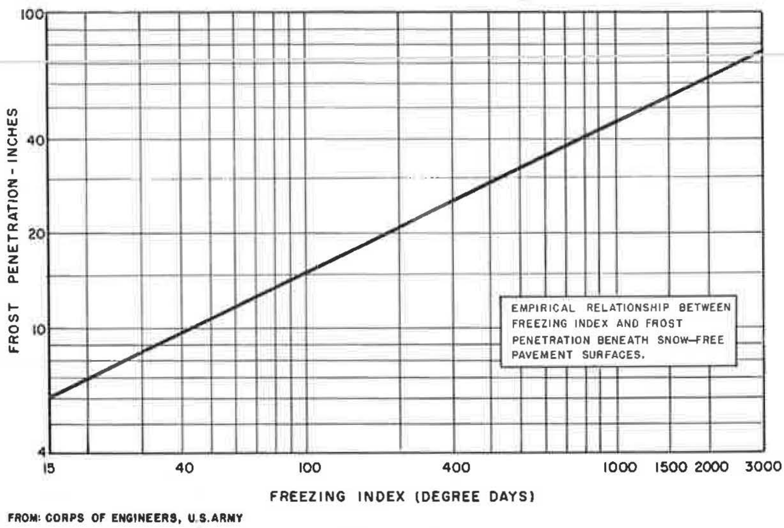

Figure 5

LOAD RESTRICTIONS

All heavy duty highways are being designed for unrestricted use in all seasons. Maine restricts the use of town and state aid roads during the thawing period when conditions warrant. The following is abstracted from a sign which the state posts to restrict the use of such roads:

> The State Highway Commission hereby closes from November 15, 1962 to May 15, 1963 all parts of such state and state aid highways, (including the bridges thereon) as will be in danger of abuse from the traffic hereinafter described:
>
> Travel by all motor trucks, tractors, trailers or other vehicles or objects, when
>
> 1. The gross weight of the vehicle (vehicle and load combined) exceeds the weights set forth in the following schedule:

Type of Vehicle	Allowable Gross Weight
2-axle truck	8 tons
3-axle truck	9 tons
2-axle tractor and 1-axle semitrailer	10 tons
2-axle tractor and 2-axle semitrailer	11 tons
3-axle tractor and 1-axle semitrailer	11 tons
3-axle tractor and 2-axle semitrailer	11 tons

> 2. The load imposed upon the road surface exceeds 400 pounds per inch width of tire (manufacturer's rating).
> 3. The vehicle or object has attached to its wheels (or such part of the vehicle as has contact with the road) any clamp, rib or other object likely to injure the surface of the highway.
>
> Provided, however, that this rule and regulation shall not apply to any particular closed way when the way is solidly frozen.

In New Hampshire, the principal roads are designed for the legal weight limit during the frost melting period, but the issuance of overweight permits is restricted during

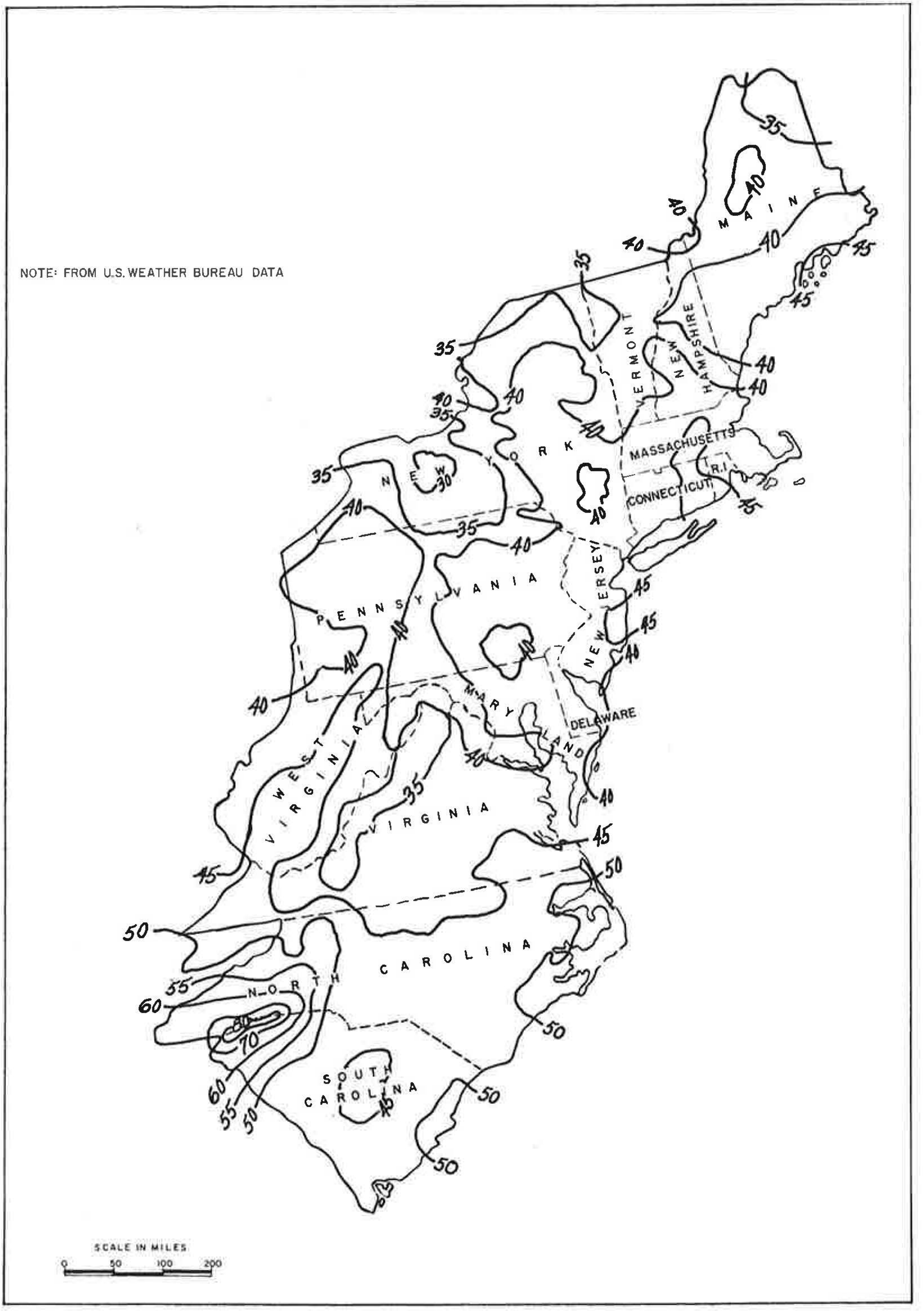

Figure 6. Average annual precipitation.

TABLE 1

FROST CONSIDERATIONS IN PAVEMENT DESIGN—EASTERN UNITED STATES

State	Frost Susceptibility Criteria	Subgrade Preparation	Drainage Criteria	Pavement Section	Remarks
Maine	Frost susceptibility is determined by running a grain size with a hydro meter analysis similar to the Corp. of Engineers classification. The #200 sieve is usually the controlling factor. H. R. B. Bulletin 71.	In general removal of frost susceptible soils is left up to the field engineer. In transition areas between varying types of soil the engineer can require undercutting and selective backfilling.	1. Side ditches are deepened by at least 1 ft. in problem areas. 2. Subgrades are carried for the full width of the roadway and sloped 1/4" to the foot. 3. Base thickness is increased and underdrains installed in shady areas under bridges where greater frost penetration occurs.	1. For both rigid and flexible pavements no ledge is allowed within 5 ft. of the finished grade. 2. Both rigid and flexible pavement sections are increased by 6" in cut sections.	1. Although there are no specifications to this effect, efforts being made to insure uniformity of subgrade soils to a depth of 4 ft. and to eliminate boulders 12" width in the area of frost action
New Hampshire	With respect to frost, soils are grouped from good to poor using the percent passing the #200 sieve as the criterion for grouping. No other tests are used. Soils broadly classed relative to frost heaving as follows - A2, Good less than 10% - #200 slight A2, Fair 10-20% - #200 moderate A2, Poor 25-35% - #200 severe A4, More than 35% - #200 remove for full depth of frost penetration.	Care is taken to see that frost susceptible soils, especially silts, do not lie within the zone of freezing after earthwork has been completed.	1. No special drainage controls are used other than typical use of ditches and free draining gravel. In areas where the subbase does not extend through the fill, gravel weepers are sometimes used to carry off excess water. This is only in areas where gravel fill is scarce. 2. Bottom of V-ditches are carried 4 ft. below the edge of the shoulder.	1. On all primary and interstate roads the thickness of pavement structure is based upon complete removal of all frost susceptible soils within the zone of freezing. 2. On lesser roads the heaving material is removed to a depth of 50% of the depth of frost penetration. 3. Sand subbase or blanket course are not considered to add strength to the pavement structure. 4. No rigid pavements are being built.	
Vermont	Mechanical and hydrometer analyses of soil are used. Soil is considered susceptible if more than 10% passes the #200 sieve or more than 3% finer than 0.02 mm. Other specifications for subbase and base materials include the #4, #100, and #270 sieves.	1. Types of material for backfilling are specified, but final decision lies with the field engineer. 2. Working mats of sand and gravel over wet fine grained soils are specified where needed.	1. Longitudinal underdrains below the subgrade line in conjunction with drainage ditches 9"-21" below roadway subgrade are used. Underdrains are outletted on slopes rather than in drainage structures. 2. Culverts are kept a minimum of 2 ft. below the subgrade to prevent a roadway depression during the winter months.	1. Design is fairly uniform throughout the state. Depths of frost free material used range from 18 to 42 inches. 2. Sand and gravel subgrades require 1 to 2 ft. less thickness of pavement section. 3. Pavement structure thickness is not varied between cuts and fill sections. 4. A one mile test section of rigid pavement is now being studied to evaluate subgrade requirements.	
Massachusetts	Soils with 15% or more passing the #200 sieve are considered frost susceptible.	1. The appearance of a susceptible soil does not influence embankment design, however no fill can be placed on frozen soil. 2. Specifications include what type material is to be removed and what is to be used as backfill. 3. In embankments the poorer material is sandwiched between layers of select granular material.	1. In areas of high ground water such as ledge, cuts and lowlands, both increased subbase thickness and underdrains are utilized.	1. Total flexible pavement structure is determined using an average frost penetration and applying it to the AASHO formula. 2. Rigid pavement structures are a constant 8" thickness underlain by a minimum 12" gravel layer. 3. A proposed revision to specifications advocates the use of a 2 ft. layer of granular fill at the top of embankments. 4. Pavement structure thickness is not varied between cuts and fills.	

TABLE 1 (Continued)

State	Frost Susceptibility Criteria	Subgrade Preparation	Drainage Criteria	Pavement Section	Remarks
Rhode Island	No criteria reported.	No specific details reported.	No specific details reported.	No specific details reported.	Pavement sections being used with substantial bases and subbases have practically eliminated frost problem. Minor maintenance on older secondary roads.
Connecticut	1. 3" or 6" increases in subbase thickness in questionable cases for heavy-duty roads. 2. In the northern half of the state subbases are often 6" thicker than the minimum. In the N.W. corner of the state the subbase is often increased 12" thicker than the specified minimum. 3. For silt and clay subgrades in the frost zone the subbase is increased 6" or 12"±.	1. Susceptible soils are identified through use of Casagrande's criterion. 2. Requirements for subbase material include material having less than 10% passing the #100 sieve and that the soil be non-plastic.	1. Subbase extends laterally to meet underdrain, if any, in cuts or ditch; in fills to meet embankment slope. Ditch invert 6" below subgrade surface. 2. Where G.W.T. is 3 ft. below frost zone in glacial till and 6 ft. in silts and clays, it is not considered to affect frost action. Only surface water would be a problem. 3. Where the G.W.T. is 4 ft. below the pavement, underdrains are placed 5 ft. below the pavement or ditches 4 ft. below the pavement.	1. For heavy duty roads the pavement and base = 13", subbase = 10" minimum for all cuts and fills except rock cuts where the minimum subbase = 18". 2. For other secondary roads the pavement thickness = 8" with a subbase varying from 6" to 18" depending on embankment or cut conditions. 2. For further information see "Subgrade Preparation."	
New York	1. The basic criterion is to obtain uniformity of the subgrade in the zone of freezing. 2. Granular materials are a separate pay item and are used to replace excavated susceptible soil when called for on the plans or as by order of the engineer. 3. Often times use of granular material is dictated by need of a working mat rather than the presence of frost susceptible soils. 4. A granular filter course is used over fine grained soils to prevent intrusion into the subbase or base.	1. Potentially frost susceptible soil is that having more than 3% passing the 0.02 mm. sieve. 2. Subbase materials must have less than 10% passing the #200 sieve and a plasticity index no greater than 3.	1. Every means within economical reason is taken to keep the water table below the zone of freezing under the pavement. 2. All subbase courses extend across the entire roadway section. 3. The invert of side ditches is carried a minimum of 24" below the top of the subgrade or 48" below the top of the pavement.	1. Pavement structures are designed based on an evaluation of performance of similar pavements under similar conditions. 2. Selected backfill where unstable soils are encountered is not considered as part of the structure and is considered to impart strength to the roadway during construction only.	Standardized treatment and criteria in this field are impossible, impractical and/or uneconomical. Success of finished work depends mainly on skill, experience and judgment of Engineer.
New Jersey	1. Frost susceptible materials are excavated, as shown on plans or directed by the engineer and selected backfill is placed. 2. The "Vicksburg" filter criteria is used to check intrusion of fine grained soils into the subbase. 3. Subbase and base courses extend for the full width of the roadway cross section.	1. The Casagrande and Corps of Engineers criteria are used to determine frost susceptibility.	1. In areas where the G.W.T. is a problem, french drains are installed in a herringbone pattern beneath the pavement, along the longitudinal edge of the pavement, at the toe of cut slopes or in the slopes. 2. Low points of subbase materials are drained either to the edge of the embankment or catch basins by modified french drains. 3. Storm drains used are comparable to city street designs.	1. The total pavement structure for flexible and rigid pavements is usually equal to the depth of the zone of frost penetration. 2. No differing criteria for varying soils is used. 3. When rock embankments are constructed the gradations are specified such that the top course is considered as part of the flexible pavement.	

TABLE 1 (Continued)

State	Frost Susceptibility Criteria	Subgrade Preparation	Drainage Criteria	Pavement Section	Remarks
Delaware	1. Frost susceptible soils are those which have more than 35% passing the #200 sieve. 2. Susceptibility is considered to increase with an increasing % passing the #200 sieve and decreasing plasticity.	1. If frost susceptible soil is located within 26" of the proposed pavement it is excavated and backfilled according to plans and specifications. If susceptible soil is discovered, below this depth, during construction it is not removed unless it is unstable. 3. All materials used for base and subbase are specified to be non-frost susceptible.	1. No special design considerations are used when the G. W. T. is within susceptible soil. It is assumed that a water source will always be available to frost susceptible soil. 2. Ditches are made deeper in frost areas to intercept drainage.	1. Frost is considered to be a problem in Kent and New Castle counties only.	1. If the design depth of both flexible and rigid pavements by any method is less than the frost penetration the subbase thickness is increased so that the total structure thickness is equal to the maximum depth of frost penetration. 2. Both full width and box construction are used when placing base courses.
Maryland	1. Frost susceptible soils are determined through use of the Corps of Engineers criteria.	1. In frost areas, susceptible soil is excavated to a depth as determined by the engineer and then backfilled with locally available materials. 2. A 2" compacted blanket is used over fine materials to prevent intrusion.	1. Different drainage plans are used, but generally not for reasons of frost.	1. The total pavement structure is thicker in areas of fine grained soils due to possibility of frost action. 2. Reference is made to Corps of Engineers frost criteria.	1. The main criteria used with respect to frost is a reliance on engineering and experience. 2. Frost is a problem in Garrett, and Allegany counties only.
Virginia	1. Silty micaceous soil is considered frost susceptible, but no design criteria with regard to frost is used in this state.	1. No special consideration is given for frost effects. Design is based on elimination of saturated material only.	See "Subgrade Preparation."	1. See "Subgrade Preparations." 2. On some high-type roads sufficient select subbase material is provided to overcome an 18" frost penetration. (See "Remarks")	1. Frost considerations in northern part of state only.
West Virginia	1. Frost susceptibility is determined by use of the Corps of Engineers classification system, and the HRB criteria. 2. The amount of material finer than 0.02 mm is the controlling factor.	1. Location of frost susceptible soil in a horizon not considered critical. 2. Placement of selective soil is not provided for in design.	In frost areas ditches are deepened when economically feasible. 2. No special drainage criteria in frost areas.	1. The Bergren formula is used to calculate depth of penetration. 2. Material used for capping rock-embankments must have no stones 3" and must be compactable.	1. Choice of materials to be used is the decision of the field engineer acting upon advice from a soils engineer. 2. Univ. of West Virginia conducting frost research at this time.
North Carolina	1. Frost susceptible soil is that which has more than 3% finer than 0.02 mm.	1. The location of frost susceptible material in a horizon is not considered critical.	No special drainage criteria exists for frost susceptible areas.	No special pavement criteria exists for frost susceptible areas.	1. Frost is a problem in areas above 2500 ft. in elevation only.
South Carolina					1. Frost is not a design consideration.
Georgia	1. No frost susceptibility criteria exists.		Shoulder to shoulder granular subbase is provided mainly in the northern two-thirds of the state.		1. Frost is not a design consideration.

NOTES:

1. LOAD RESTRICTIONS - All states design their roads for unrestricted use except Maine, New Hampshire, and New York which may restrict heavy traffic on some of their secondary roads during the spring melt period.

2. GENERAL FROST CONSIDERATIONS - All states consider frost in pavement design except as noted in the "Remarks" column.

this period. New York State may post town and county roads during the critical frost melting period.

FROST SUSCEPTIBILITY CRITERIA

Most Zone 1 states use the so-called Corps of Engineers' or Casagrande criterion for evaluating whether or not a soil is frost susceptible. Such a determination involves sieve and hydrometer tests to determine the percentage by weight finer than the 0.02-mm fraction.

In Massachusetts, the proposed revision to the state specifications limits the percent passing the No. 200 mesh sieve to 15 percent. In the author's opinion, gravels with fines near the 15 percent value could be frost susceptible. Although the amount of heaving in such soils would be relatively minor, the loss of shear strength during the thawing period could be quite significant. In Delaware, the upper limit is specified as 35 percent passing the No. 200 sieve. Based on cold room tests at the Corps of Engineers Frost Effects Laboratory, it is believed that soils in this upper limit would be susceptible to heaving and weakening. In Virginia, the relatively common silty micaceous soil is considered to be frost susceptible but a criterion based on grain size is not used.

ADMIXTURES

The questionnaire requested information on the use of admixtures to control or minimize frost susceptiblity of soils. Most Zone 1 states have not used such admixtures; for those states that have, the results generally have not been promising except for portland cement. In Maine, a test section is undergoing its first cycle of freezing; a dirty base material was treated with calcium chloride, lime, and sulfite liquors. New Hampshire has tried calcium chloride and sulfite liquors on a limited scale. Due to the permeable nature of the soils, however, the effect of these admixtures was lost after the first spring. No admixture used to date except soil cement has survived the spring thaw.

Connecticut highway maintenance crews placed calcium chloride flakes and brine in a limited area after drilling 2-in. diameter holes approximately 3 ft on centers through both flexible and rigid pavements. The benefits from this treatment were inconclusive. Maryland reports that portland cement in silt soils, and lime in clay soils have been successful in improving the supporting value and the frost heave control of frost-susceptible soils. North Carolina has used sodium chloride beneath bituminous surface treatments and thin plant-mix pavements and reports that its use has been satisfactory. However, such admixtures are not used beneath asphaltic concrete pavements 3 in. in thickness and over. Georgia has added portland cement to the native soils to stabilize and waterproof base materials for secondary roads. There is no record of failure of such materials due to freezing and thawing.

In summary, the use of admixtures has received relatively limited acceptance. The most commonly used admixture, and the one apparently most successful, has been portland cement.

DRAINAGE

The questionnaire answers were unanimous as to the importance attached to drainage. The vast majority of the states report that base and subbase courses are extended laterally in cuts to meet the underdrain, if any, or ditch; and in fills, to meet the embankment slope. Some states, such as New Hampshire, report that in areas where gravel is in short supply, gravel weepers may be designed to carry off the accumulated water. This, however, is not the customary practice.

Several states report that when the groundwater table is near the surface of the more frost-susceptible soils, the side ditches are lowered or subsurface drains are installed at the shoulder. The surface of the subgrade is sloped to permit drainage of the base material. Two states report occasional use of herringbone drainage systems under pavement areas.

Several states attempt to lower the water table in the frost-susceptible subgrade on the more important roads; however, this practice is not generally used on secondary roads because of the expense involved.

PAVEMENT SECTION

The answers to the questionnaire indicated that standard criteria for thickness of pavement base and subbase over certain types of soils within a state are not generally used. In New Jersey and other states to the south, the total thickness of pavement and base used for heavy-duty roads is generally equal to or greater than the depth of frost penetration. The use of a free-draining base material has generally become the accepted practice in these states.

Full protection against the penetration of freezing temperatures into frost-susceptible subgrades in the northern states requires very thick sections. In the more frost-susceptible soils, such as the inorganic silts in New Hampshire and the varved clays in the Connecticut River valley, combined thickness of pavement and base used on the more recent projects is equal to the anticipated depth of frost penetration.

In many instances the thick subbase courses are specified for reasons that are not exclusively concerned with frost action. The need of a thick working platform in order to operate construction equipment for construction of base courses and pavements dictates a greater thickness of subbase than would normally be required to prevent frost penetration in the subgrade. On a recently constructed Interstate route in western Massachusetts, construction personnel requested that the design include a 36-in. thick gravel working platform over varved clay subgrades and a 24-in. working platform over inorganic silts. For stability under construction equipment, the Massachusetts personnel prefer the use of gravel for the working platform. In a recent project in Connecticut, a 21-in. sand working platform was used over varved clay of medium consistency.

In New York, plans usually indicate the removal of soils anticipated to be unstable for construction conditions in cuts. The purpose is to obtain a stable working platform for construction operations, not frost considerations. However, most unstable soils are frost susceptible to a considerable degree. The marine and glacial lake clays and silts in northwestern New York would generally require a thick working platform. Although some of the states report that they do not consider the working platform as adding to the structural strength of the pavement, they are unquestionably of great benefit in preventing loss of pavement supporting capacity.

SUMMARY

The survey of frost design practices in the eastern states indicates that all of the states have established criteria for designing pavements to resist the detrimental effects of frost action. Although in design approach and detail the criteria may vary from state to state, the objectives and end results have a marked similarity.

Many design measures that are employed for reasons other than frost action are of benefit to the frost problem. On the other hand, some of the design procedures that are made primarily for the purpose of protecting pavements against frost action have other benefits. Thicker free-draining non-frost-susceptible base courses to attain adequate pavement supporting capacity during the frost melting period also improve the strength and durability of pavements under normal use. The advantages of a free-draining base as compared to a base with a relatively high percentage of clay and silt are not confined to the frost problem. Water entering the free-draining base course at the pavement edges or through joints and cracks in the pavement surface will be less detrimental to pavement supporting capacity during all seasons of the year.

It is believed that drainage trenches and ditches at the edges of wide expressways have little effect on the magnitude of frost heaving, particularly in the more fine-grained frost-susceptible soils. An exception to this would be a drain to intercept flow from a side-hill cut. The primary benefit derived from drainage trenches and ditches at the pavement edge is more rapid drainage of water released into the base course by frost melting. This drainage would tend to reduce the length of the critical period of subgrade weakening and the resultant loss of pavement supporting capacity.

ACKNOWLEDGMENTS

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