CHAPTER 3

INVESTIGATION OF POTENTIAL FOR ICE SEGREGATION

3-1. Investigation procedure. The field and laboratory investigations conducted in accordance with EM 1110-3-141 will usually provide enough information to determine whether a given combination of soil and water conditions beneath the pavement will be conducive to frost action. Particular attention should be given to the degree of horizontal variation of subgrade conditions. This involves both soil and moisture conditions and is difficult to express simply and quantitatively. Subgrades may range from uniform conditions of soil and moisture that will result in negligible differences in frost heave, thaw settlement, and supporting capacity, to extremely variable conditions. These variable conditions may require extensive processing of subgrade materials to eliminate the frequent and very abrupt changes between high and low frost heave and high and low strength loss potentials. Following is a summary of procedures for determining whether or not the conditions of soil properties, temperature, and moisture that are necessary for ice segregation are present at a proposed site. In addition to assessing the potential for detrimental frost action, consider all reliable information about past frost heaving of airfield and highway pavements already built in the area.

3-2. Temperature. Air freezing index values should be based on actual air temperatures obtained from the meteorological station closest to the construction site. This is desirable because differences in elevation, topographical position, or nearness to bodies of water, cities, or other sources of heat may cause considerable variation in air freezing indices over short distances. These variations are of greater relative importance in areas of design freezing index of less than 1,000 degrees F.-days (i.e., mean air freezing index of less than about 500 degrees F.-days) than they are in colder climates.

a. Daily maximum and minimum and mean monthly air temperature records for all stations that report to the U.S. National Weather Service are available from Weather Service Centers. One of these centers is generally located in each state. The mean air freezing index may be based on mean monthly air tempertures, but computation of values for the design freezing index may be limited to only the coldest years in the desired cycle. These years may be selected from the tabulation of average monthly temperatures for the nearest first-order weather station. (A Local Climatological Data Summary, containing this tabulation for the period of record, is published annually by the National Weather Service for each of the approximately 350 U.S. first-order stations.) If the temperature record of the station closest to the construction site is not long enough to determine the mean or design freezing index values, the available data should be related, for the same period, to that of the nearest station or stations of adequate record. Site air freezing index values can then

be computed based on this established relation and the indices for the more distant station or stations.

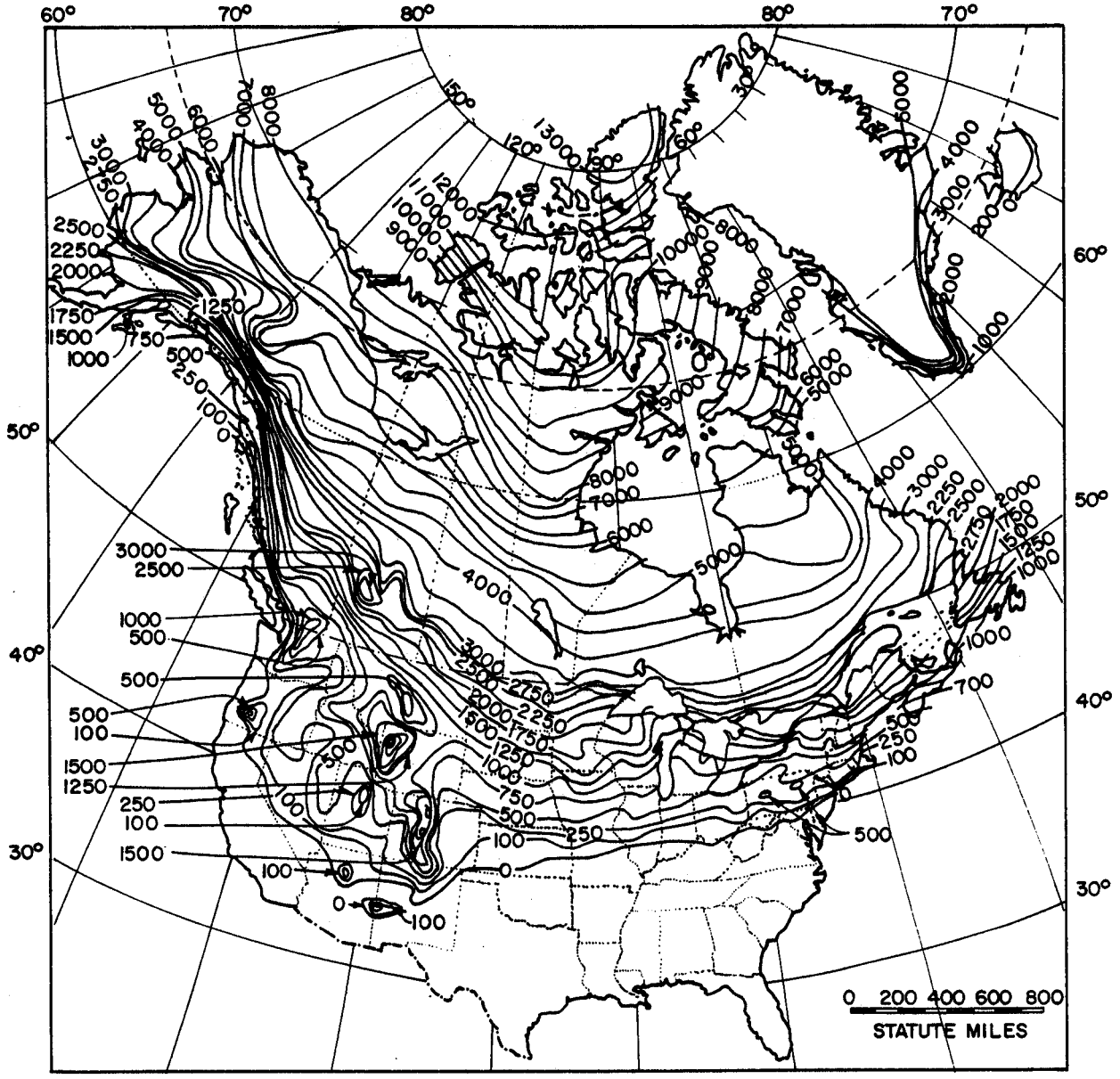
b. The distribution of freezing indices in North America is illustrated by figures 3-1 and 3-2. The figures show isolines of air freezing index values for the normal year (mean air freezing index), and the average of the 3 coldest years in 30 or the coldest year in 10 (design freezing index). Relationships between mean air freezing indices and values computed on various other statistical bases are shown in figure 3-3. For designing pavements, the design air freezing index should be calculated from available air temperatures or estimated from figure 3-2.

3-3. Depth of frost penetration. The depth of which subfreezing temperatures will penetrate below a pavement kept clear of snow and ice depends principally on the magnitude and duration of below-freezing air temperatures, on the properties of the underlying materials, and on the amount of water that becomes frozen. Curves in figure 3-4 may be used to estimate depths of frost penetration beneath paved areas kept free of snow and ice. They have been computed for an assumed 12-inch-thick rigid pavement, using the modified Berggren equation and correction factors derived by comparison of theoretical results with field measurements under different conditions. The curves yield the maximum depth to which the 32 degrees F. temperature will penetrate from the top of the pavement under the total winter freezing index values in homogeneous materials of unlimited depth for the indicated density and moisture content. Variations due to use of other pavement types and of rigid pavements of lesser thicknesses may be neglected.

a. The curves in figure 3-4 are not applicable for determining transient penetration depths under partial freezing indices. For specific problems of this type, the fundamental equations of heat transfer are applicable, for which various numerical solutions are available.

b. Maximum seasonal frost penetration depths obtained by use of figure 3-4 should be verified whenever possible by observations in the locality under consideration.

3-4. Water. A potentially troublesome water supply for ice segregation is present if the highest ground water table or a perched water table is, at any time of the year, within 5 feet of the proposed subgrade surface or of the top of any frost-susceptible subbase materials used. A water table less than 5 feet deep indicates potential ground moisture problems. When the depth to the top of the water table is in excess of 10 feet throughout the year, ice segregation and frost heave may be reduced, but special subgrade preparation techniques are still necessary to make the materials more uniform. Silt subgrades may retain enough moisture to cause significant frost heave and thaw weakening even when the water table is



NOTES

Design freezing index values are cumulative degree days of air temperature below 32 degrees F. for the coldest year in a 10-year cycle or the average of the 3 coldest years in a 30-year cycle.

The isolines of design freezing index were drawn using data from nearly 400 U.S. Weather Bureau Stations. The map is offered as a guide only. It does not attempt to show local variations, which may be substantial, particularly in mountainous areas.

The actual design freezing index used should be computed for the specific project using temperature data from station nearest site.

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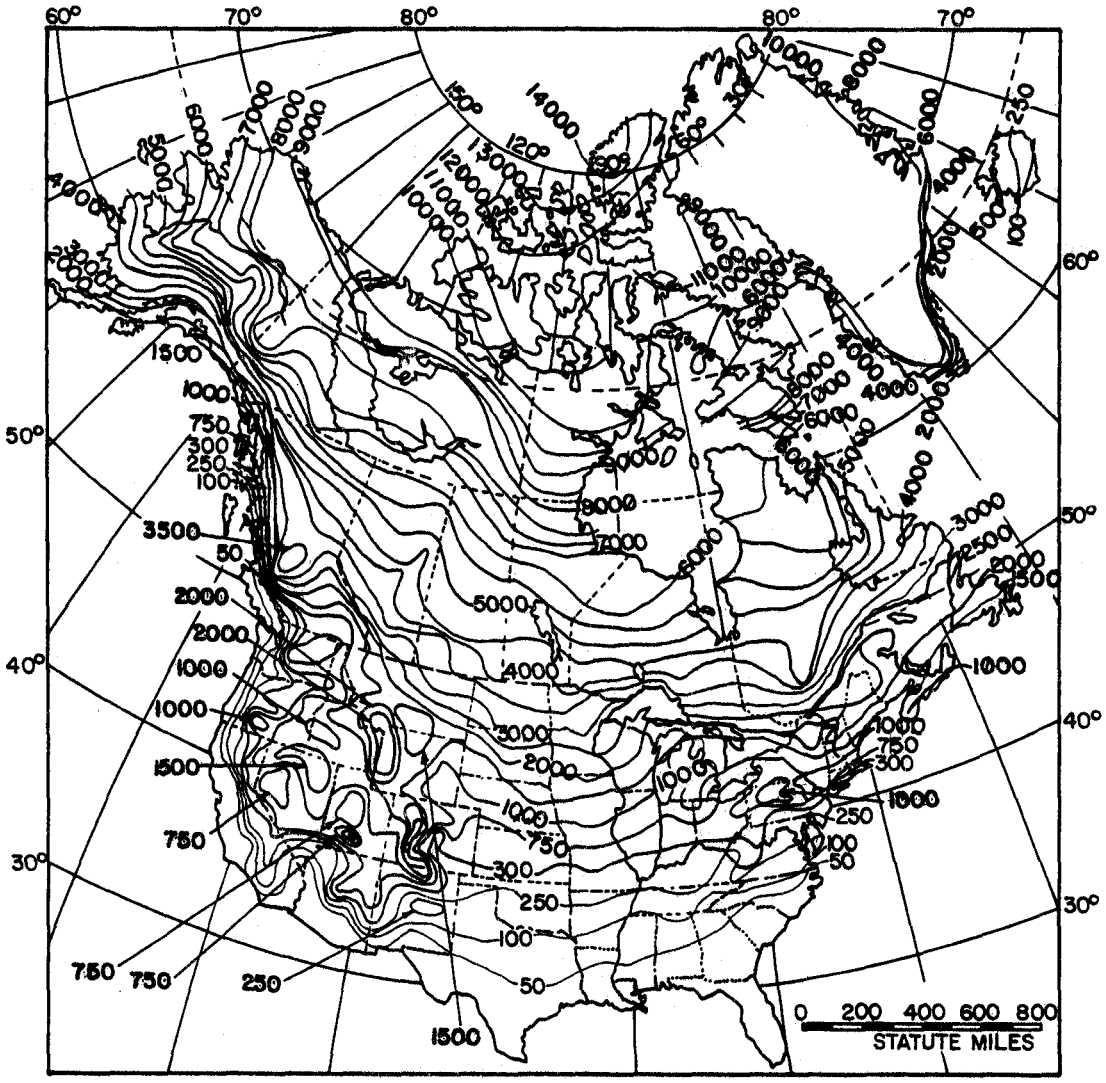
FIGURE 3-1. DISTRIBUTION OF MEAN AIR-FREEZING INDEX VALUES IN NORTH AMERICA



Notes

Design freezing index values are cumulative degree days of air temperature below 32 degrees F. for the coldest year in a 10-year cycle or the average of the 3 coldest years in a 30-year cycle.

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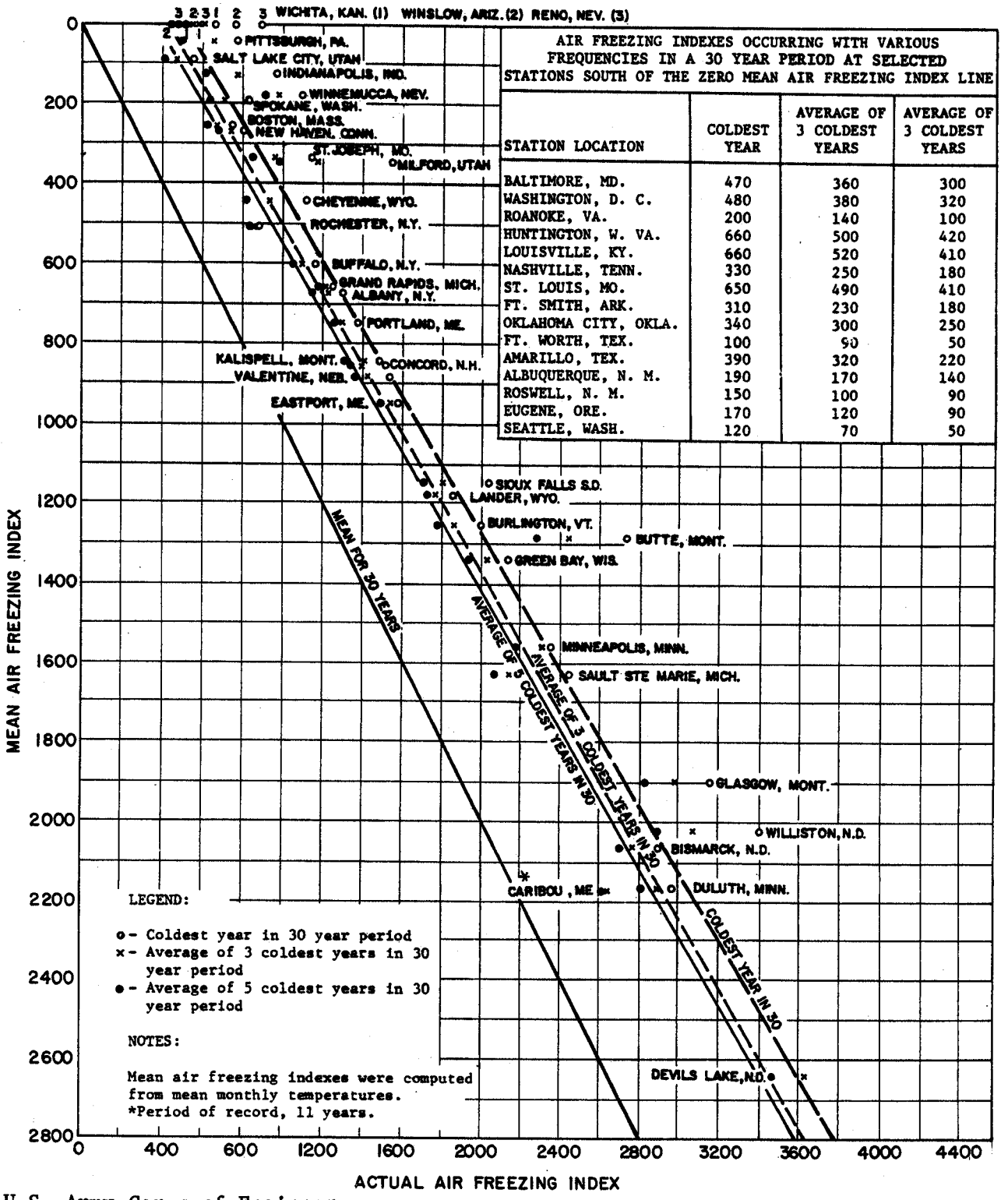
FIGURE 3-2. DISTRIBUTION OF DESIGN AIR-FREEZING INDEX VALUES IN NORTH AMERICA



AIR FREEZING INDEXES OCCURRING WITH VARIOUS FREQUENCIES IN A 30 YEAR PERIOD AT SELECTED STATIONS SOUTH OF THE ZERO MEAN AIR FREEZING INDEX LINE

STATION LOCATION	COLDEST YEAR	AVERAGE OF 3 COLDEST YEARS	AVERAGE OF 3 COLDEST YEARS
BALTIMORE, MD.	470	360	300
WASHINGTON, D. C.	480	380	320
ROANOKE, VA.	200	140	100
HUNTINGTON, W. VA.	660	500	420
LOUISVILLE, KY.	660	520	410
NASHVILLE, TENN.	330	250	180
ST. LOUIS, MO.	650	490	410
FT. SMITH, ARK.	310	230	180
OKLAHOMA CITY, OKLA.	340	300	250
FT. WORTH, TEX.	100	90	50
AMARILLO, TEX.	390	320	220
ALBUQUERQUE, N. M.	190	170	140
ROSWELL, N. M.	150	100	90
EUGENE, ORE.	170	120	90
SEATTLE, WASH.	120	70	50

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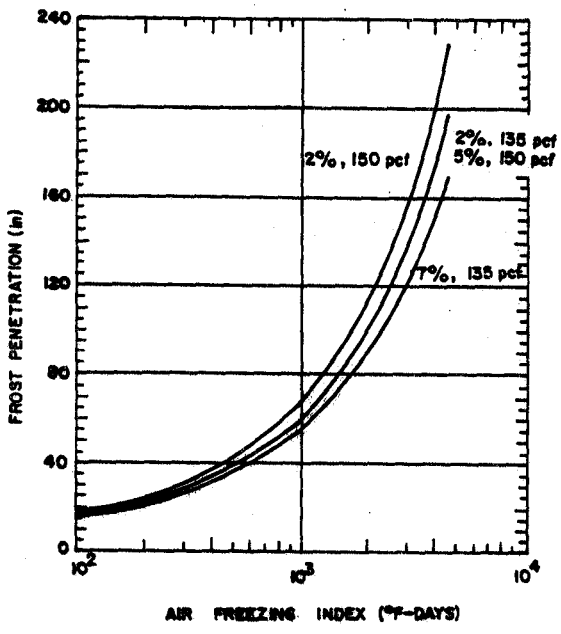
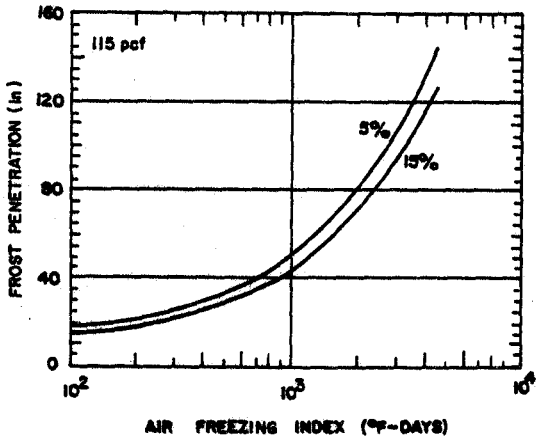
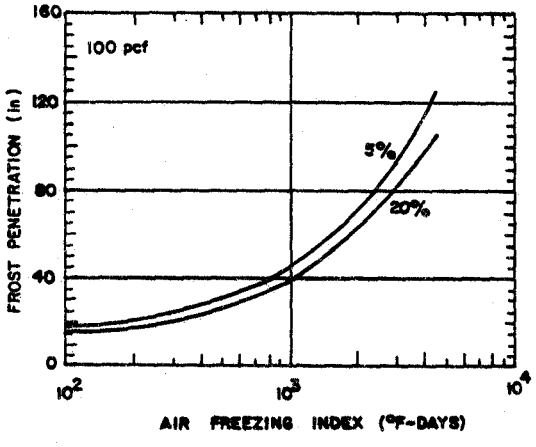
FIGURE 3-3. RELATIONSHIPS BETWEEN MEAN AND OTHER AIR-FREEZING INDICES



A. 135 pcf AND 150 pcf MATERIAL



B. 115 pcf MATERIAL



C. 100 pcf MATERIAL

NOTES:

1. Frost penetration depths are based on modified Berggren formula and computation procedures outlined in USACRREL Special Report 122.
2. Frost penetration depths are measured from pavement surface. Depths shown are computed for 12-inch PCC pavements kept free of snow and ice, and are good approximations for bituminous pavements over 6 to 9 inches of high quality base. Computations also assume all soil beneath pavements within depths of frost penetration is granular and non-frost-susceptible with indicated dry unit weight and moisture content.
3. It was assumed in computations that all soil moisture freezes when soil is cooled below 32 degrees F.
4. Dry unit weight and moisture content (in percent) given on figures.
5. For pavement design, use design freezing index (para 1-2b and 3-3).

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FIGURE 3-4. FROST PENETRATION BENEATH PAVEMENTS

more than 10 feet below them. Special precautions must be taken when these soils are encountered and a relatively thin pavement section is planned, e.g., all-bituminous concrete. The water content that homogeneous clay subgrades will attain is usually sufficient to cause some ice segregation, even with a remote water table. Closed-system laboratory freezing tests that correspond to a field condition with a very deep water table usually indicate less severe heaving than will actually take place. This is because moisture contents near complete saturation may occur in the top of a frost-susceptible subgrade from surface infiltration through pavement and shoulder areas or from other sources.