Thaw Weakening of Pavement Structures in Seasonal Frost Areas

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Pavement structures in the northern United States, Canada, Scandinavia, and other seasonal frost areas of the world are subject to freezing in winter and thawing in spring. Most damage to pavements in seasonal frost areas occurs during the spring thaw and, to a lesser extent, during partial thaw periods in winter. To minimize damage, pavement engineers must be able to determine the structural capacity of road and airfield pavements during thawing periods. Four pavement test sections were built in the Frost Effects Research Facility at the U.S. Army Cold Regions Research and Engineering Laboratory in Hanover, N.H., to study the performance of various pavement structures subjected to freeze-thaw cycling. The test sections consisted of asphalt concrete pavement over a clay subgrade, asphalt concrete over crushed gravel on a clay subgrade, asphalt concrete over 178 mm of crushed gravel and 203 mm of clean sand on a clay subgrade, and asphalt concrete over 254 mm of crushed gravel and 127 mm of clean sand on a clay subgrade. Thermocouples were embedded throughout the pavement structure and subgrade, and the pavement structure was subjected to several freeze-thaw cycles. Deflection measurements taken during the thawing periods at four locations in each test section used a Dynatest falling-weight deflectometer (FWD) to validate existing back-calculation procedures for pavements subject to seasonal frost. Soon it became apparent that the back-calculation procedures had difficulties. Another study was initiated to determine if additional information pertaining to freeze-thaw cycling could be obtained from the FWD measurements. The results of the second study are presented.

A pavement evaluation procedure reveals the allowable traffic that a pavement can support for a given loading condition or the allowable load for a given amount of traffic. This allowable traffic is assumed to be applicable at any time of the year, which may be an adequate approximation in non-frost areas. However, seasonal changes in the thermal and moisture regimes of a cold regions pavement structure can greatly affect its (the structure's) bearing capacity and substantially change the allowable traffic loads.

Pavement structures in seasonal frost areas are subjected to freezing in winter, thawing in spring, and intermittent thawing during the winter season. In the winter, the pavement structure modulus increases because of ice bonding of particles in the unbound base and subgrade and in the asphalt layer because of the influence of temperature on the viscosity of the asphalt. During spring thaw, the pavement foundation can become saturated with water from thawing ice lenses, thus reducing the structural adequacy of the base or subgrade, or both. The permeability of the subgrade and existing frozen layers can restrict the drainage of excess water. Therefore, one can expect most damage to occur during the spring thaw period and, to some extent, during the partial winter thaws. Damage to the pavement structure will reveal itself on the surface in the form of fatigue cracking and rutting caused by deformation in the base or subgrade. The length of time a pavement structure is subjected to thaw weakening will vary depending on the frost depth, soil type, degree of saturation, and drainage conditions (*1–5*).

There are several ways to determine pavement strength during thaw. Strength determinations can be made by using destructive methods, such as coring in conjunction with laboratory testing; with the present types of nondestructive testing equipment, for example a falling-weight deflectometer (FWD); or with existing estimated reduction factors (*6–8*). Reduction factors that have been applied in the spring vary from 50 to 85 percent of autumn values. This estimation of strength during thaw periods then allows the appropriate authorities to impose or remove load restrictions to minimize damage to pavements. Using the reduction factors over the entire spring period may be overly conservative on load restrictions.

The U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) is currently developing a nondestructive pavement evaluation procedure for seasonal frost areas using an FWD. Data are lacking on the response of pavements founded on fine-grained subgrade soils subjected to freeze-thaw cycles. To study this effect, test sections were built in the Frost Effects Research Facility (FERF) and subjected to several cycles of freezing and thawing. During the thaw cycles, the pavement response was monitored using the FWD.

This paper describes the test sections, the instrumentation of the pavement sections, and the results of the FWD testing. Further details can be found in a forthcoming CRREL report (*9*).

TEST SECTIONS

Four test sections were constructed in the CRREL Frost Effects Research Facility, which has an interior area of 2,694 m^2 and incorporates 12 test cells (TC) and basins (Figure 1). The test cells in which the pavement structures were built (TC-1–3) are 6.4 m wide, 7.6 m long, and 2.4 m deep. With the exception of TC-1 and TC-2 (Figure 1), all other test cells and basins have concrete floors. TC-1 and TC-2 are founded on a natural till subgrade. The refrigeration system in the FERF can maintain air temperatures in the building between −4°C and 24°C and within a tolerance of ±3°C. Individual test cells or test basins are generally cooled by placing freezing panels on the surface. A minimum temperature of −35°C maintained within a tolerance of ±0.8°C is available to the panels.

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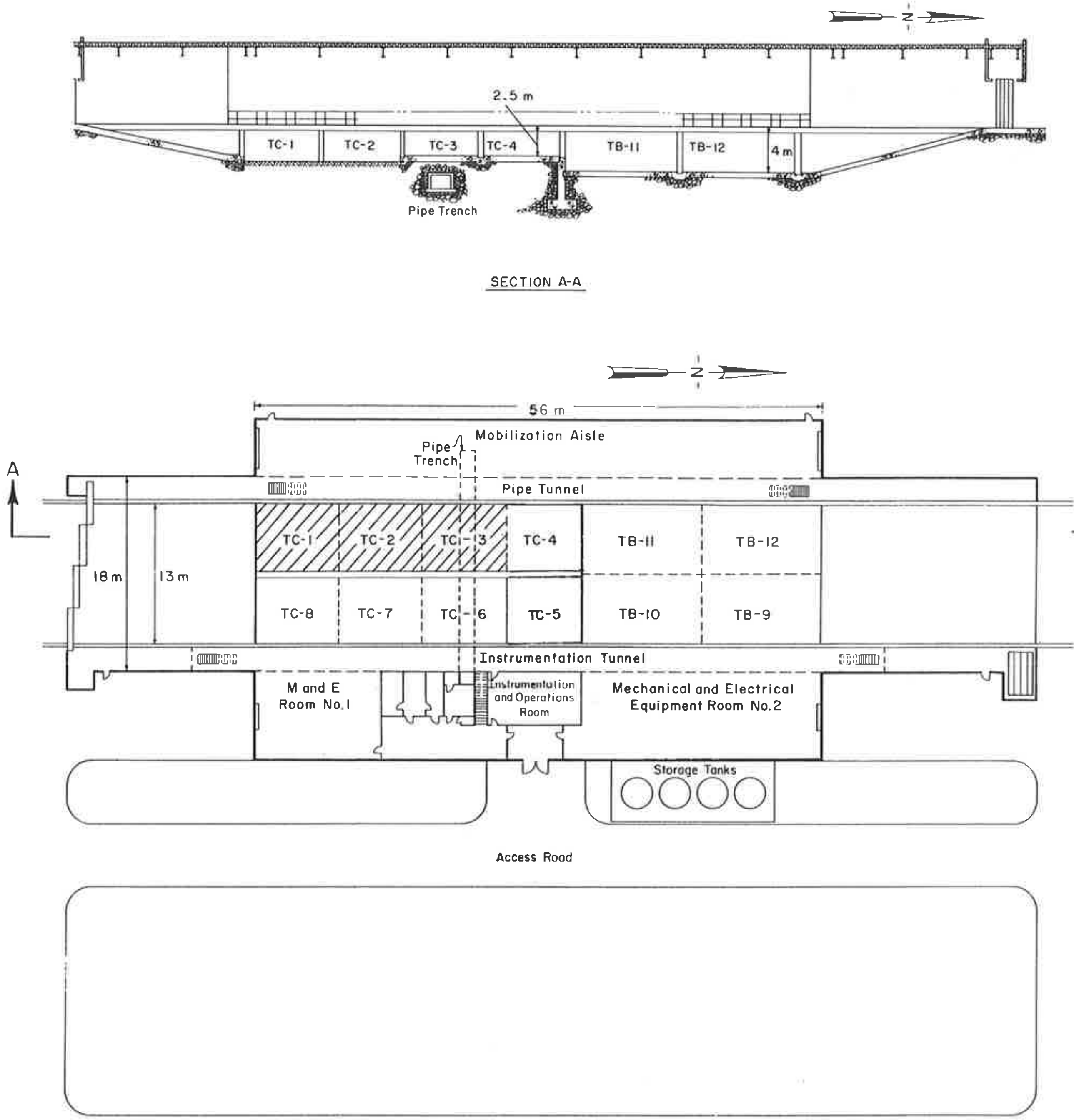

FIGURE 1 Plan and cross-section of Frost Effects Research Facility.

The test sections were 610 cm by 533 cm and 160 cm deep. Test section 1 was extended 150 cm from TC-1 into the ramp area (Figure 1). Cross-sections of the four test sections are shown in Figure 2. Test sections 1 and 2 are full-depth asphalt (152-mm) concrete pavements. The minimum 102 mm of free-draining base, required by the Corps of Engineers in seasonal frost areas, was included in test section 2. Test section 3 was made up of 51-mm asphalt concrete pavement on a 178-mm base course over a 203-mm clean gravel subbase. Test section 4 consisted of a 51-mm asphalt concrete pavement and a 254-mm base course over a 127-mm sandy subbase. A 6.4-mm-thick woven filter fabric was used as a separator between the base and subgrade in TS-2 and between the subbase and subgrade in test sections 3 and 4.

The grain size distribution for subgrade, base, and subbase materials is presented in Figure 3. The subgrade was constructed of clay obtained near the town of Fort Edward in upstate New York. The in situ moisture content of the clay was between 38 and 41 percent. The clay was classified as inorganic and of high plasticity (CH) according to the Unified

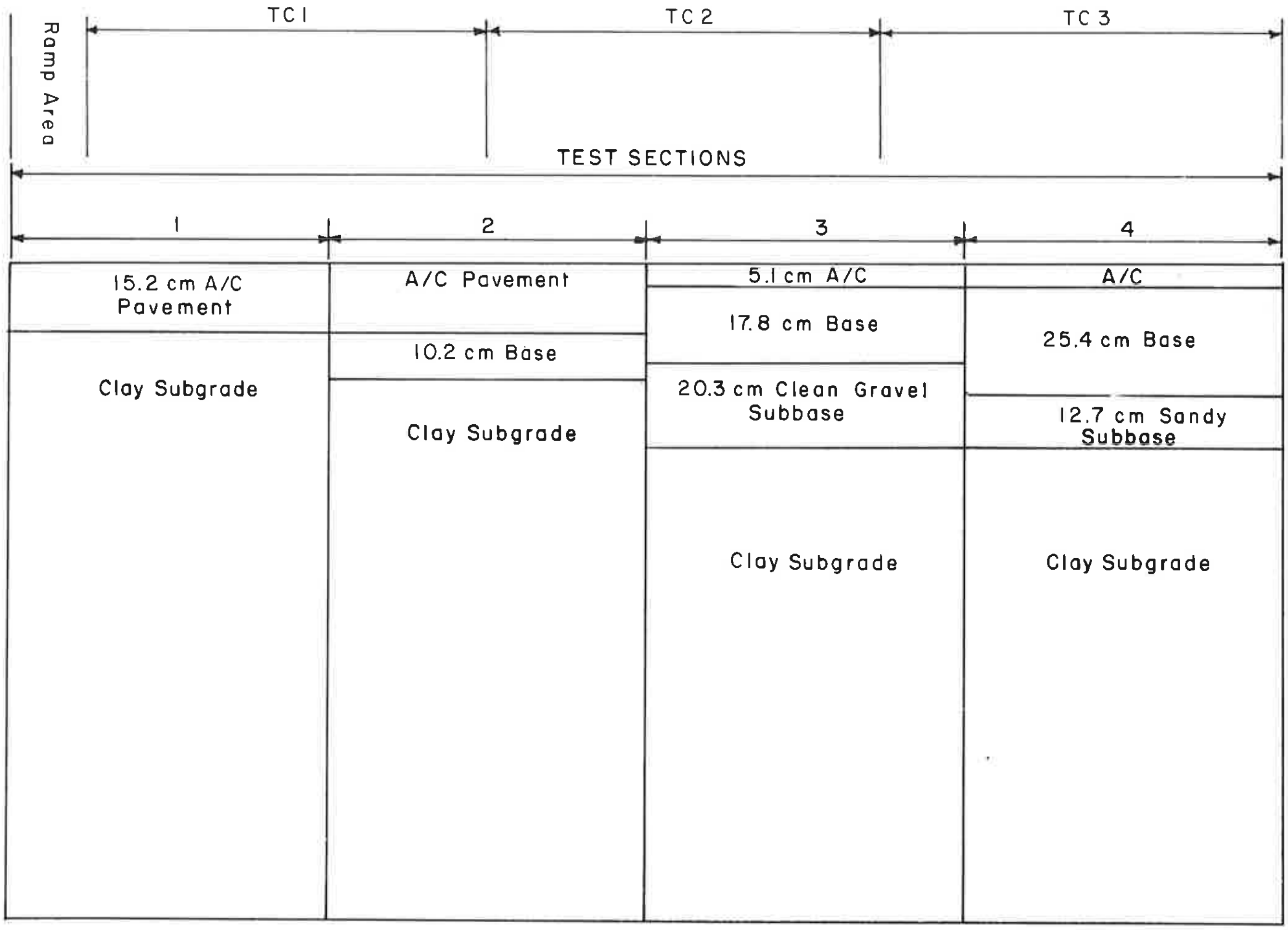

FIGURE 2 Cross-section of test sections.

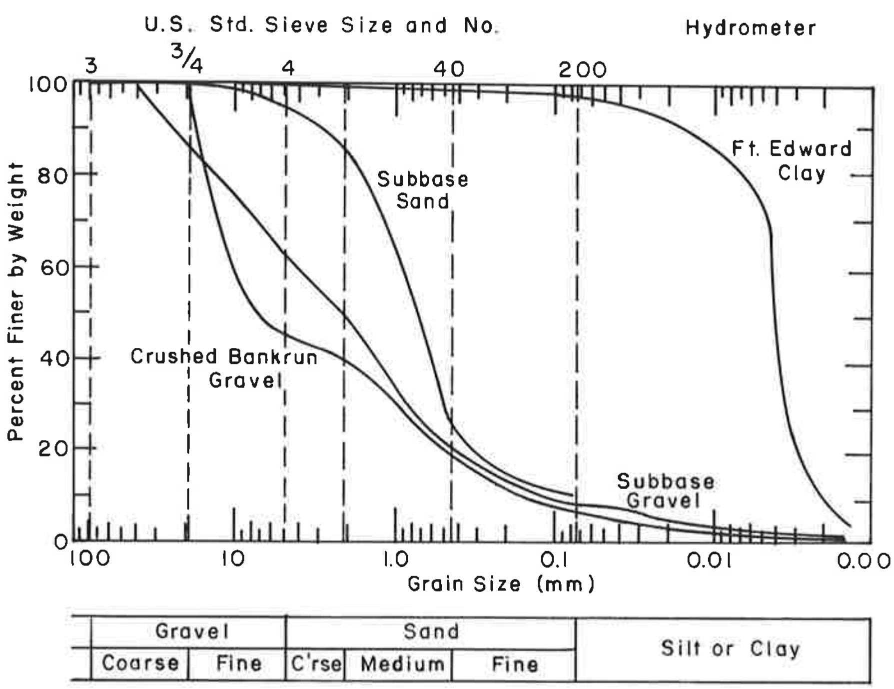

FIGURE 3 Grain-size distribution of test material.

Soil Classification System. Other properties of the clay are presented in Table 1. Based on grain size and Atterberg limit analysis, the clay was classified as an F3 soil with respect to frost susceptibility. From frost-heave laboratory tests, the heave rate was determined to be 0.8 mm per day, which can be considered negligible (*10*).

The base course (Table 1) used in test sections 2, 3, and 4 was crushed bankrun gravel obtained from a gravel pit in West Lebanon, N.H. The material had a coefficient of uniformity (C_u) of 47 and a coefficient of curvature (C_c) of 0.5. The amount of material passing the No. 200 sieve was less than 5 percent. It was classified as a poorly graded gravel with little fines (GP). The final densities of the base course ranged from 2.11 to 2.19 g/cm^3, and water contents ranged from 2.7 to 3.4 percent.

Two subbase materials (Table 1) were used in test sections 3 and 4. In test section 3, the subbase material had a C_u of 30.5 and a C_c of 1.2. The material had more than 50 percent passing the No. 4 sieve and 7 percent passing the No. 200 sieve. It was classified as a gravelly sand with little fines (SW-SC) using the Unified Soil Classification System. The gradation for this material is shown in Figure 3 as "subbase gravel." In test section 4, the subbase material had a C_u of 7 and a C_c of 3.0. The material had more than 90 percent passing the No. 4 sieve and 8 percent passing the No. 200 sieve and was classified as a poorly graded sand with little fines (SP-SC). The gradation of this material is shown in Figure 3 as "subbase sand." The subbase materials were assumed to be compacted at their natural water content of 3.0 percent in test section 3 and 4.4 percent in test section 4.

The asphalt concrete layers in TS-1 and TS-2 consisted of 101 mm of black base and 51 mm of wearing course. The base course was designated as Type B and the wearing course, Type E in the New Hampshire State specifications. The asphalt used for all of the AC layers was an AC 20 (absolute viscosity at 60°C of 2,065 poise; kinematic viscosity at 135°C of 400 cst; penetration at 25°C of 80 dmm; and Penetration Viscosity Number of −0.44. The optimum asphalt content for the base course was 5.25 percent and for the wearing course, 6.4 percent. In TS-3 and TS-4, the AC layer was 51 mm thick, laid in two 25.5-mm lifts. It met all the specifications for the New Hampshire Type E wearing course.

PAVEMENT INSTRUMENTATION

The test sections were instrumented with thermocouples and electrical resistance gauges. The location of these gauges in the test sections is shown in Figure 4. Temperature measurements were made with copper-constantan thermocouples that were placed 152 mm apart in the clay subgrade and 51 mm apart in the subbase, base, and AC layers (with some exceptions). The temperature measurements were taken at a single location in each test section and were assumed to be representative throughout the respective test sections. Determining frost penetration by temperature measurements alone has two disadvantages. First, impurities in the soil/water system tend to depress the freezing point below 0°C. Second, during spring thaw, subsurface temperatures can become nearly isothermal at 0°C.

To overcome this problem, sensors to measure the resistivity of soils during freezing and thawing have been developed at CRREL (*11*). It has been found that water containing small quantities of impurities, such as groundwater, has a typical volumetric resistance of approximately 20 kΩ. Frozen groundwater has a volumetric resistance of from 100 kΩ to several megaohms. A schematic of a resistance probe is shown in Figure 5. The wooden dowel and sensors were placed in a 76-mm-diameter hole to the various depths shown in Figure 5. The holes were then backfilled and compacted in 152-mm lifts using a wooden dowel as a compactor. Measurements were taken every 4 hours, and the data were stored on magnetic tape. Typical temperature and resistance measurements for locating the freezing or thaw depths are shown in Figures 6 and 7.

TESTING PROGRAM

Deflection measurements were obtained using a Dynatest 8000 falling-weight deflectometer at the end of subgrade placement, at the end of construction of the pavements, and during the thawing periods. The test sections were subjected to five freeze-thaw cycles. Traffic was applied during the third and fifth thaw cycles, but the analysis presented in this paper is concerned primarily with the first two freeze-thaw cycles dur-

TABLE 1 PROPERTIES OF CLAY, BASE, AND SUBBASE

	Subgrade	Base	Subbase
Unified Soil Classification System	CH	GP	SW
Specific gravity (G_s)	2.79	2.8	2.8
Liquid limit (LL)	64	–	–
Plastic limit (PL)	28	–	–
Plasticity index (PI)	36	–	–

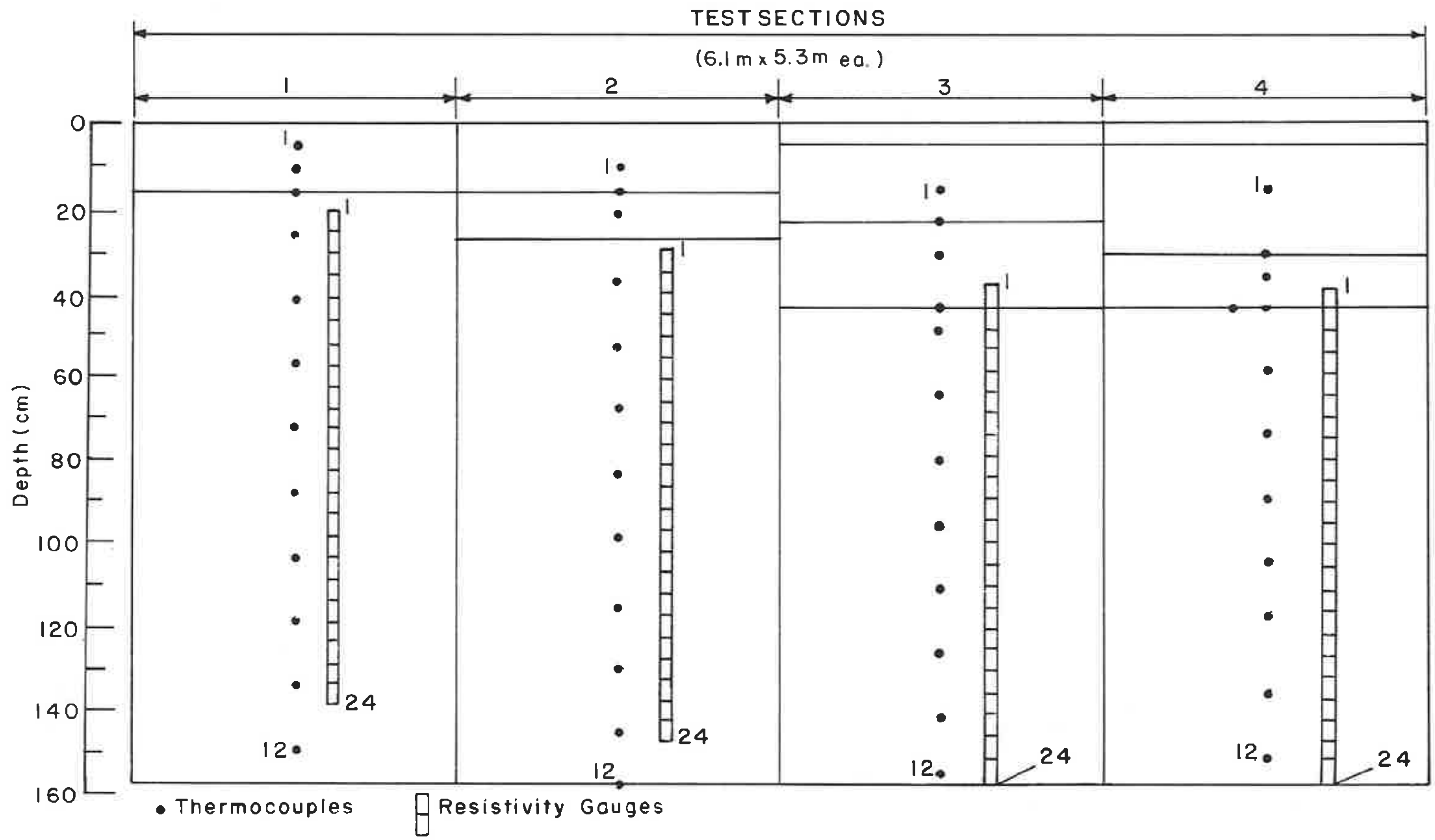

FIGURE 4 Location of thermocouples and resistance gauges in test sections.

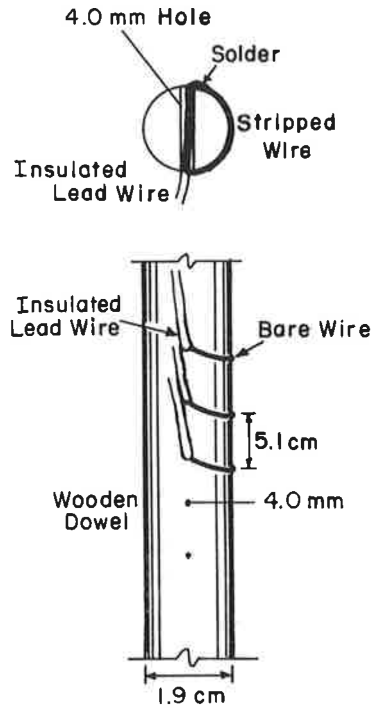

FIGURE 5 Schematic of resistance probe.

ing which the changes in the strength of the pavement structure were caused only by thermal effects.

The test sections were frozen from the top down by placing cooling panels on the surface of the pavements. Freezing was stopped when the frost penetration reached the target depth. This depth was 122 cm for the first cycle and 152.4 cm (the bottom of the test basins) for the second cycle. The freezing rate in the clay subgrade was calculated to be close to 16.5 mm per day during the first freeze cycle and approximately 25.4 mm per day during the second freeze cycle. Berg (*4*) has reported that frost penetration in the field is in the range of 6.4 to 25.4 mm per day. Deflection measurements were taken once a day during the thaw periods at four locations in each test section. Four load levels, composing a set, were used during the thaw cycles: 27, 40, 50, and 67 kN. At each location, each of the load levels was applied twice and two sets of deflection measurements were recorded. The FWD measurements on the pavements were conducted using a 30-cm-diameter plate, with the sensors located at 0, 17.5, 30, 70, 110, 150, and 245 cm.

Thawing of the pavement structure was induced by changes in the ambient building temperature. The temperature during the first two thaw cycles is shown in Figure 8. During the first cycle, the air temperature in the FERF ranged from 15°C to 36°C and during the second thaw cycle it ranged from 4°C to 19°C. The corresponding thaw depths (located by the 0°C isotherm) during the thaw cycles in all test sections are presented in Figures 9 and 10. The average thaw rate during the first thaw cycle was 45 mm per day. During the second thaw cycle, the average thaw rate was 27 mm per day.

ANALYSIS OF FWD DEFLECTION DATA

A representative deflection basin was used to characterize the structural change in the pavement structures during the thaw periods. It was selected with the BASIN program developed at the U.S. Army Corps of Engineers Waterways Experiment Station. The program averages the deflections for a given load (in this case four deflection basins at each load level, because only the second set of deflections from each location was used) and calculates the area of the averaged deflection basin. It then compares the deflection measurements at each location with the averaged values and chooses the input deflection basin that is closest to the averaged basin and area as the representative basin.

We used BASIN to obtain representative 40- and 50-kN-load deflection basins for further analysis. These load levels were of interest to us because one represents current allowable loading conditions (40 kN), and the other (50 kN) could represent high tire pressure loadings, which are more detrimental to thaw-weakened pavements.

Before freezing, FWD measurements were conducted on all the pavement test sections (Figure 11). It can be seen from the figure that the full-depth pavements (TS-1 and TS-2) have lower deflections than their counterparts (TS-3 and TS-4). Based on similar moisture and density measurements in the subgrade in all the test sections (*9*), it was concluded that the difference in the deflection basins in Figure 11 was because the pavement structure was different above the subgrade. Higher deflections from the same applied load signifies a lower modulus, which usually signifies lower shear strength (*12,13*). Based on the above conclusion and on inspection of the deflection basins in Figure 11, one can further conclude that the fourth sensor (70 cm from the center) apparently measured the deflection of the subgrade caused by the applied load. This fourth-sensor deflection was used to characterize the subgrade response during the thaw period as well as to determine the thaw depth. The deflection basins in Figure 11 were also used as reference basins during the thaw cycles.

Typical deflection basins during the first and second thaw cycles for the 40-kN load levels for TS-1 and TS-3 are presented in Figures 12 and 13. The figures clearly show that, as the thaw depth increased, the deflections increased, which, as mentioned previously, can be related to loss of strength of the pavement structure. Similar observations were seen in TS-2 and TS-4. In the second thaw cycle, some recovery was seen (Figure 13). However, in the interest of time, this recovery process was not continued to its conclusion.

Several parameters were studied to characterize pavement response during the thaw period. These parameters were the impulse stiffness modulus (ISM), center deflections, fourth-sensor deflections, and deflection basin areas. The ISM (*14*) is defined as the ratio of the applied FWD load to the corresponding center deflection and is equivalent to the spring constant k in an elastic system. The ISM was found to distinguish various pavement structure types (Figure 14). The full-depth pavement (TS-1 and TS-2) structures show higher ISM values than their TS-3 and TS-4 counterparts. However, the differentiation in ISM in any one pavement structure during thaw is difficult to discern.

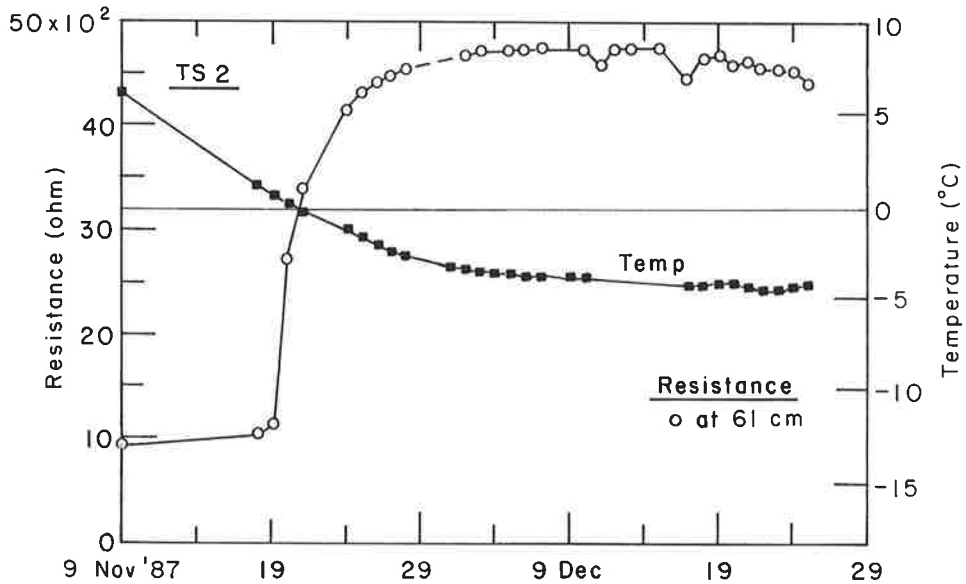

FIGURE 6 Typical temperature resistance measurements for locating freezing front.

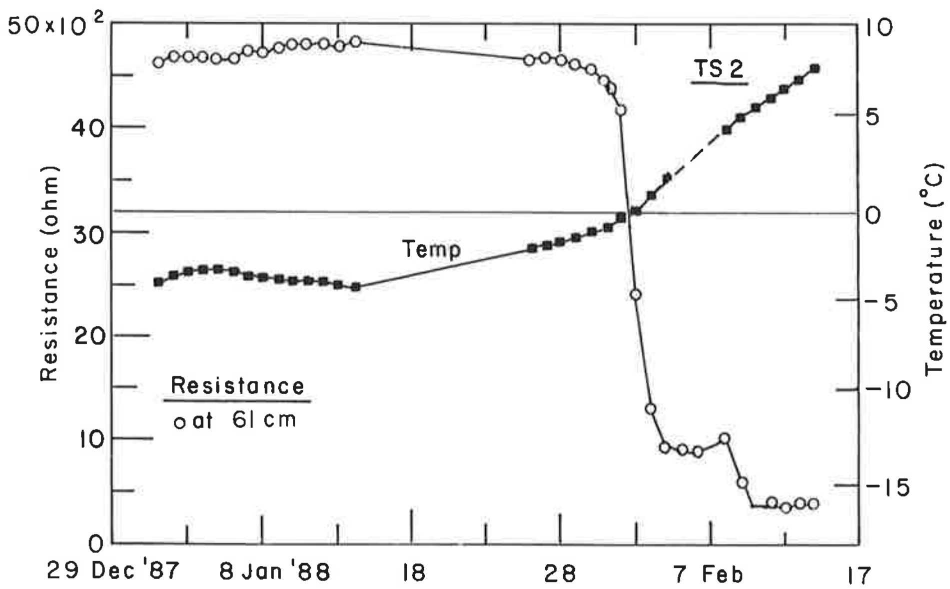

FIGURE 7 Typical temperature resistance measurements for locating thaw depth.

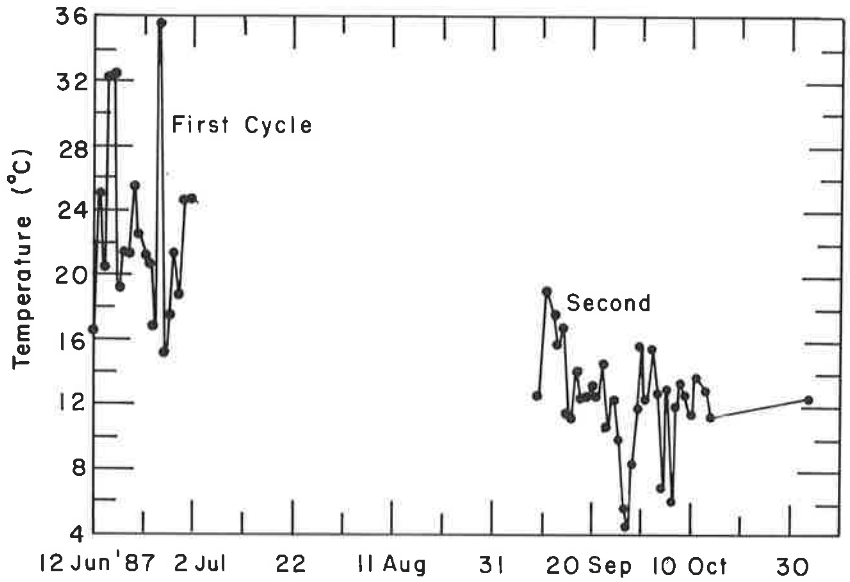

FIGURE 8 Ambient temperature in FERF building during thaw cycles.

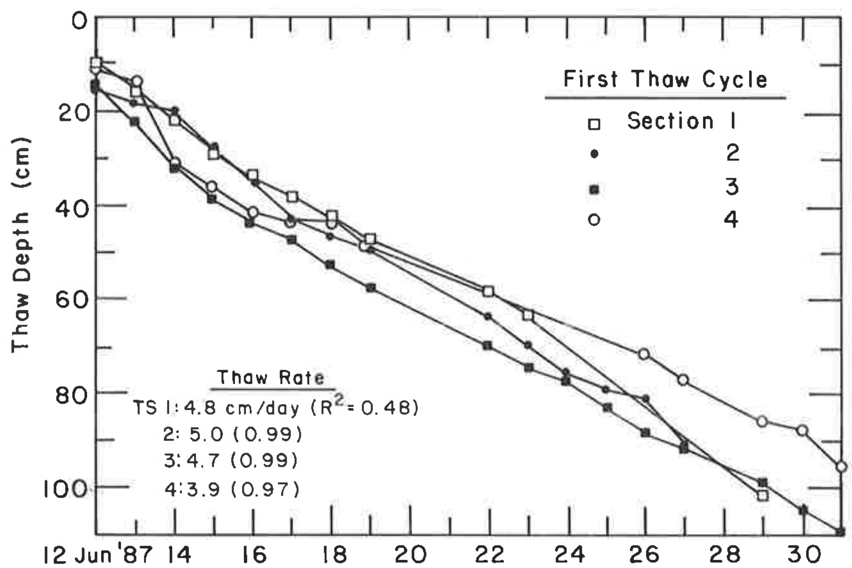

FIGURE 9 Change in thaw depth with time (first cycle).

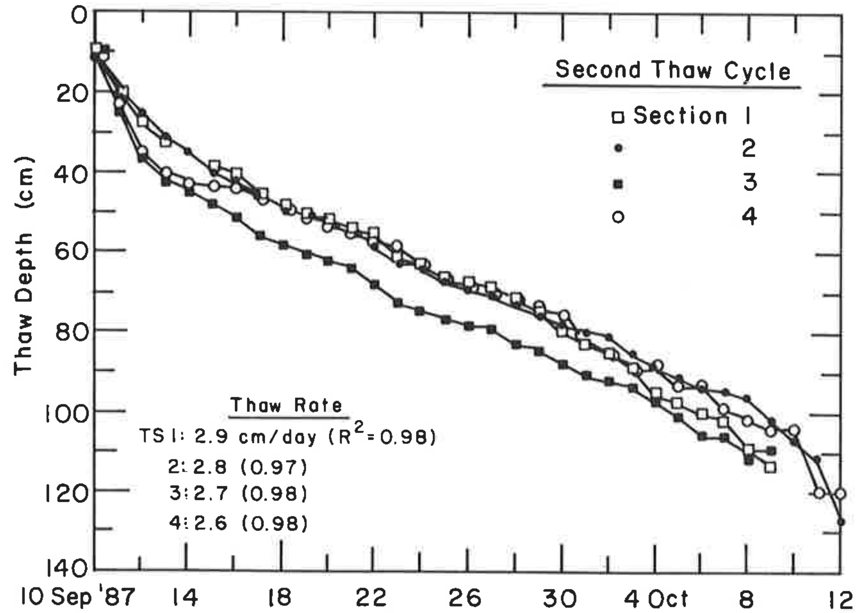

FIGURE 10 Change in thaw depth with time (second cycle).

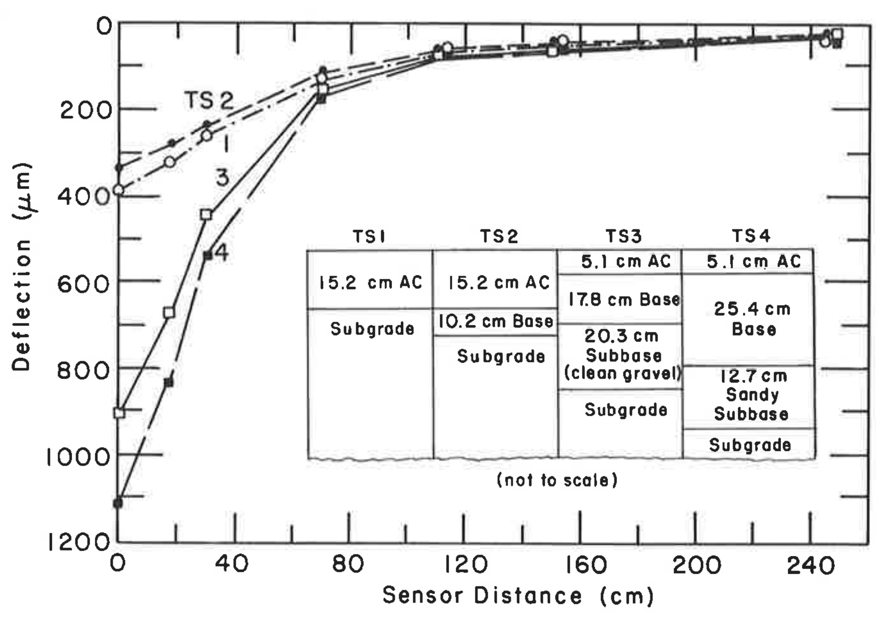

FIGURE 11 Mean deflection basins for all test sections before freezing.

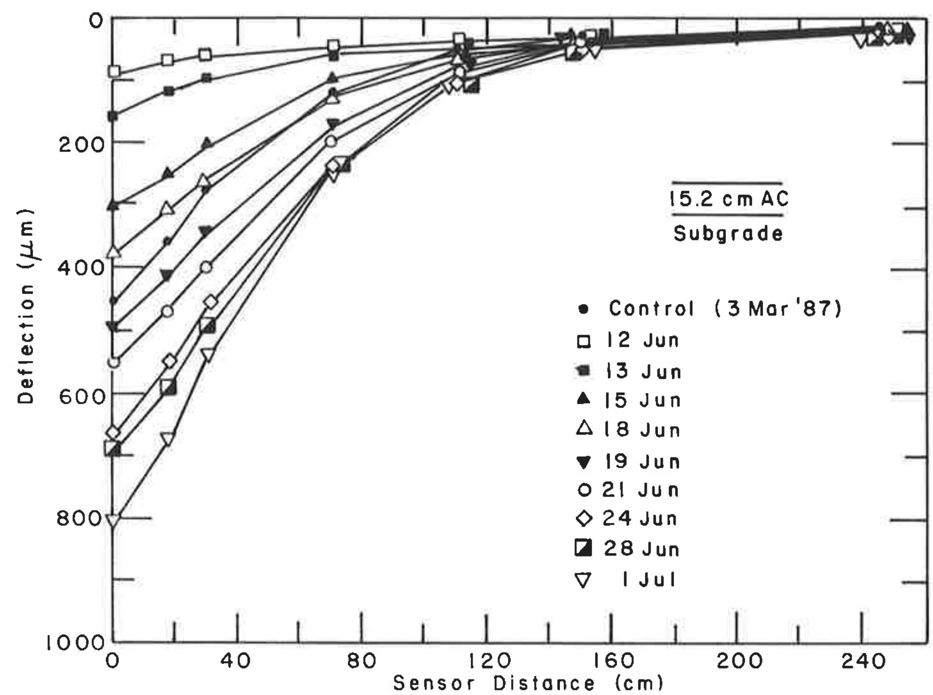

FIGURE 12 Variation of deflection basin area with time in TS-1 (first cycle).

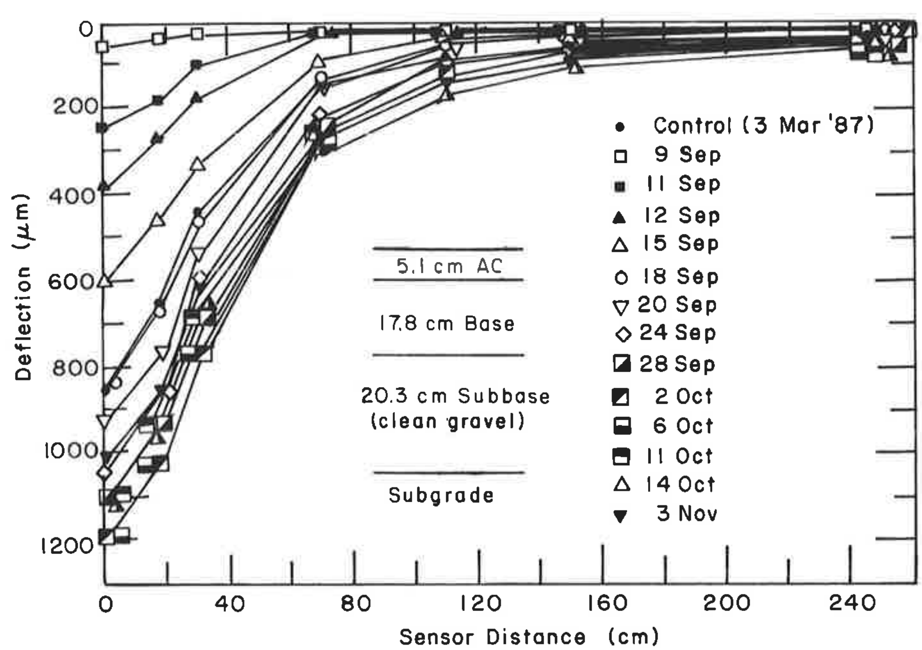

FIGURE 13 Variation of deflection basin area with time in TS-3 (second cycle).

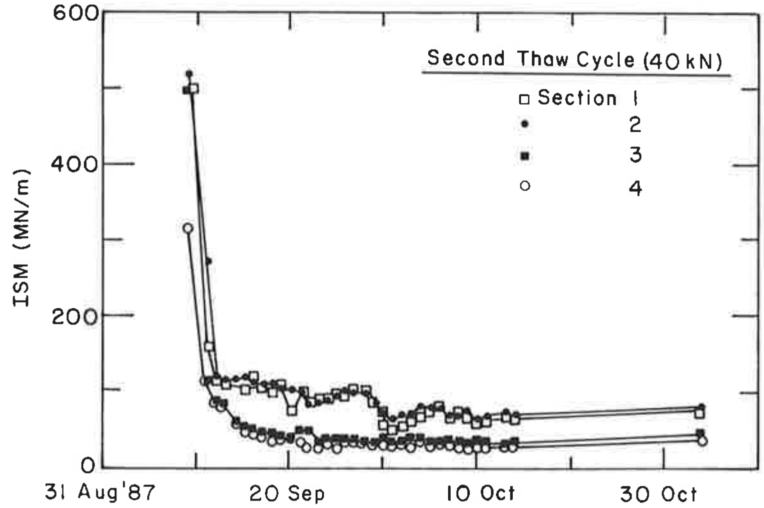

FIGURE 14 Variation of impulse stiffness modulus (ISM) with time (second cycle).

When center deflections are used, it is recommended *(14)* that temperature corrections be applied to the measured deflections or ISMs to account for the deflection of the asphalt concrete pavement at high temperatures. A temperature correction factor based on the ISM values obtained from the test sections was developed. The correction factor (CF) for a thawing pavement structure was determined from

$$CF = \frac{\delta_0 \text{ at } 20°\text{C}}{\delta \text{ at other temperatures}}$$

The results are shown in Figure 15. The correlation between the correction factors developed from the test sections and that developed by Bush *(14)* is poor. Similar results were found with TS-1. No attempt was made to determine correction factors for TS-3 and TS-4 because the asphalt concrete thickness was only 51 mm. Bush *(14)* found that for pavement thicknesses less then 76 mm, other factors such as moisture conditions, accuracy of FWD load, and deflections had a greater influence on the measured deflection than did temperature.

It was also found *(9)* that, during the thaw period, approximately 90 percent of the total deflection can be attributed to the deflection of the layers below the asphalt concrete. It was concluded that during winter and spring, and possibly during autumn, correction factors are unnecessary. However, in summer, because of high temperature ranges, correction factors are a critical part of the evaluation procedure.

The other parameters—center deflection, fourth-sensor deflection, and basin areas—showed great promise for use

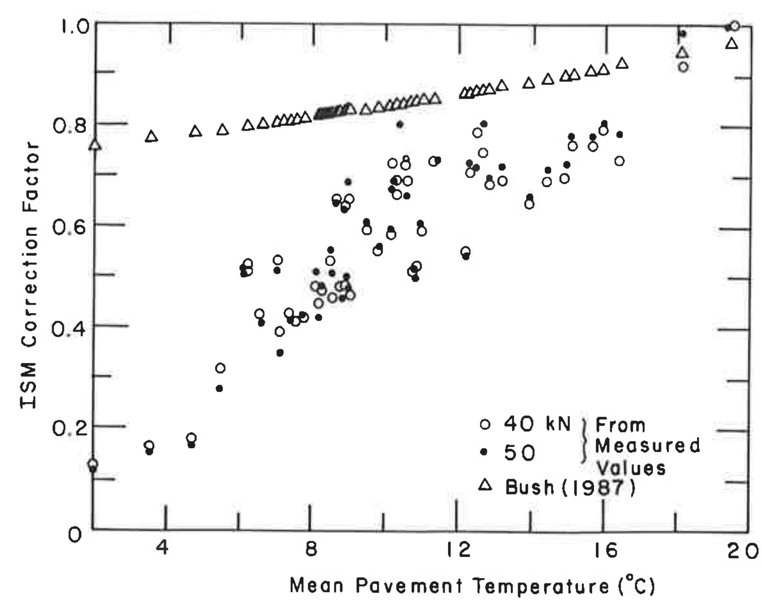

FIGURE 15 Comparison of WES correction factors with correction factors developed from measured deflections.

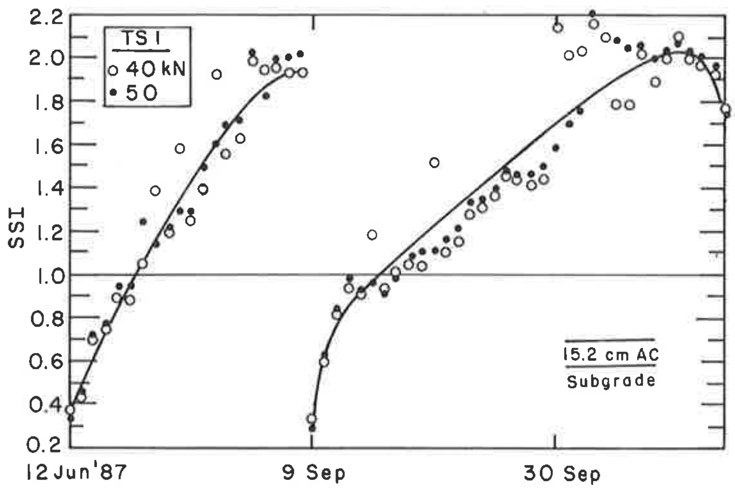

FIGURE 16 Change in the subgrade strength index (SSI) with time in TS-1.

in characterizing pavement response during thaw. However, to be usable all year around, it was decided that the fourth-sensor deflection, which appears to characterize the response of the subgrade only, is the one to use. It is proposed that the ratio of the fourth-sensor deflection during thaw to the same sensor deflection measured before freezing is an indicator of the subgrade strength. This ratio, called the subgrade strength index (SSI) was used to characterize the subgrade strength during thaw. The use of the deflections 70 cm from the center is similar in concept to utilizing the last sensor deflection with the Dynaflect device (placed 124 cm from the center) to characterize the subgrade response.

The variations in SSI with time for TS-1 and TS-3 are shown in Figures 16 and 17. Similar responses were seen in TS-2 and TS-4. The smaller numbers relate to winter conditions and, as thaw progresses, the SSI increases. As seen during the second cycle, this number starts to drop as recovery starts. The data presented in this fashion clearly show the reduction in the subgrade strength (a factor ranging from 2 to 2.2) during thaw. It can also be seen in Figure 17 that the SSI does not change significantly until the thaw depth reaches the bottom of the subbase, i.e., 42 cm from the surface. The results also suggest that in clayey materials recovery from thaw takes time and is not rapid, as suggested by some models.

As mentioned above, the deflection basin areas were studied to characterize the strength of the subgrade during thaw. This concept is similar to that developed by Hoffman and Thompson (*15*), who used the center deflection and a normalized deflection basin area bounded by the first four sensors to characterize pavement performance. We calculated the basin area bounded by the fourth, fifth, sixth, and seventh sensors and their respective deflection measurements. When the ratio of the basin area to the basin area before freezing was plotted with respect to time, the curves were similar to SSI.

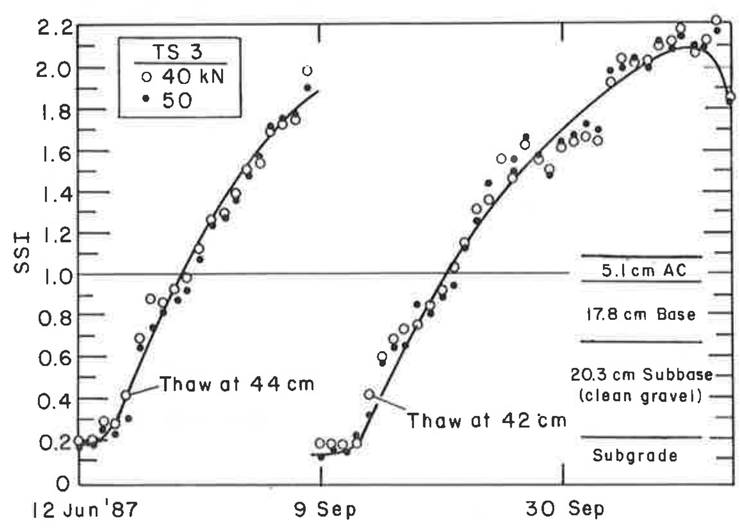

FIGURE 17 Change in the subgrade strength index (SSI) with time in TS-3.

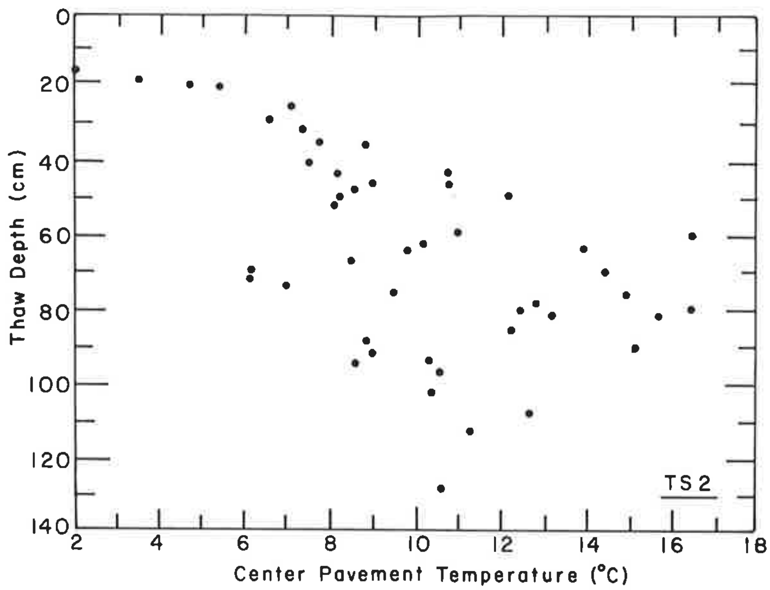

FIGURE 18 Variation in center pavement temperature with measured thaw depth in TS-2.

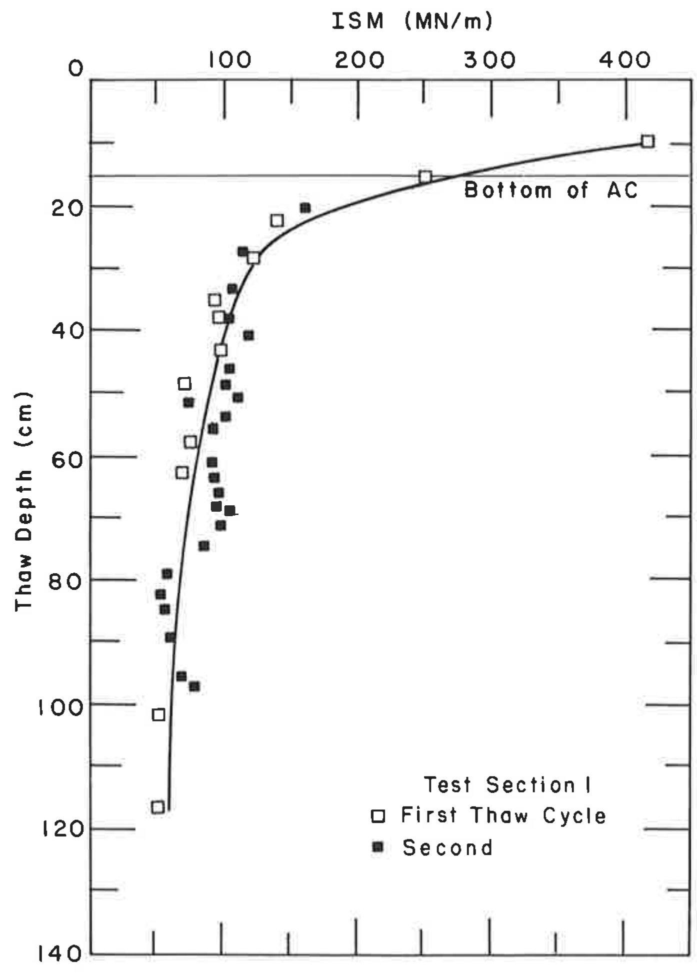

FIGURE 19 Change in ISM with measured thaw depth in TS-1.

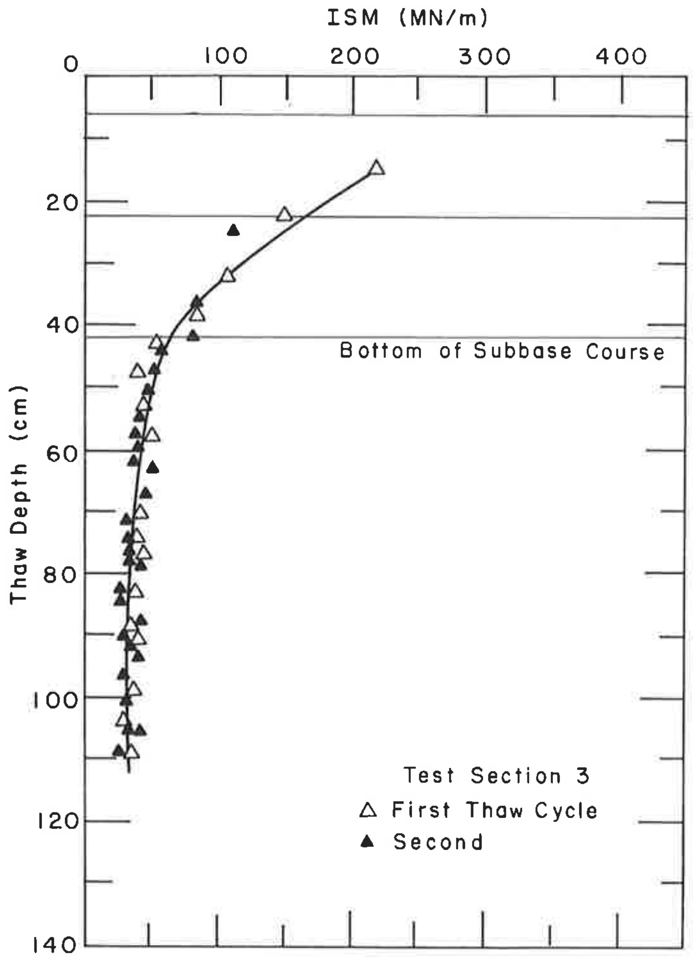

FIGURE 20 Change in ISM with measured thaw depth in TS-3.

ESTIMATING THAW DEPTH

The locations of the thaw depth have been used for imposing/removing load restrictions on pavements. Connor (*16*) found that, when back-calculating layer moduli in thawing pavement structures, knowing the location of the thaw depth was critical. The thickness of the thawed layer was found to affect the outcome of the back-calculated layer moduli. Currently there are no techniques for predicting thawed-layer thicknesses from NDT data (*16*). However, the authors feel that methods such as the modified Berggren equation or finite element or finite difference techniques could be used to estimate thaw depths. As an alternative, we investigated the possibility of using pavement temperatures and/or the deflection measurements (ISM, basin area, fourth-sensor deflections, or a combination of these parameters) to estimate thaw depth. In clay subgrades, especially with full-depth sections, the thawed-layer thickness will nearly correspond with the thaw depth because of the low permeability of the clay.

Pavement Temperature

The simplest prediction of thaw depth would be based on the pavement temperature. Figure 18 shows the variation of thaw depth with mid depth pavement temperature in TS-2. There was a poor correlation between pavement temperature and thaw depth; similar observations were made in TS-1 and TS-3.

Impulse Stiffness Modulus (ISM)

The ISM, as mentioned earlier, is equal to the FWD load divided by the center deflection; it has been used as an indicator of the bearing capacity of various pavement structures. The ISM, with respect to thaw depth for TS-1 and TS-3, is shown in Figures 19 and 20. A similar response was seen in TS-2 and TS-4. In TS-1, when thaw occurred in the subgrade, the ISM varied between 50 and 100 MN/m. The ISM dropped rapidly from about 300 to 100 MN/m, a factor of 3, when the thaw depth was between 15 and 30 cm. In TS-3, once thaw reached the subgrade, the ISM remained fairly constant at approximately 30 MN/m. It is interesting to note that the ISM changed the most, from about 200 to 30 MN/m, a factor of nearly 7, when thaw was in the base and subbase layer.

The ISM was found to distinguish between frozen and thawed pavements, but it remained fairly constant with thaw depth when thaw was in the subgrade. It was concluded that thaw depth in the subgrade cannot be determined using the ISM.

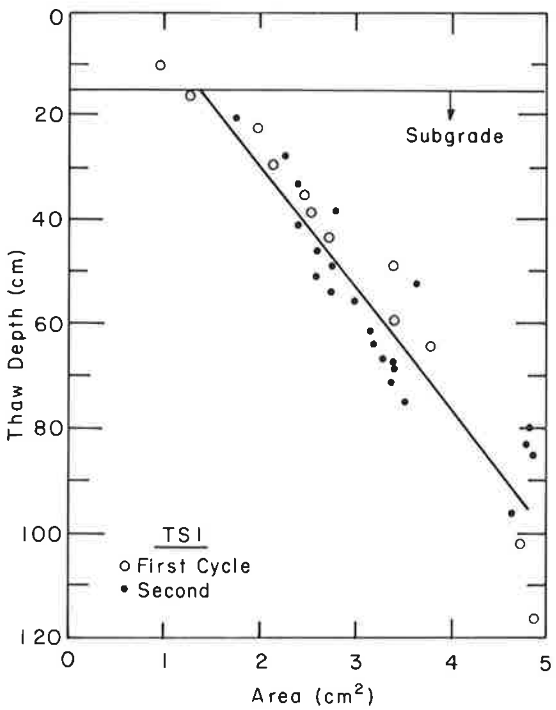

FIGURE 21 Change in total basin area with measured thaw depth in TS-1.

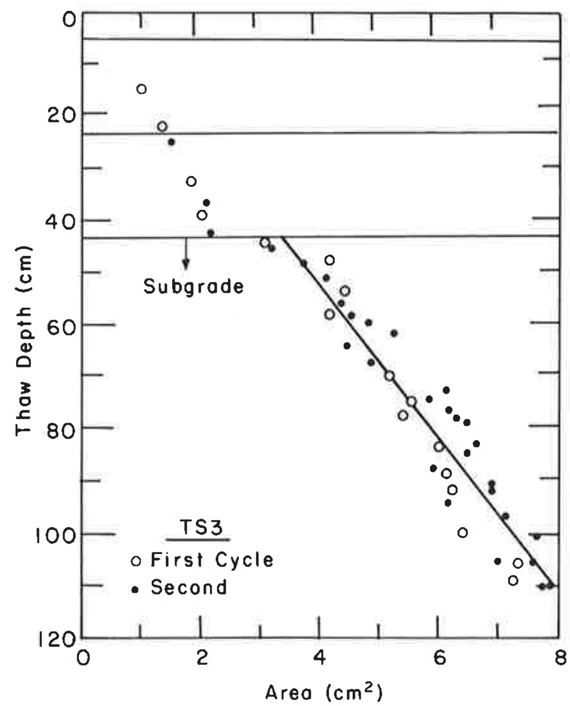

FIGURE 22 Change in total basin area with measured thaw depth in TS-3.

Area Of Deflection Basin

We studied whether the area of the deflection basin could be used as an indicator of thaw depth. The area was determined by summing the polygon enclosed by the seven sensors and the measured deflection in the vertical plane. The variations of the area of the deflection basin with thaw depth for TS-1 and TS-3 are shown in Figures 21 and 22. The figures show a strong correlation between thaw depth in the subgrade and basin area in all test sections. Figure 22 also shows a distinctive break in the relationship between area and thaw depth in the base/subbase courses and in the subgrade, which denotes a faster thaw rate in the base/subbase. With this method, estimation of thaw depth appears to be better at depths below 60 cm for full-depth sections and below 80 cm in conventional pavement structures.

Deflection Ratio

Finally, we looked at the possibility of using deflection ratios to predict thaw depth. Although using deflection ratios instead of deflections only will require taking FWD deflection measurements at other times of the year (summer or fall), easy comparison can be made of the strength of the pavement during spring thaw. Comparisons of the fourth-sensor deflection ratios (or SSI) with thaw depth in TS-1 and TS-3 are presented in Figures 23 and 24. From these figures, several observations can be made. First, the deflection ratios from the fourth sensor tend to increase with increasing thaw depth. Second, the fourth-sensor deflection ratios remain constant at 0.2 in the base and subbase, which further confirms that this sensor is sensing the deflection of the subgrade.

The SSI method appears to estimate the thaw depth reasonably well at thaw depths below 80 cm in the full-depth sections and below 95 cm in the conventional sections. The thaw depth in a clay soil subgrade can be estimated using either the basin area or the SSI (fourth deflection ratio). A graph for determining thaw depths using the basin area and SSI was developed, but it was found that two graphs were required, and the thaw depth depended on the pavement structure above the subgrade. Instead of using the total basin area, the area of the basin from the fourth sensor to the seventh sensor was used together with the SSI (Figure 25). In this case, the thaw depth in the clay subgrade was found to be independent of the pavement structure above the subgrade.

SUMMARY AND CONCLUSIONS

Four flexible pavement test sections, of which two were 152-mm full-depth asphalt pavements and two were 51-mm-thick asphalt pavements over a total of 381 mm of base and subbase courses, were constructed in the FERF and subjected to several freeze-thaw cycles. The subgrade was a clay classified as CH under the Unified Soil Classification System.

The test sections were instrumented with thermocouples and resistance gauges to determine the location of the 0°C isotherm, which was assumed to be the location of the freezing

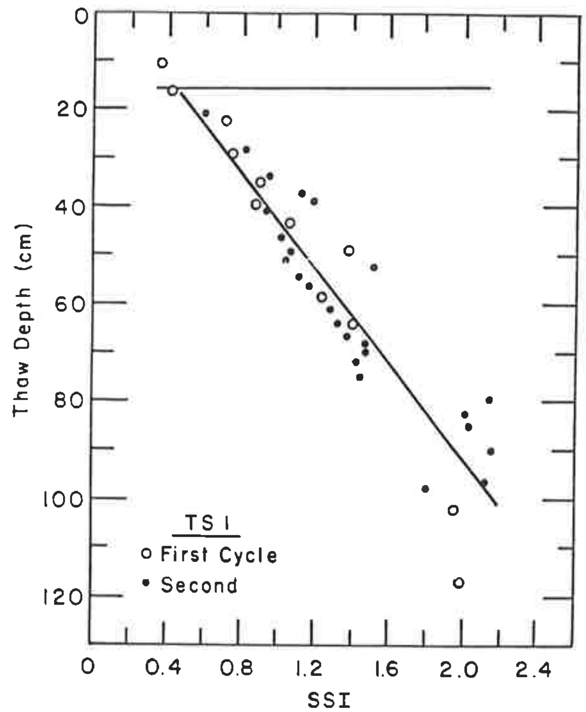

FIGURE 23 Variation in the SSI with measured thaw depth in TS-1.

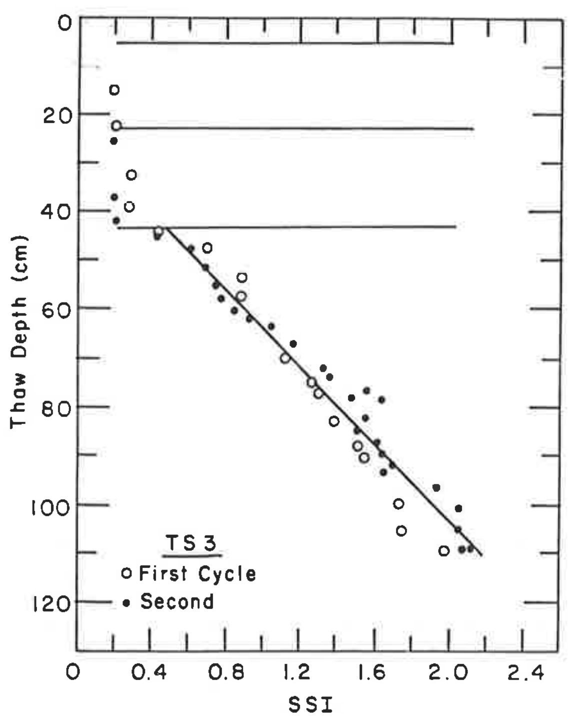

FIGURE 24 Variation in the SSI with measured thaw depth in TS-3.

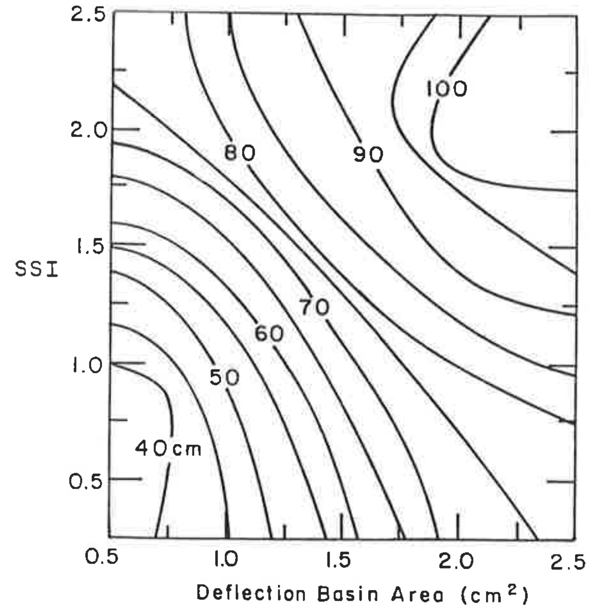

FIGURE 25 Nomograph for determining thaw depth using basic areas and SSI.

or thawing front. The resistance gauges were found to complement the temperature measurements and there was, as expected, a dramatic change in resistance when the soil water changed from frozen to the thawed state or vice versa.

It was found that the clay subgrade was weakened by a factor ranging from 2 to 2.2 when it was subjected to freeze-thaw. This information implies that a 50 to 60 percent reduction in the modulus of a CH subgrade is necessary in any mechanistic design procedure for determining damage (in terms of vertical strains) to pavement.

Because predicting thaw depth is considered a critical element in back-calculation of layer modulus procedures, an attempt was made to develop a method for predicting thaw depths in the subgrade based on FWD deflection measurements. Thaw depth could be estimated by using the area of the deflection basin and/or the fourth-sensor deflection ratio for a CH subgrade. It is recommended that this method be validated in the field. It is also recommended that similar studies be conducted with other fine-grained subgrades, thus enabling development of a thaw depth prediction model for all frost-susceptible soils based on FWD measurements.

Finally, the preliminary results from this study clearly show that, besides obtaining deflection basins from FWDs, in seasonal frost areas, additional information on the variation of the pavement strength and location of thaw depths can be developed. This additional information would not require any sophisticated analytical tools and could easily be incorporated in any pavement evaluation procedure.

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