

INVESTIGATION OF PAVEMENT HEAVING  
ON BRIDGE APPROACHES, I 275  
(Control Section I 58171-06463A)

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## Introduction

The six bridges at two railroad crossings and the Newburg Rd grade separation, located as shown in Figure 1, have pavement approach slabs that are heaving as much as 2 in. or more above the bridge decks. As a result of this surface level differential, the pavement edge was chipped down to the level of the bridge deck to form a transition section as shown in Figure 2. In spite of this corrective measure, traffic still bounced and pitched when going on and off the bridge deck. When a thawing condition exists, the pavement settles so that its edge is lower than the bridge deck (Fig. 3).

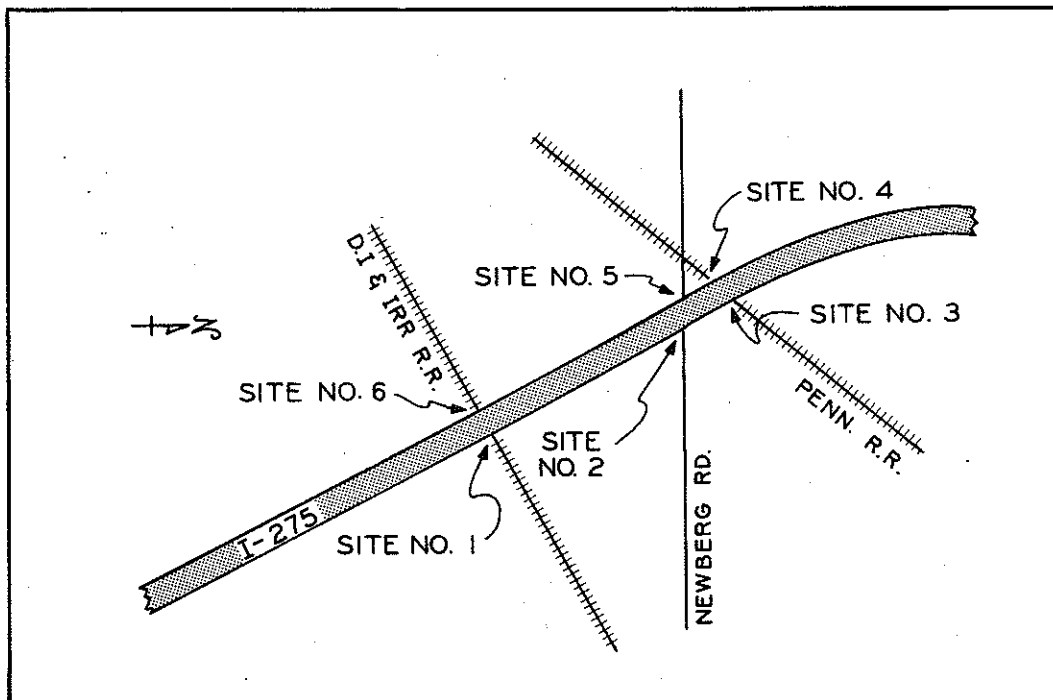


Figure 1. Location of the test sites.

This study was conducted to identify the pavement layer or layers responsible for the frost heave, determine why the heave occurs, and recommend remedial measures that may be used to attenuate frost heave of the pavement.

## Test Procedures

Test Sites 1, 2, 3, and 4 were selected for foundation study including the installation of frost-depth indicators. At each of these sites, a 6-in.

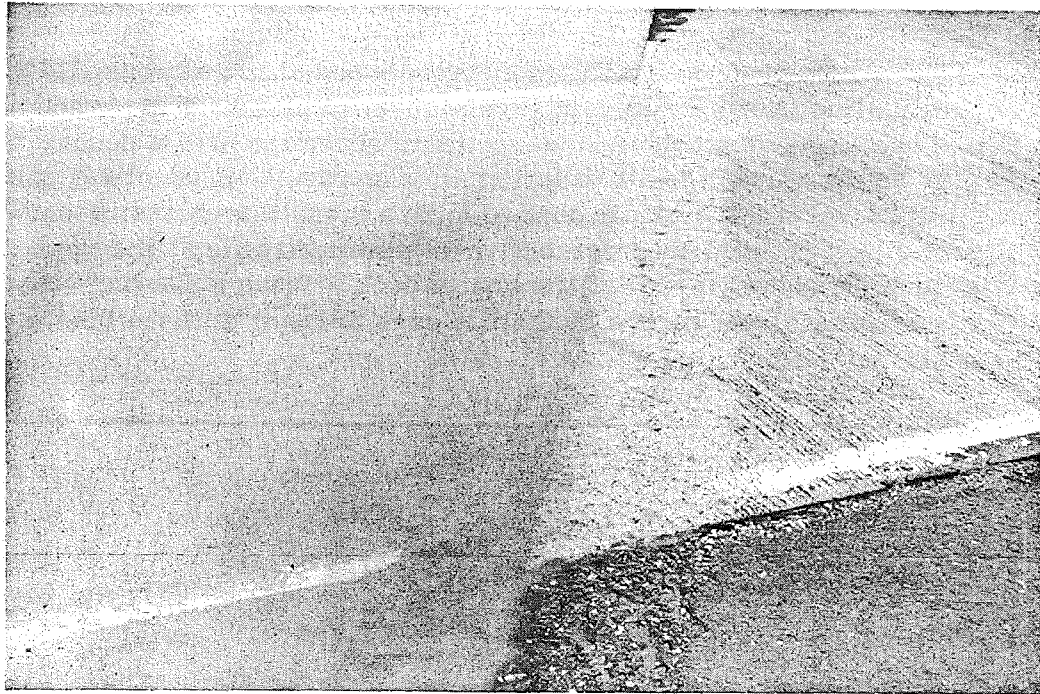


Figure 2. Typical pavement transition formed by chipping down the pavement. Note the presence of surface water, trapped by heave of the pavement slab and shoulders.

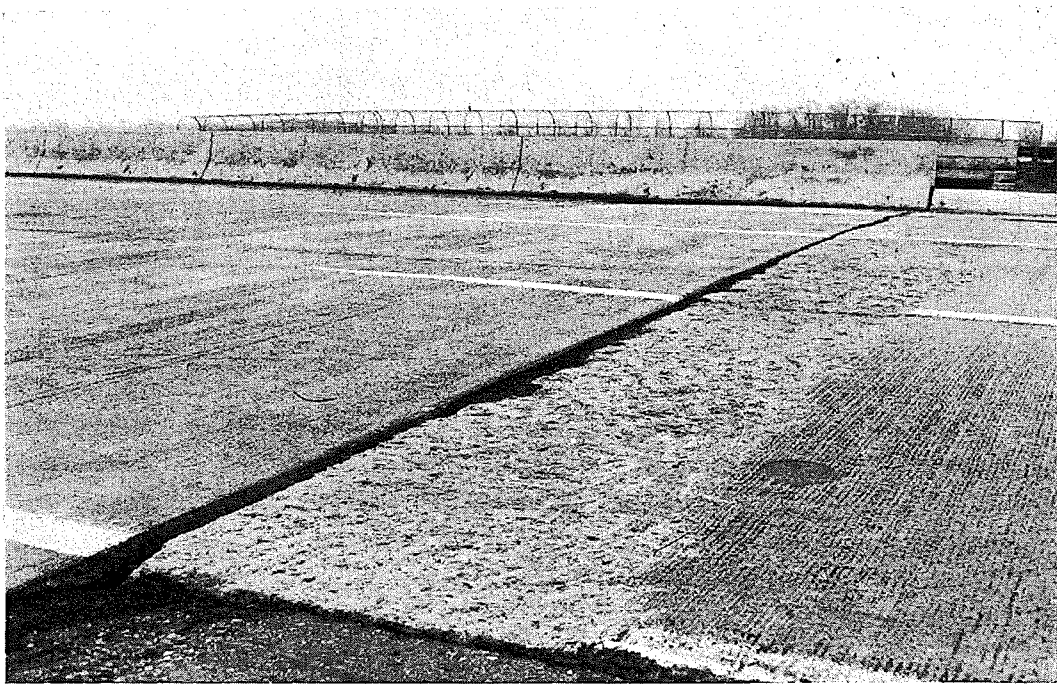


Figure 3. Settlement of the pavement slab after thawing creates a "reverse" bump at the abutment during summer.

pavement core was taken in the outside lane for access to the pavement foundation. At Site 3 the median lane was also cored so that base thickness could be determined. Each base sample was tested to determine its permeability, frost susceptibility, and gradation. Undisturbed 3-in. diameter Shelby tube samples of the subbase and granular backfill were taken to a depth of about 5-1/2 ft from the pavement surface. Disturbed subbase samples were collected for gradation analysis and frost susceptibility testing. Shelby tube samples were tested to determine in-situ water content, percent saturation, permeability, and effective porosity.

Frost heave measurements were made by taking level readings at the bridge deck adjacent to the pavement slab and at every pavement transverse joint, transverse crack, station marker, and terminal beam joint for a distance of roughly 150 ft. Bridge deck elevations are used for reference, and were taken in March and May. Additional elevations will be taken again in the fall of 1979.

It was planned that the frost-depth indicators would be used to monitor frost depth which could then be correlated with frost heave measurements. However, frost depth on February 27 was only about 12 in. below the bottom of the pavement.

#### Test Results

Figure 4 summarizes the laboratory test results. Frost susceptibility tests were conducted in accordance with procedures outlined in Ref. (1), and permeability-effective porosity tests were conducted in accordance with procedures outlined in Ref. (2). Other tests were performed in accordance with standard Department procedures.

Figure 5 summarizes the frost heave data by pictorially showing the difference between March and May pavement elevations. These figures indicate the degree to which the pavement has settled between March and May. They also indicate the differential elevation of the bridge deck and pavement slab at the end transverse joint. At the bridge abutment, the pavement elevation was always taken at the unchipped edge of the transition section.

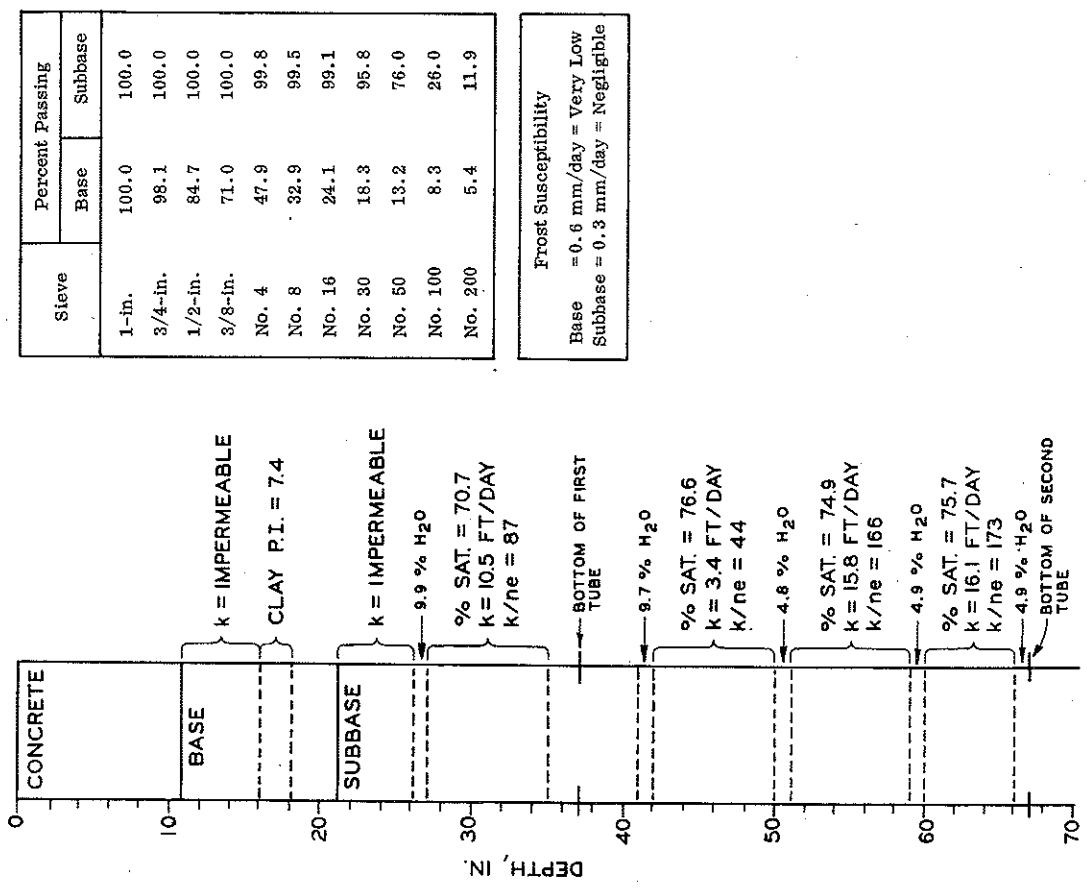


Figure 4. Summary of test data for Site 1, north side of south railroad bridge.

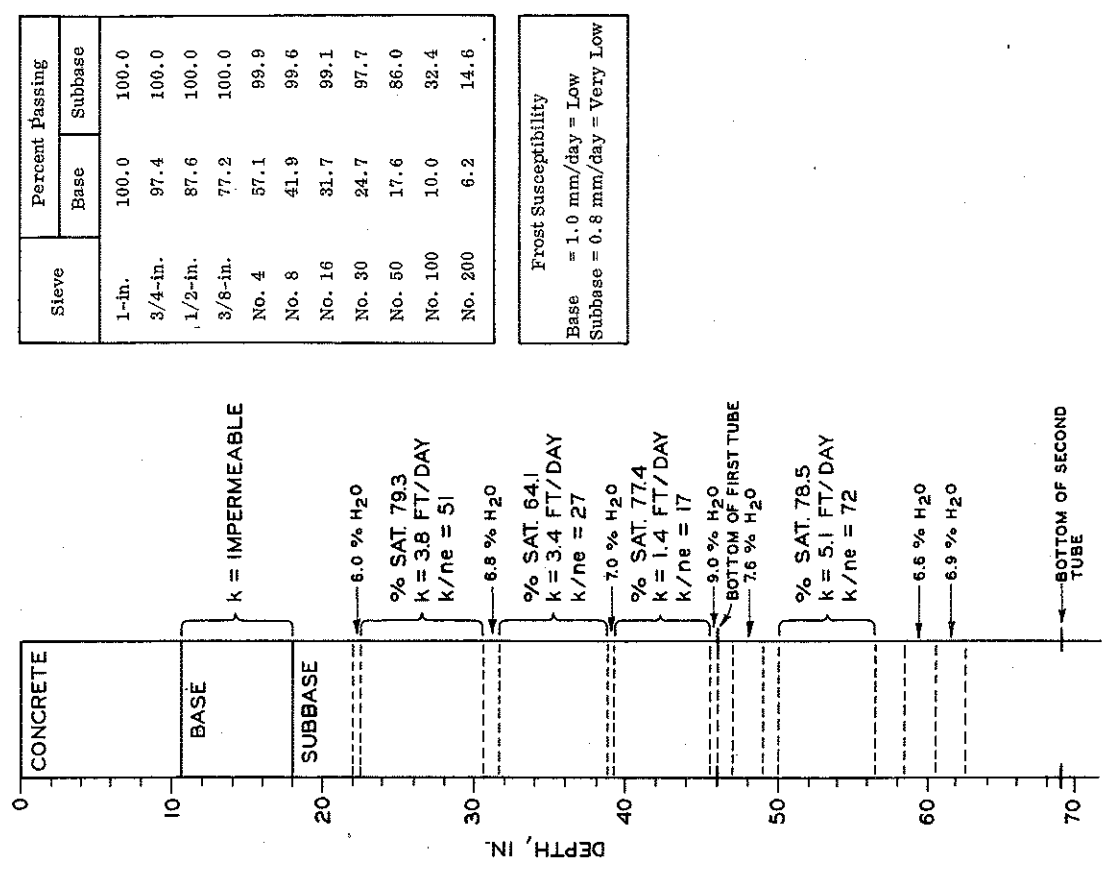


Figure 4 (Cont.). Summary of test data for Site 2, south side of Newburg Rd bridge.

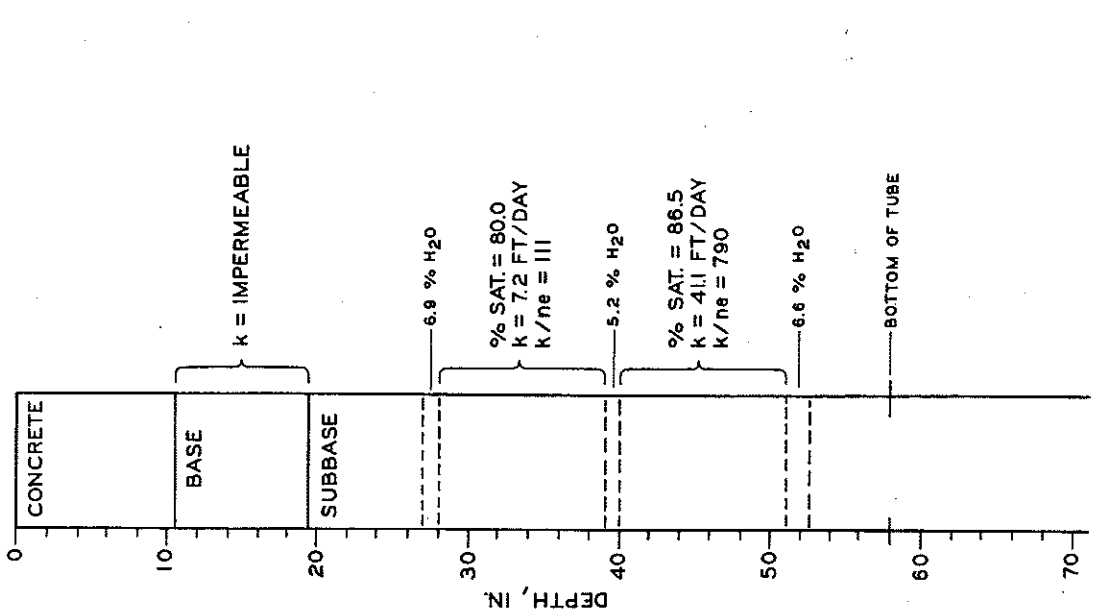


Figure 4 (Cont.). Summary of test data for Site 3, median side, south side of north railroad bridge.

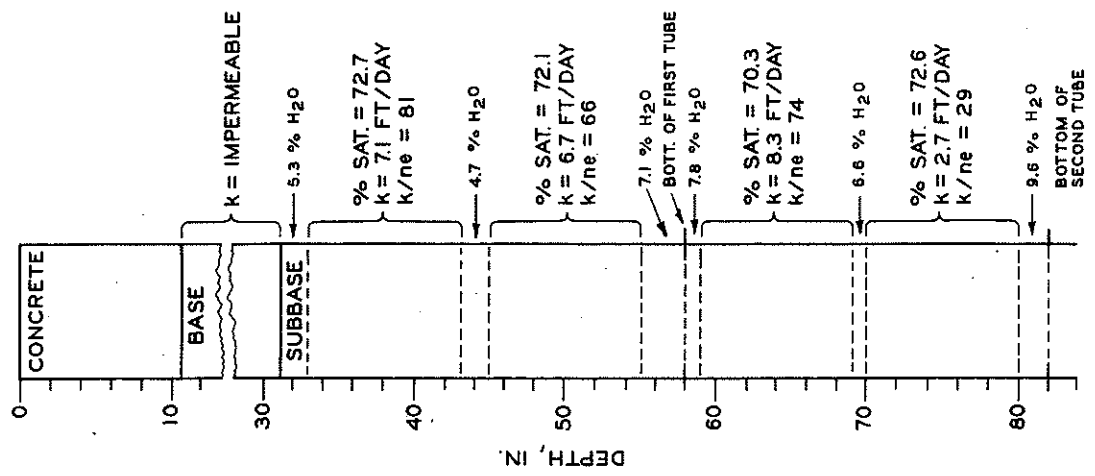


Figure 4 (Cont.). Summary of test data for Site 3, south side of north railroad bridge.

Sieve	Percent Passing	
	Base	Subbase
1-in.	100.0	100.0
3/4-in.	97.1	100.0
1/2-in.	96.4	100.0
3/8-in.	75.4	100.0
No. 4	50.6	100.0
No. 8	33.8	100.0
No. 16	23.1	99.8
No. 30	16.8	96.8
No. 50	12.6	70.6
No. 100	8.6	19.0
No. 200	5.4	5.6

Frost Susceptibility  
 Base = 3.6 mm/day = Medium  
 Subbase = 0.5 mm/day = Very Low

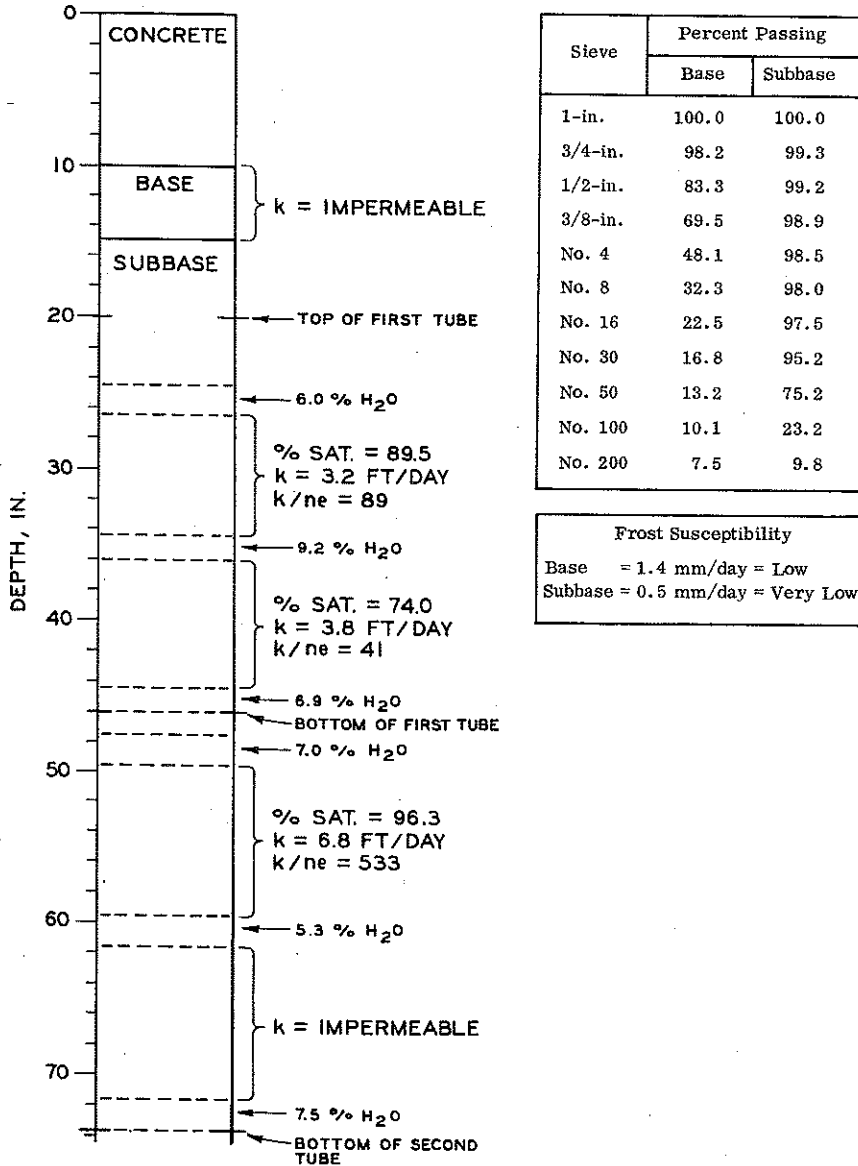


Figure 4 (Cont.). Summary of test data for Site 4, south side of north railroad bridge.



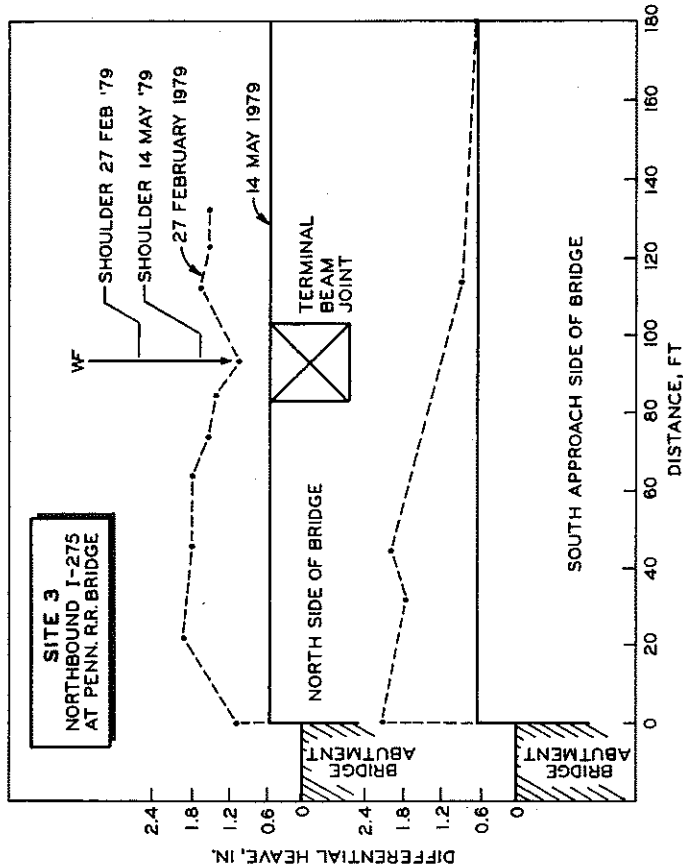
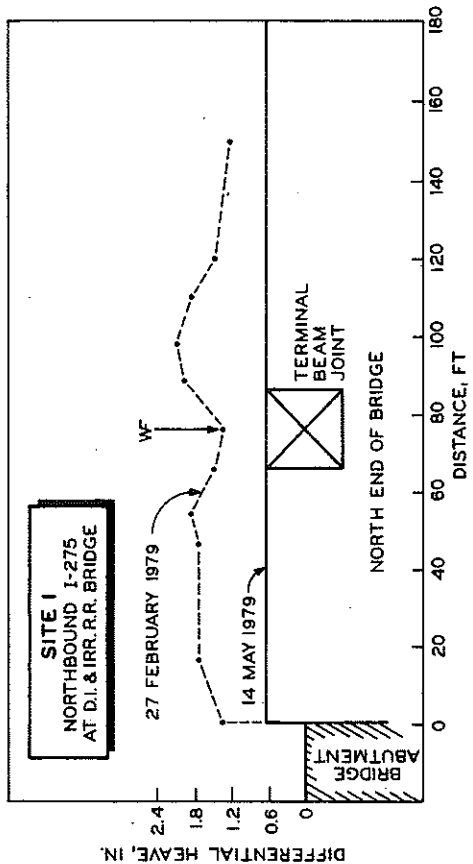
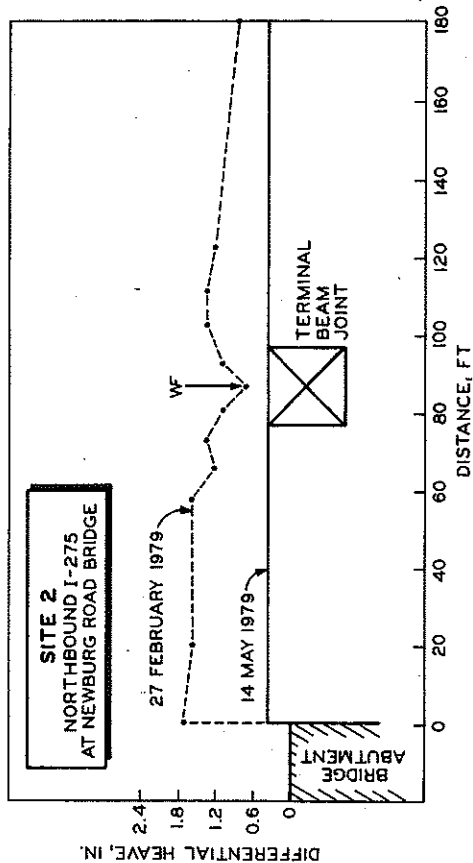


Figure 5. Pavement heave.

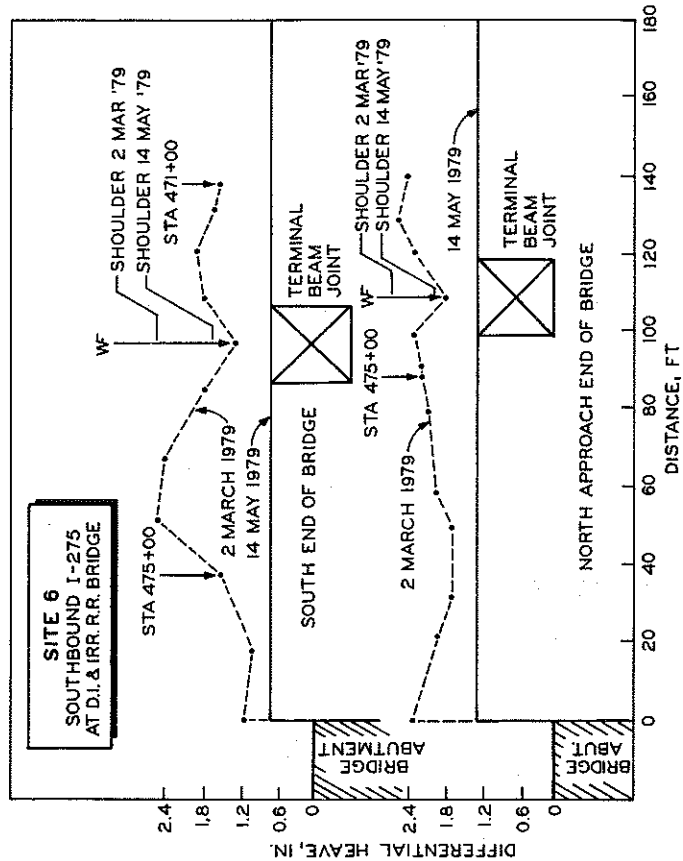
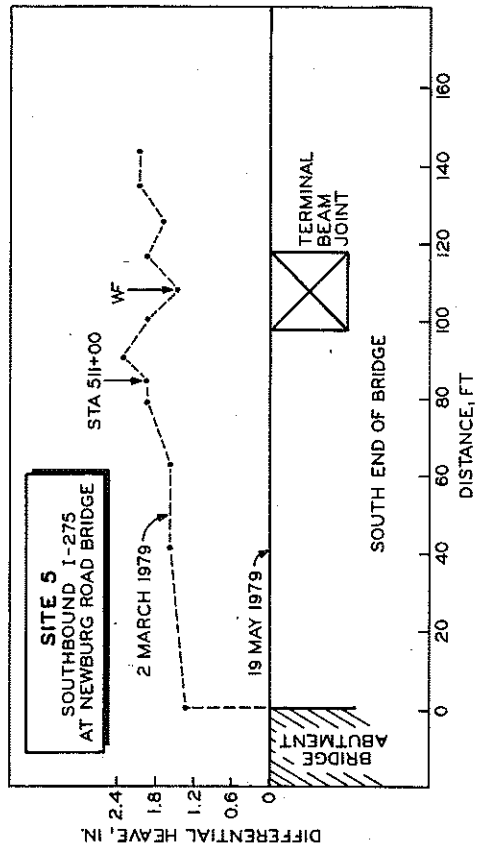
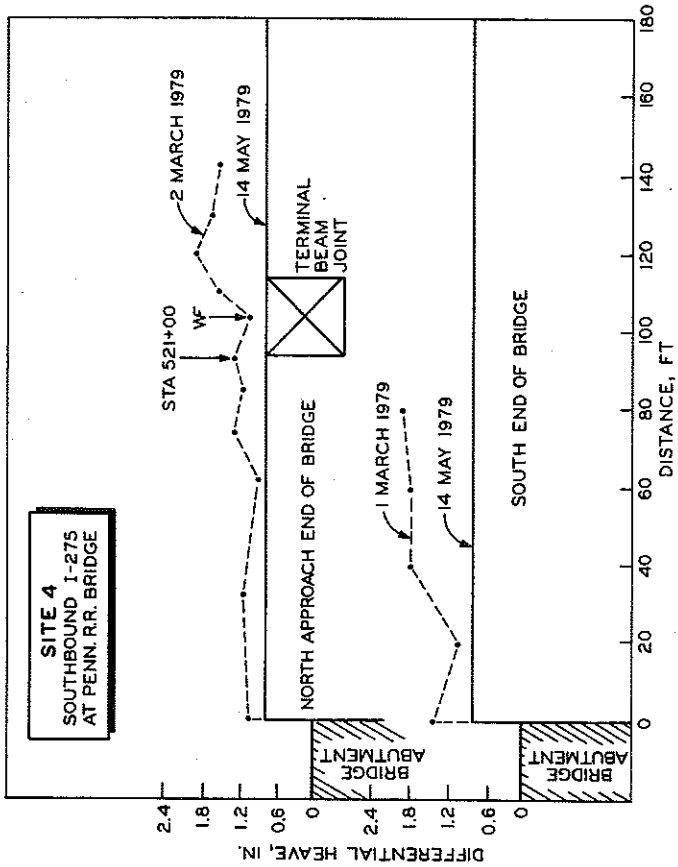


Figure 5 (Cont.). Pavement heave.

## Analysis of Results

The thickness of the slag base varies considerably as does the heave measured at each site. Figure 6 is a plot of the frost susceptibility of the slag vs. the measured heave at bridge Sites 1 through 4. As can be seen, there is no correlation. At Site 3 (Fig. 7) the traffic lane is heaved more than the median lane. Consequently, the thickness of the base in the inside lane was also determined. The base was found to be 9 in. thick in the inside lane compared to 20-1/2 in. in the outside lane. Figure 8 compares frost heave with base thickness at each site, no correlation exists, however.

Only at Site 3 did the slag base sample have a frost susceptibility in the range normally obtained with dense graded slag (3, 4). No explanation could be found for the low frost susceptibility test results. Greatest heave was noted where the greatest quantity of surface water was present (Fig. 2). The frost heave could occur predominantly as a result of freeze-thaw action in which additional water is absorbed by the slag on each thaw cycle. Refreezing causes additional heave. Such conditions can cause heave to exceed 10 percent of the layer's thickness.

The slag base was found, also, to be impervious. As Figure 9 shows, the slag's gradation follows the densest gradation line, ensuring the material to be essentially impervious. Since the slag base is essentially impervious, the addition of supplemental drainage would not remove water from it. However, supplementary drains, if specially designed, may help limit the quantity of surface water saturating the slag base as it thaws. Such drains would be experimental in nature because it is not known to what degree they may be able to attenuate frost heave.

The subbase was found to be either of very low or negligible frost susceptibility. This indicates little or no frost action should come from the subbase layer unless it should freeze when over 90 percent water saturated. The permeability data indicate the subbase and granular fill both have generally fair permeability and they tend to have a good volume of gravity drainable water. Only at sample Site 4 does the sand tend to have a high water holding capacity. In addition to the fact that the subbase would be considered fair material, the in-situ moisture contents also indicate that the sand was relatively dry at the time when the pavement was subject to the most frost heave. Gradation of the subbase samples indicates it to be a medium fine sand. Such sands normally have a fair permeability and can have low water holding capacity under high moisture tensions. On the basis of these results, it is concluded that the sand subbase and granular fill material are adequately drained so that they should contribute little, if any, to the frost heave noted at the bridge abutment.

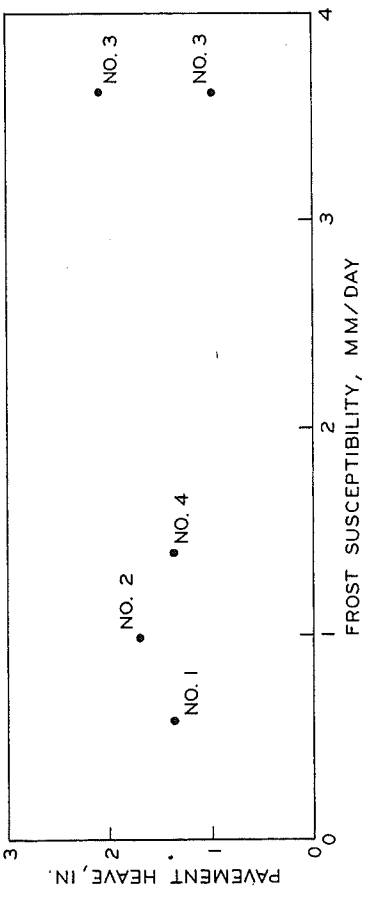


Figure 6. Frost susceptibility of slag base vs. pavement heave at bridge abutment.

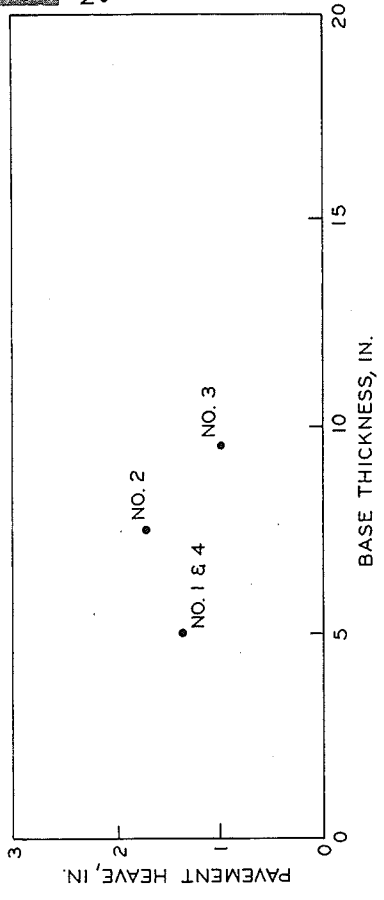


Figure 8. Pavement heave at bridge abutment vs. slag base thickness.

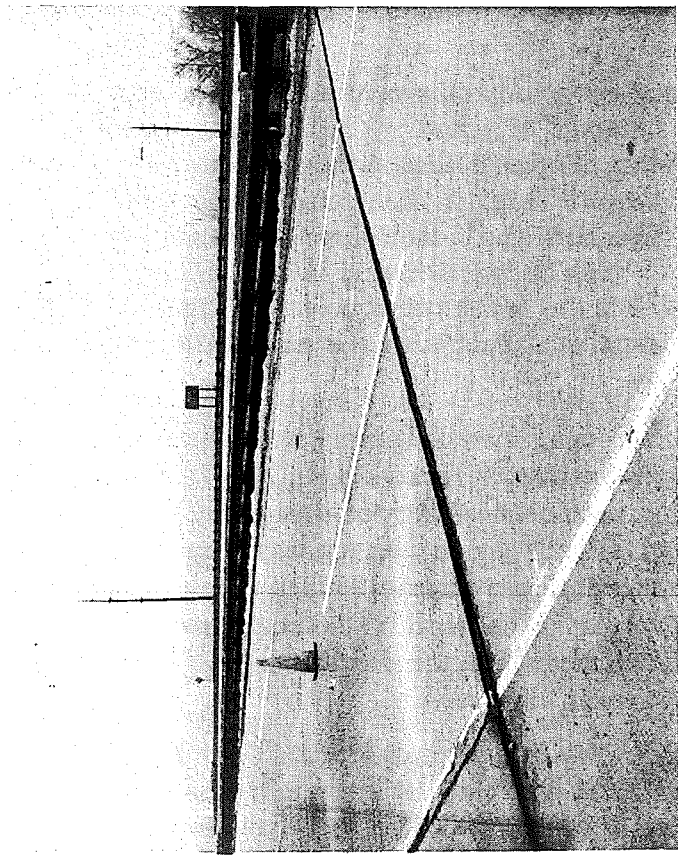


Figure 7. Photo of pavement heave at Site 3 indicating the traffic lane has heaved much more than has the median lane.

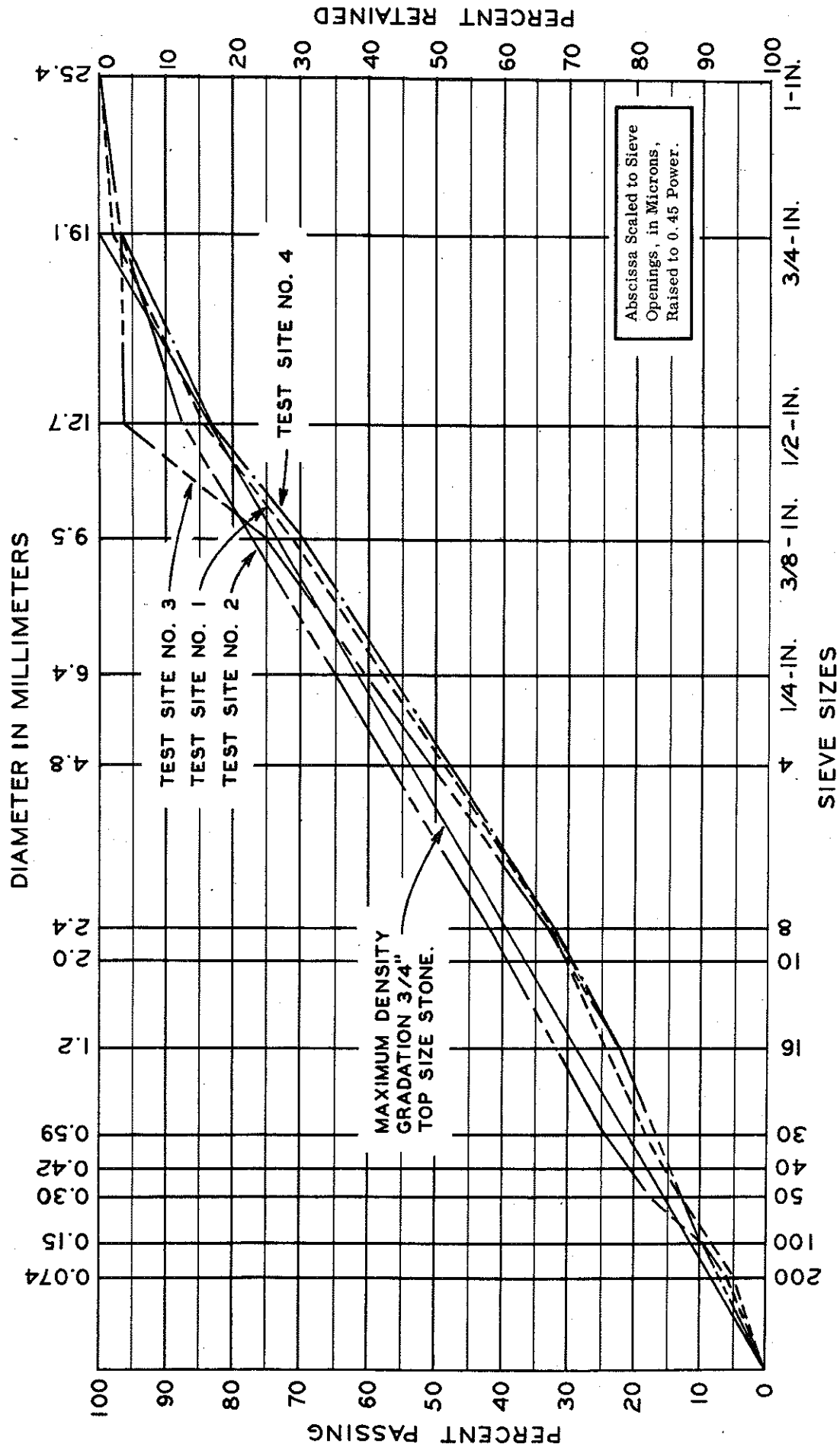


Figure 9. Grain size distribution of slag base material at test sites 1, 2, 3, and 4.

Analysis of the differential pavement heave, Figure 5, indicates that the CRC terminal beam joints frost heave less than the rest of the pavement because of the presence of the sleeper slab (Fig. 10). That is, the sleeper slab in which the terminal beam is anchored heaves, but to a lesser extent than the adjacent pavement slabs. As can be seen from Figure 11, which is the plan drawing from which these joints were constructed, no indication is made as to what material the sleeper slab is to rest on, i.e., base or subbase material. Also, no indication is made as to what minimum subbase thickness is to be used under the sleeper slab. Since the materials used under and around the sleeper slab are not known, the material causing the sleeper slab heave cannot be identified. However, it is concluded that the heave noted at each terminal beam is the result of the difference in thickness of frost susceptible granular foundation materials and that the granular material under the sleeper slab is also subject to frost heave. Because the slag base is not gravity drainable, supplemental drainage about the terminal beam area should have little value in attenuating the differential frost heave.

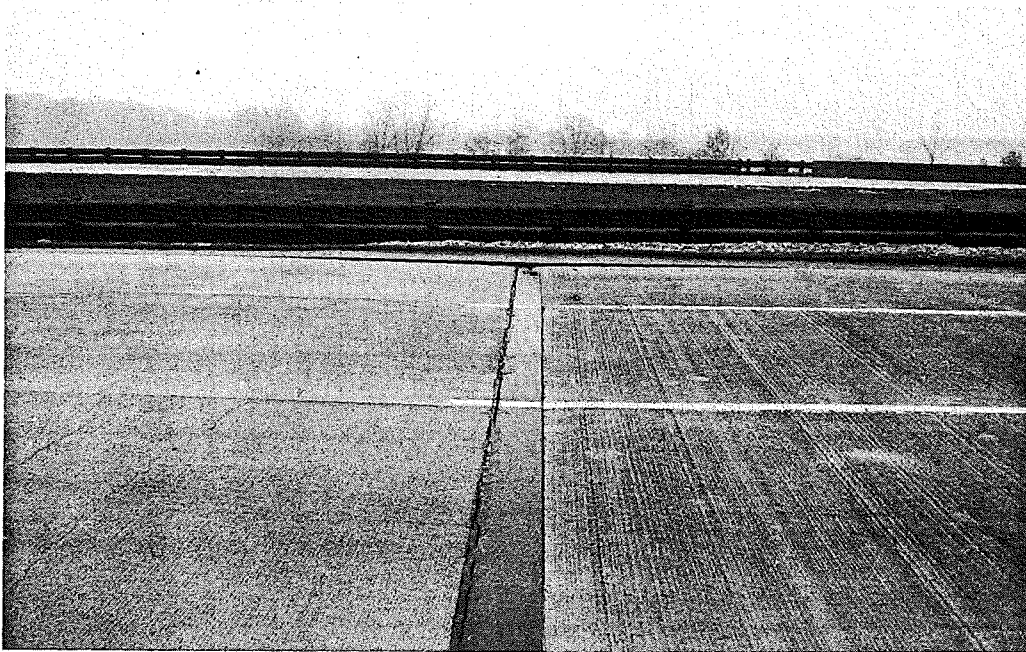
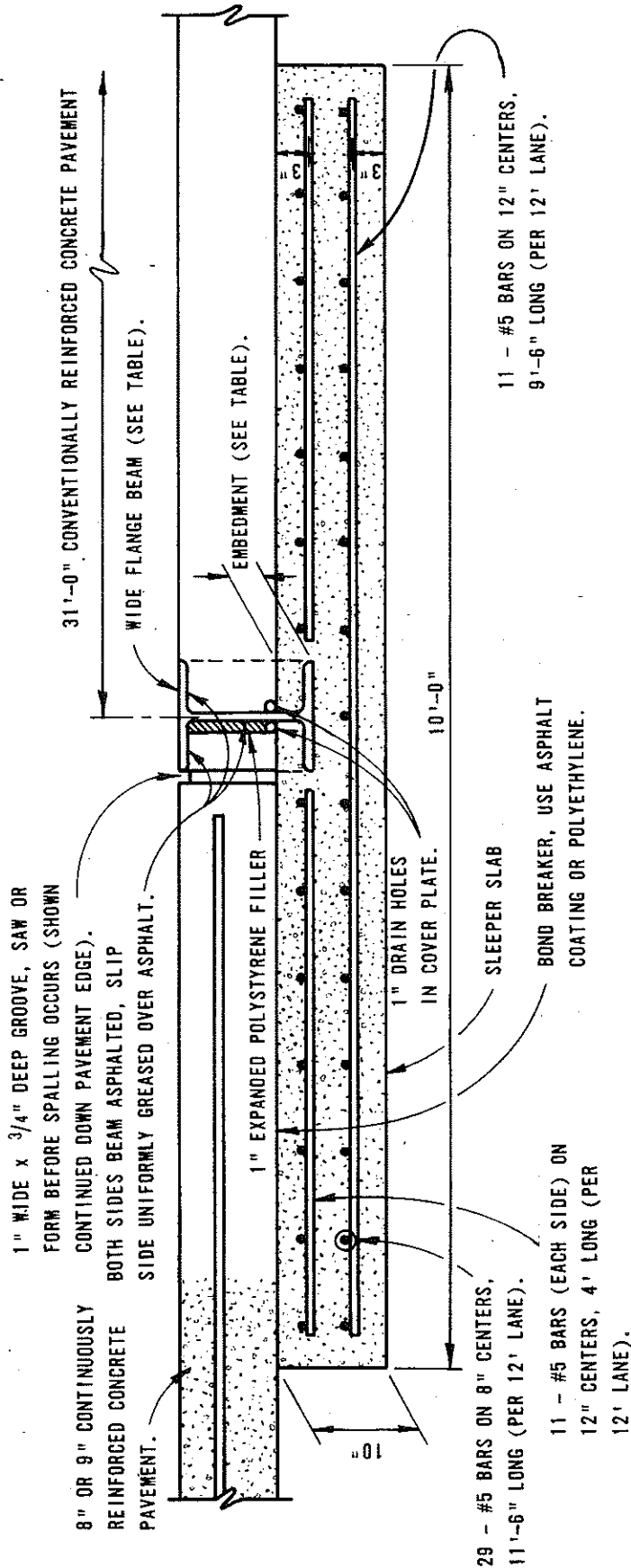


Figure 10. As indicated by the shoulder line in the background, the terminal beam, which is embedded in a sleeper slab, heaves less than the adjacent pavement.



C. R. C. P. THICKNESS IN INCHES	EMBEDMENT IN SLEEPER SLAB - INCHES	STEEL BEAM WEIGHT (LBS)
8	4	12 WF...58
9	3	12 WF...58

**ELEVATION VIEW - WIDE FLANGE BEAM TERMINAL JOINT**  
 (CONNECTING C. R. C. P. TO CONVENTIONALLY REINFORCED CONCRETE PAVEMENT)

Figure 11. Continuously reinforced concrete terminal beam detail.

## Conclusion

On the basis of the field and laboratory study conducted at four bridge sites and the monitoring of frost heave at six bridges, conclusions are as follows:

1) The differential frost heave noted at the bridge abutments of the six bridges shown in Figure 1 is caused, predominantly, by frost action in the slag base material.

2) The subbase layer may be contributing to frost heave of the pavement but such frost heave should be negligible.

3) The use of supplemental subbase drains at the pavement-shoulder construction joint would not be effective in significantly attenuating frost heave of the pavement.

4) No damaging frost heave would have occurred if the pavement surface was constructed to provide more positive surface drainage; if the base thickness was limited to its specified 4-in. thickness; if 10 in. of subbase sand were placed under the sleeper slab; and, if a non-frost-susceptible base material were used.

5) The CRC terminal beam joint design is poor since it does not attempt to eliminate the possibility of differential frost heave nor does it provide for adequate drainage under the sleeper slab.

## Recommendations

The only positive means of preventing the pavement from heaving at the bridge abutment is to remove the slag base and replace it with a free-draining material such as 6A or 9A gravel. Of the six bridges identified, in Figure 1, frost heave correction is recommended at each end of each bridge with the exception of the south end of bridge No. 1 and the north end of bridge No. 5 which do not frost heave significantly. The recommended corrective action is shown in Figure 12.



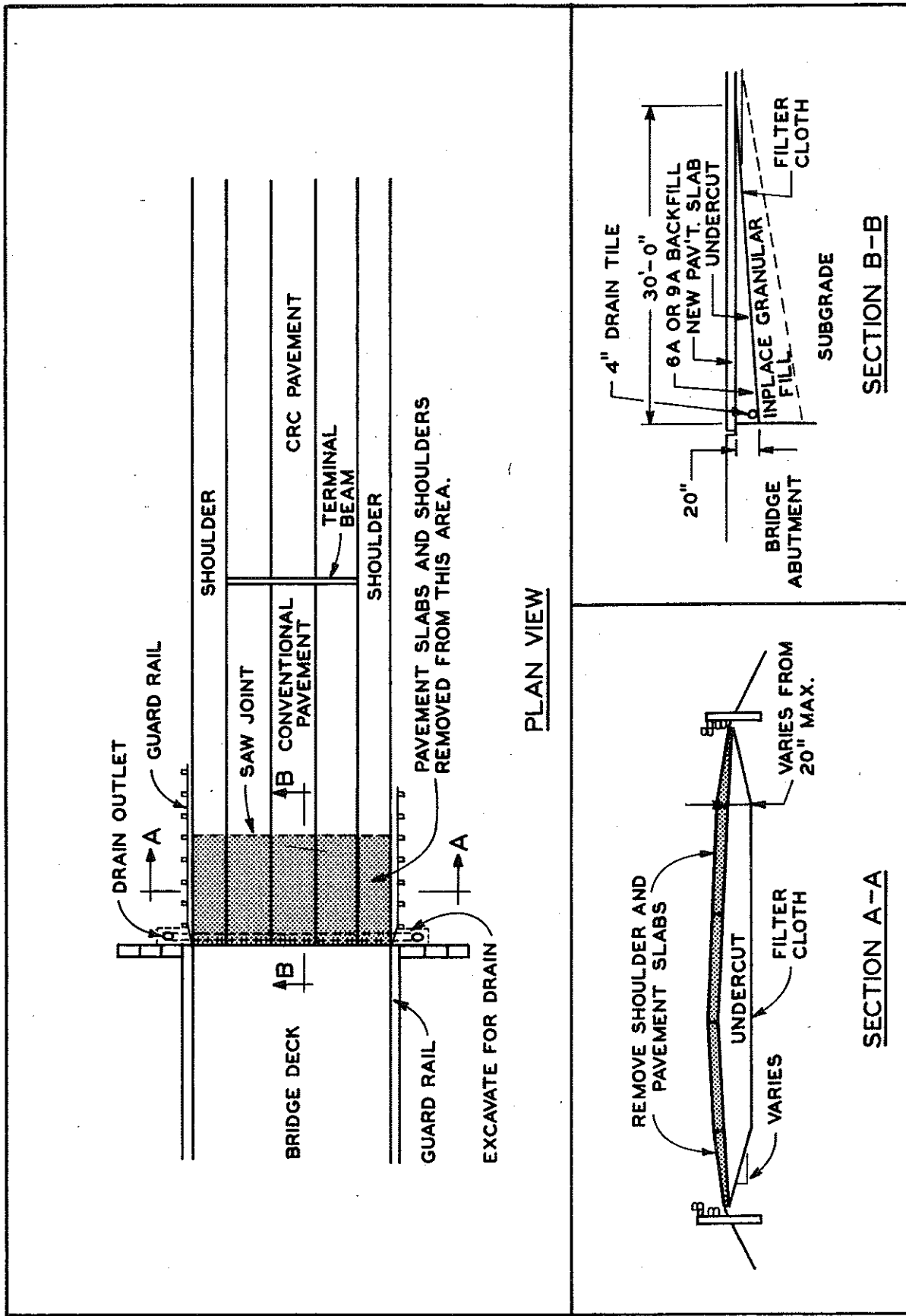


Figure 12. Recommended action to correct pavement heave at bridge abutments.

## REFERENCES

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2. Nettles, E. H., Calhoun, C. C., Jr., "Drainage Characteristics of Base Course Materials Laboratory Investigation," U. S. Army Engineers Waterways Experiment Station, Corp of Engineers Technical Report No. 3-786, July 1967.
3. DeFoe, J. H., "Evaluation of Open Hearth Slag as a Highway Base Material," Michigan Department of Transportation, Research Report No. R-739, May 1970.
4. Mainfort, R. C., DeFoe, J. H., "Further Evaluation of Open Hearth Slag as a Highway Base Material," Michigan Department of Transportation, Research Report No. R-769, July 1971.