1041

DRAINAGE AND FOUNDATION STUDIES FOR AN EXPERIMENTAL SHORT SLAB PAVEMENT

MICHIGAN DEPARTMENT OF TRANSPORTATION

MATERIALS and TECHNOLOGY DIVISION

DRAINAGE AND FOUNDATION STUDIES FOR AN EXPERIMENTAL SHORT SLAB PAVEMENT

T. M. Green
E. C. Novak, Jr.

Research Laboratory Section
Testing and Research Division
Research Project 73 F-136
Research Report No. R-1041

Michigan State Highway Commission
Peter B. Fletcher, Chairman; Carl V. Pellonpaa,
Vice-Chairman, Hannes Meyers, Jr., Weston E. Vivian
John P. Woodford, Director
Lansing, February 1977

INTRODUCTION

This report describes one phase of an overall study to evaluate the performance of several different short slab pavement designs as conducted on three different types of base support: asphalt treated porous material (ATPM) base, high asphalt content and high penetration bituminous stabilized base (designed for crack resistance), and standard specification aggregate base. The specific objective of the project is to determine if short slab plain concrete pavements can perform as well as conventionally designed rigid pavements.

Because the foundation characteristics are extremely important to the objectives of this project, particularly with respect to drainability, the Soils Research Unit of the Laboratory was assigned the supervision and study of this phase of the construction. An important objective of this part of the work was to provide basic data for future evaluation of performance of the test sections. Results of these studies are included in this report.

The overall study was conducted as a Category 2 project in cooperation with the Federal Highway Administration. Details of the overall project have been described in previous reports (1, 2).

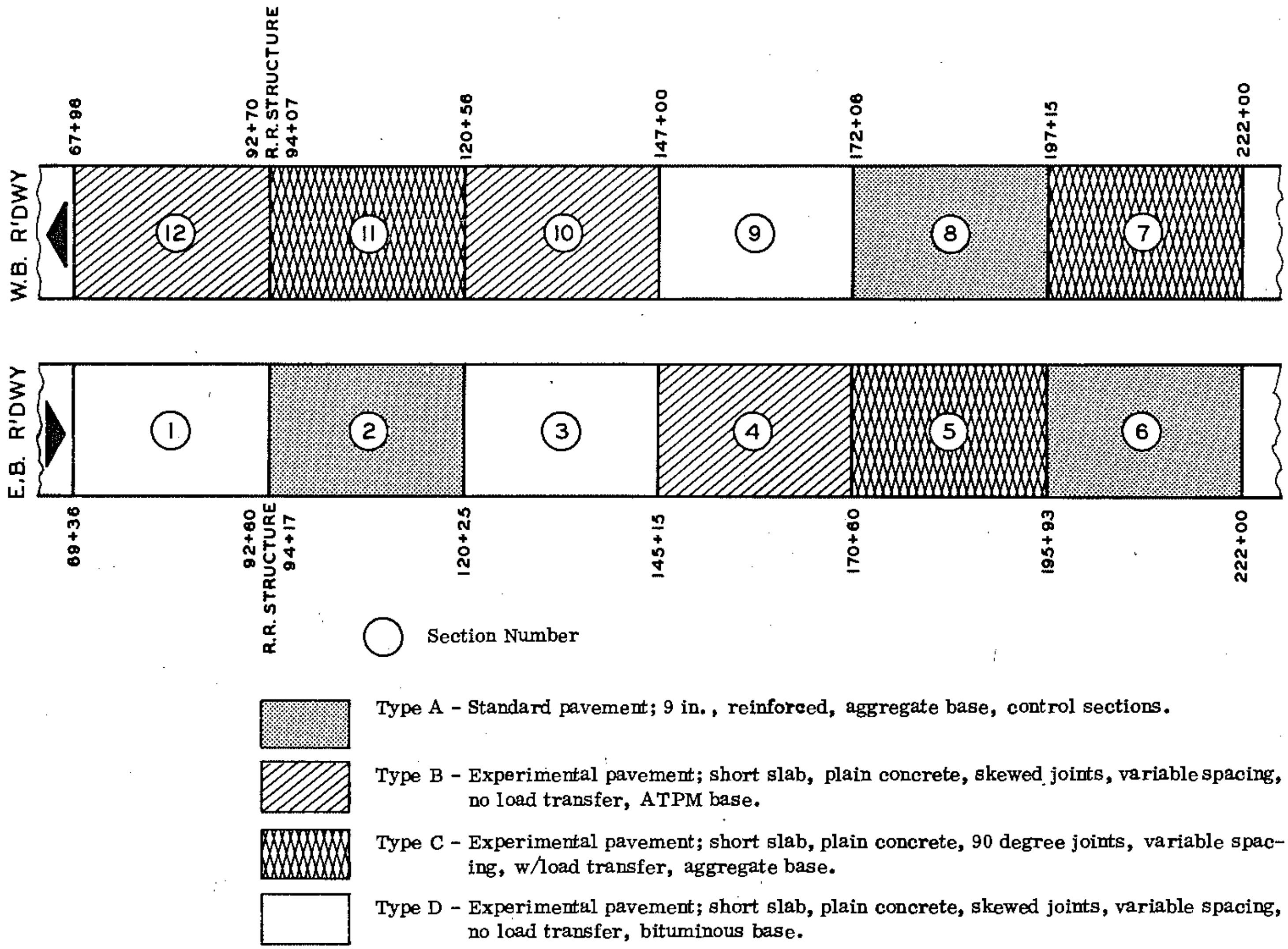
FOUNDATION CHARACTERISTICS OF THE TEST SECTIONS

General Features

The project includes four different pavement designs; Michigan's standard jointed, rigid pavement design and three different short slab pavement designs. Each is repeated in three approximately half-mile long sections randomly located as shown in Figure 1. Such an arrangement makes it possible to evaluate the performance characteristics of each design in a more unbiased manner because the influence of such variables as weather conditions, construction quality, and subgrade properties, are minimized.

Each of the four pavement designs have the same layer thickness as shown in Figure 2. The only difference in foundation design is in the material used for the base layers. The three materials used include dense graded aggregate 24AA, black base (bituminous treated dense graded aggregate 24A modified), and ATPM (asphalt treated porous material).

Special subbase drains were installed in areas where the subbase drainage capacity was low to ensure that all foundations be uniformly well drained. These subbase drains are also used to investigate the rate of surface



Type A - Standard pavement; 9 in., reinforced, aggregate base, control sections.

Type B - Experimental pavement; short slab, plain concrete, skewed joints, variable spacing, no load transfer, ATPM base.

Type C - Experimental pavement; short slab, plain concrete, 90 degree joints, variable spacing, w/load transfer, aggregate base.

Type D - Experimental pavement; short slab, plain concrete, skewed joints, variable spacing, no load transfer, bituminous base.

Note: Section limits shown are where pavement base course or slab lengths change. Exact limits of section may vary slightly near the transition areas. Section numbers correspond to sequence in which concrete pavement was placed.

Figure 1. Experimental test section layout, as constructed.

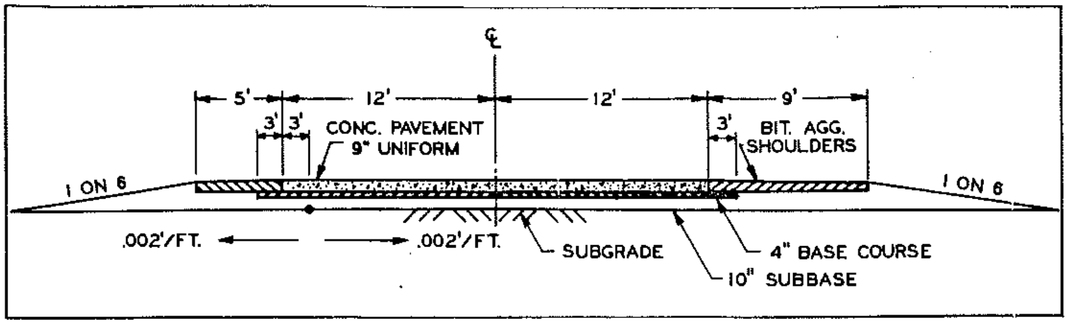


Figure 2. Typical cross-section of the test areas.

water infiltration into the pavement's foundation. All subbase drains were installed in the subbase layer, directly below the longitudinal pavement-shoulder interface as shown in Figure 3. Subbase drains consist of 6-in. diameter perforated, corrugated galvanized steel pipe, wrapped in filter cloth before placing. Metering devices will be placed at those drain outlets if later they are found to carry significant quantities of water. Subbase drains placed in ATPM Sections B-4, B-10, and B-12 were modified by deleting the filter wrap and by backfilling around the pipe with 9A stone (Fig. 4).

Special features of the four different pavement foundations are described below.

Control Sections - Type A

Three randomly located control sections (A-2, A-6, A-8) were constructed using conventional materials and construction methods. The base layer of these sections consists of dense graded aggregate 24AA.

ATPM Base Sections - Type B

Three randomly located (B-4, B-10, B-12) short slab plain concrete pavement sections having no load transfer devices at the joints were placed on ATPM bases consisting of 9A stone with 2 to 3 percent 85-100 penetration asphalt, and 2 to 6 percent fly ash added to stiffen the mix. ATPM of this composition has an extremely high permeability, usually in excess of 3,000 ft per day. The purpose of the ATPM layer is to keep the area under the slabs dry, which should help prevent faulting. It is anticipated that pumping of fines from one side of the pavement joint to the other (the cause of faulting) cannot take place because of the presence of the ATPM layer. In order to take full advantage of the large drainage capacity of ATPM base,

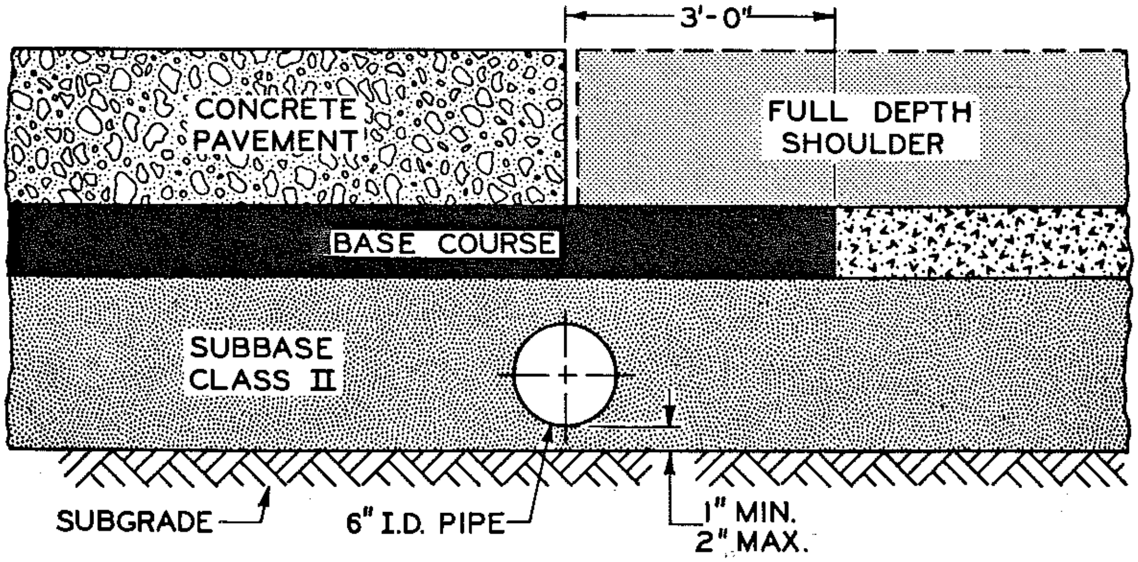


Figure 3. Cross-section of subbase drain installation.

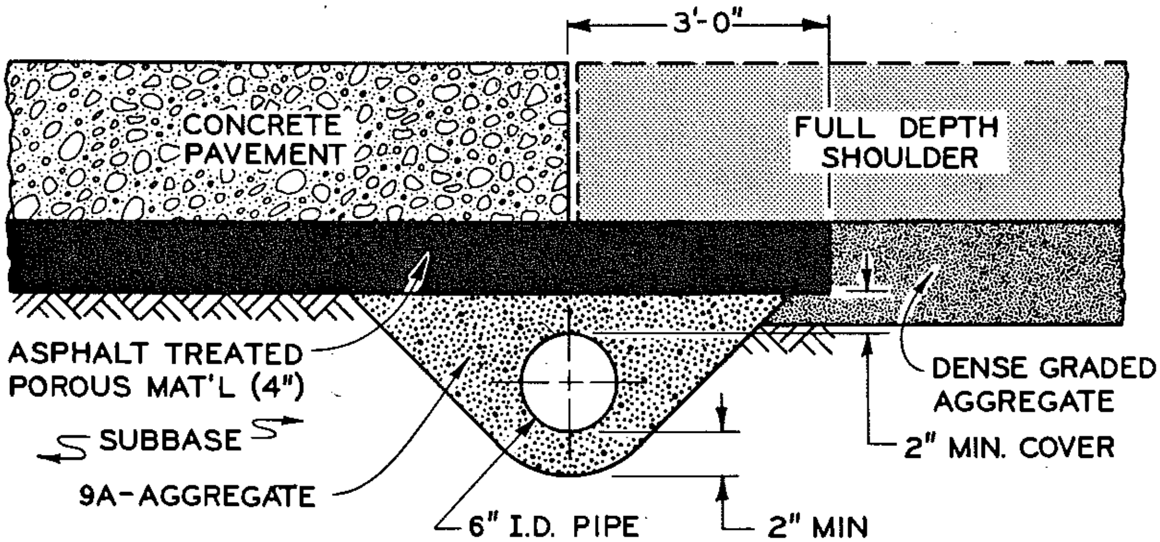


Figure 4. Cross-section of asphalt treated porous material (ATPM) drain installation.

longitudinal drain lines were installed for the full length of this type base (Fig. 4). Transverse drains were placed at the ends of each ATPM section to prevent longitudinal movement of surface infiltrated water.

Short Slab Aggregate Base Sections - Type C

Three randomly located sections (C-5, C-7, C-11) of short slab plain concrete pavement, with load transfer devices at joints, were constructed on conventional dense graded aggregate 24AA. It was known from previous experience that joint faulting will occur when using 24 series base material unless load transfer devices are used.

Black Base Sections - Type D

Three randomly located sections (D-1, D-3, D-9) of short slab plain concrete pavement, having no load transfer devices at the joints, were placed on black base. The black base consists of dense graded modified 24MOD aggregate mixed with 6 to 8 percent of 250-300 penetration grade asphalt. The purpose of the black base is to act as a continuous impervious membrane which will prevent infiltration of surface water into the subbase and thereby prevent faulting. To do this successfully, there must be no cracking of the black base. For this reason, it was designed to contain excess asphalt so that it could have high and low temperature tensile strength, low modulus, and excellent flow characteristics.

CONSTRUCTION OF THE TEST SECTIONS

Edge Drains

During subgrade construction edge drains were placed in the subgrade, at locations recommended by the District Soils Engineer for the purpose of keeping the water table at least 5 ft from the pavement surface. It was noted in at least one case that dense graded, essentially impervious, 20B material was placed around the drain which, in effect, prevented the drain from working. 20B was used because it was readily available and met specifications for porous backfill material. Inspection of edge drain outflows indicates that some carry large volumes of water while others carry none.

Subgrade

After the subgrade was shaped and compacted it was checked by Research Laboratory personnel for density and drainability characteristics.

using the procedures outlined in Ref. (3). Construction traffic used the trimmed and compacted subgrade as a haul route resulting in the development of 6 in. to 2 ft ruts. It appeared impossible to ensure that subgrade density requirements had been met or that the subbase layer placed on the subgrade was of the required minimum 10 in. thickness. However, this was not considered to be a problem since there was little difference in the drainability of the subgrade and subbase materials and because the importance of density control appears to be less critical for sand subgrades than for the more cohesive materials.

Subbase

The subbase was placed with scraper haulers, graded, rolled, and trimmed to final shape, using a CMI autograder controlled by a stringline. After initial shaping and compaction to required density, the subbase was checked for drainability and density by Research Laboratory personnel using the drainability test method described in Ref. (3). The subbase drainability data were then used to locate subbase drains. Each test section contains at least 500 ft of subbase drains. Table 1 lists the length and stationing of these drains.

TABLE 1
LOCATION AND TYPE OF DRAINS

Section	Lane Direction	Beginning Station	Ending Station	Drain Type
D1	eastbound	81+50	88+50	subbase
A2	eastbound	95+00	100+00	subbase
D3	eastbound	130+00	135+00	subbase
B4	eastbound	145+00	170+60	ATPM
C5	eastbound	180+00	194+50	subbase
A6	eastbound	206+00	212+00	subbase
C7	westbound	201+00	206+00	subbase
A8	westbound	177+00	182+00	subbase
D9	westbound	161+00	166+00	subbase
B10	westbound	120+00	147+00	ATPM
C11	westbound	108+00	118+00	subbase
B12	westbound	68+00	93+00	ATPM

Subbase and ATPM Drains

Both ATPM and subbase drains were installed after the subbase had been shaped and compacted. The trench in which the drains were placed was cut with a grader which had its blade set at an extreme angle. By dropping only the front corner of the blade, a smooth trench of the proper grade and depth was cut in a single pass. The filter-wrapped pipe was placed in the trench and covered with a single pass of the grader as shown in Figure 5.

The longitudinal ATPM drains were installed using the same procedure as that used for subbase drains except that the pipe was not wrapped with filter cloth and the backfill consisted of a 9A stone instead of the sand subbase material cut from the trench. Figure 6 depicts a typical longitudinal ATPM drain. Placement of ATPM drains could have been improved if the subbase material cut from the trench had been removed before placement of the ATPM drain. Because this was not done, some of the subbase sand clogged the 9A backfill material, as illustrated in Figure 7.

Both ATPM and subbase drains were installed between construction of the subbase and the construction of the bases. Later, after the pavement slab had been poured, the drain outlets were installed. This two stage installation caused problems such as misaligned joints and temporary blocking of drainage, that could have been avoided had the drains and outlets been installed at the same time. In the future it is suggested that specifications require that subbase drains and outlets be installed at the same time.

Haul Roads

A 10-ft wide, 6-in. thick haul road was constructed on the outside shoulder for the entire length of each roadway. 24AA was used for this purpose so that the haul road could be left in place to serve as a base for full-depth bituminous shoulders, if the contractor chose to do so. The haul roads were used to protect the ATPM and black bases from construction traffic. Generally the concept of having a haul road as opposed to using the pavement base for construction traffic worked very well. The biggest problem encountered was that silt and sand were eroded onto the ATPM surface for a distance of up to 8 ft and there was some concern that it may significantly reduce the ATPM's drainability. However, as illustrated by Figure 8 the ATPM had considerable drainage capacity since the surface could not be flooded by the water wagon and the presence of sand on the ATPM, though not desirable, did not appear to significantly reduce permeability.

Aggregate Base

Dense graded 24AA aggregate, 30 ft wide and 4 in. thick, was used for the base of pavement section Types A and C. A CMI spreader equipped

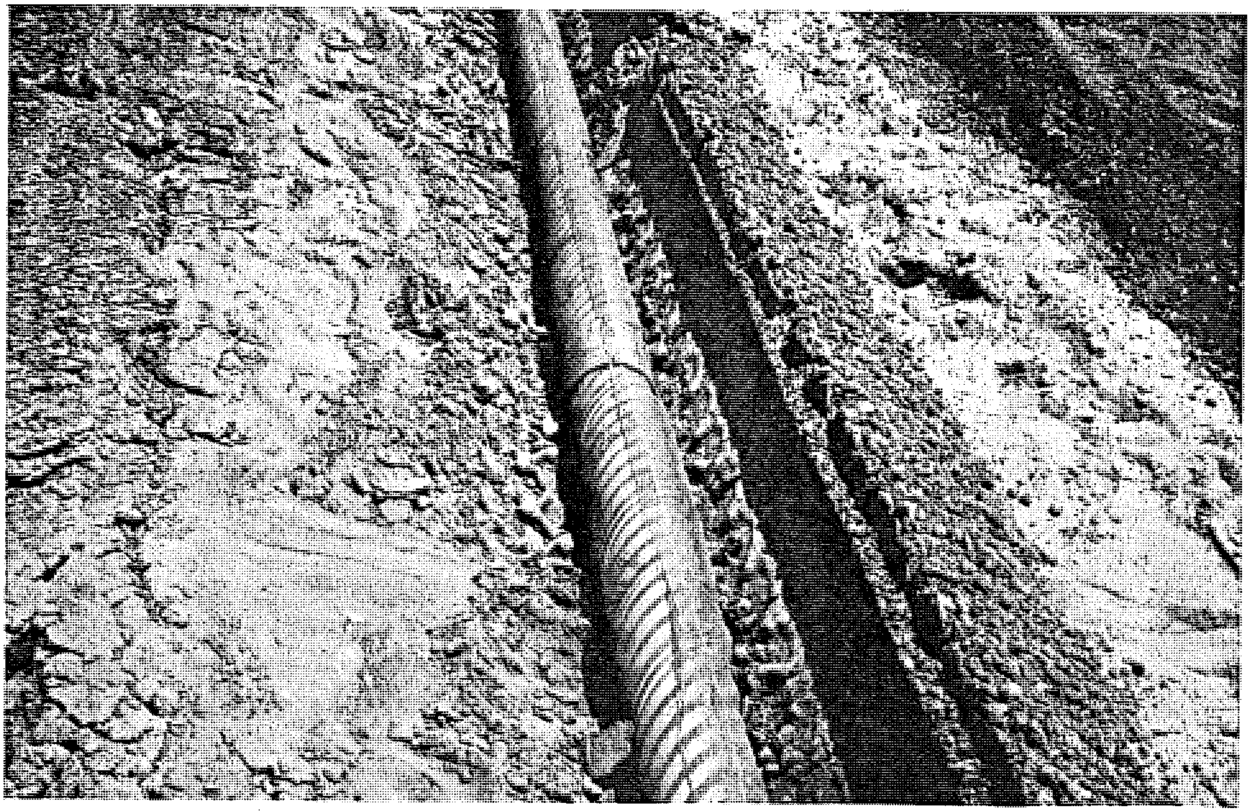


Figure 5. After installation (above) the filter-wrapped subbase drains are backfilled (below).

Figure 6. ATPM drain with partially installed 9A backfill.

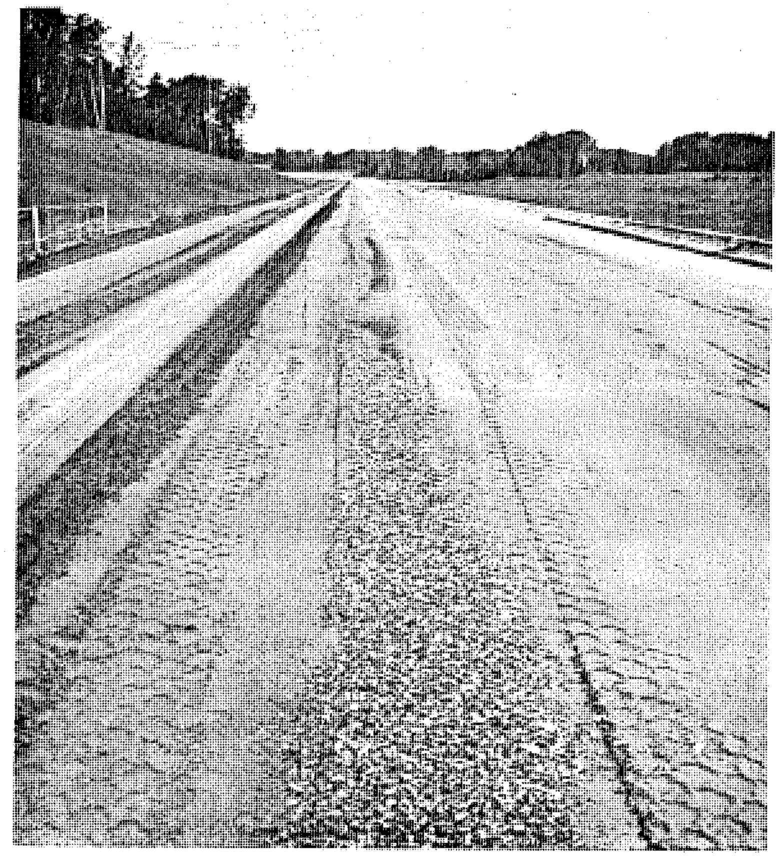
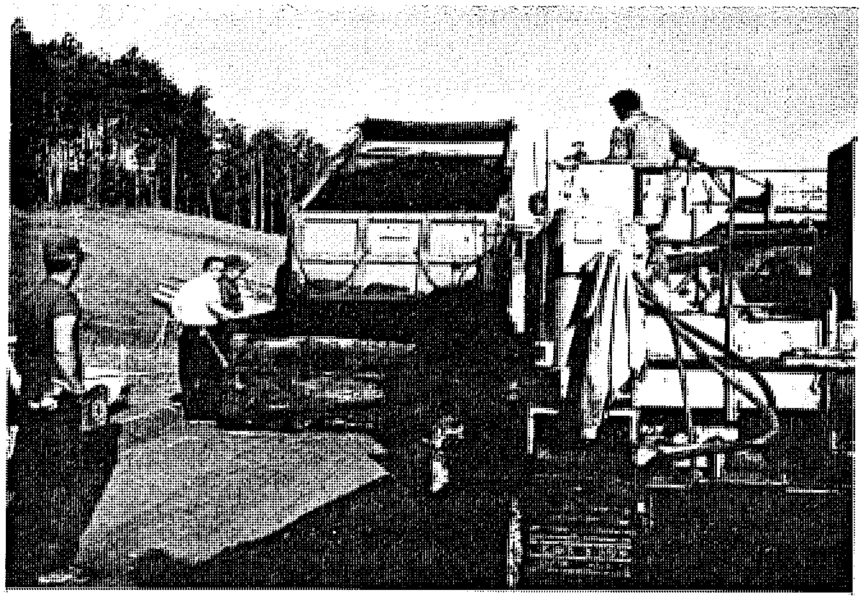
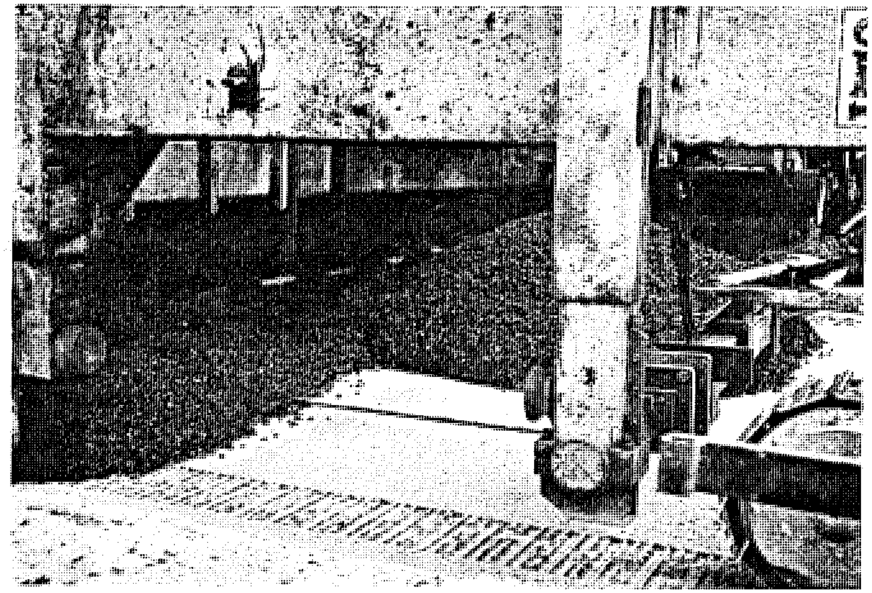


Figure 7. ATPM drain was somewhat contaminated with subbase after trimming to final grade.

Figure 8. Application of water to ATPM surface.



Filling CMI spreader with ATPM.



Spreading the ATPM.

Rolling ATPM surface with 3-ton roller.

Figure 9. Placing the ATPM base course.

with a side dump and controlled by stringline on the median side was used to place the aggregate bases.

ATPM Base

ATPM used for Type B pavement sections, was layed 30 ft wide and 4-in. thick using a CMI spreader equipped with a side dump and controlled by stringline on the median side. The ATPM mat was widened from the originally planned 25 ft width to 30 ft in order to provide a firm base for operating the CMI paver. Figure 9 shows the typical dumping, spreading, and rolling operation used to construct the ATPM bases. It was originally intended that the ATPM be compacted with a vibrating screed but because this equipment was not available to the contractor, a single pass of an empty three-ton roller was used in its place. The roller was effective in smoothing the ATPM surface but thickness checks indicated that rolling in this manner did not result in increased density.

The operator of the CMI spreader had to learn how to handle ATPM material, as it is more difficult to push than concrete or gravel. The best procedure is to keep only a small amount of ATPM in front of the augers at all times. Trying to push too much ATPM caused the spreader's tracks to cut into the subbase which in turn reduced the thickness of the ATPM layer. However, after the first hour or so the operator knew how much ATPM the CMI spreader could handle and no further problems were encountered.

The ATPM base proved to be very stable as well as highly porous. The only problem encountered during construction of these sections was the rolling of the surfaces caused by malfunctioning of the CMI spreader's leveling system. With such irregular support it would not be possible to hold the concrete surface thickness within specified tolerances without considerable increase in concrete quantities. Therefore, it was decided to use the scarifier blade on the CMI autograder to see if the irregular ATPM surface could be trimmed. It was found that this could be done easily if the surface were first allowed to warm in the sun.

A problem encountered when producing ATPM was that some batches came out looking very dry. However, this material caused no problems because it had, essentially, the same handling, drainability, and stability characteristics as did the normal appearing batches.

In general, ATPM bases were found to be easy to construct and should offer no particular problem for contractors should they be used in future construction.

Black Base

The black base, used for Type D pavement sections, was constructed in the same manner, and using the same equipment, as did the ATPM base. The black base was also placed 30 ft wide and 4 in. thick. Figure 10 shows the CMI spreader placing the black base and the smoothing effect on the surface obtained by compacting with a roller.

The CMI spreader's leveling system was also malfunctioning during construction of the black base sections and it was, therefore, necessary to trim these sections too. The same trimming procedure was used for black base as was used for ATPM, with equally good results. Figure **11** shows the CMI autograder trimming a section of black base.

TESTING METHODS AND RESULTS

Considerable testing was conducted to document the subgrade, subbase, and base properties of each test section. Generally, it is assumed that all sections of pavement constructed with the same base and subbase materials would have equal performance characteristics because the materials used were produced, and the layers constructed, in accordance with the same specifications. However, experience indicates there may be significant differences that should be determined in order to properly evaluate the relative performance of the various test sections. For this reason, samples of subgrade, subbase, and base were collected from each 200 lin ft of roadway. Each 200-ft section of subgrade was divided into a 40 block grid (two blocks wide and 20 long) and random numbers were drawn to select the block from which the sample would be taken. The same locations were used to take subbase and base samples.

Testing was limited to a determination of those engineering properties of the subgrade, subbase, and base which are known to influence performance. Tests conducted in the field on the subgrade and subbase included permeability, effective porosity, percent saturation when gravity drained, and density. The field testing procedures used are presented in Ref. (3) and the test results are summarized in Table 2.

The following criteria was used to interpret the drainability data shown in Table 2. The degree of saturation when gravity drained should be 90 percent or less and the k/N_e ratio should be greater than 55.2 assuming the subgrade is impervious (4). On the basis of these drainage criteria, two sections of subgrade, A2 and D1, are better drained than is the subbase and three sections, A6, C7, and A8, have comparatively poor drainability.

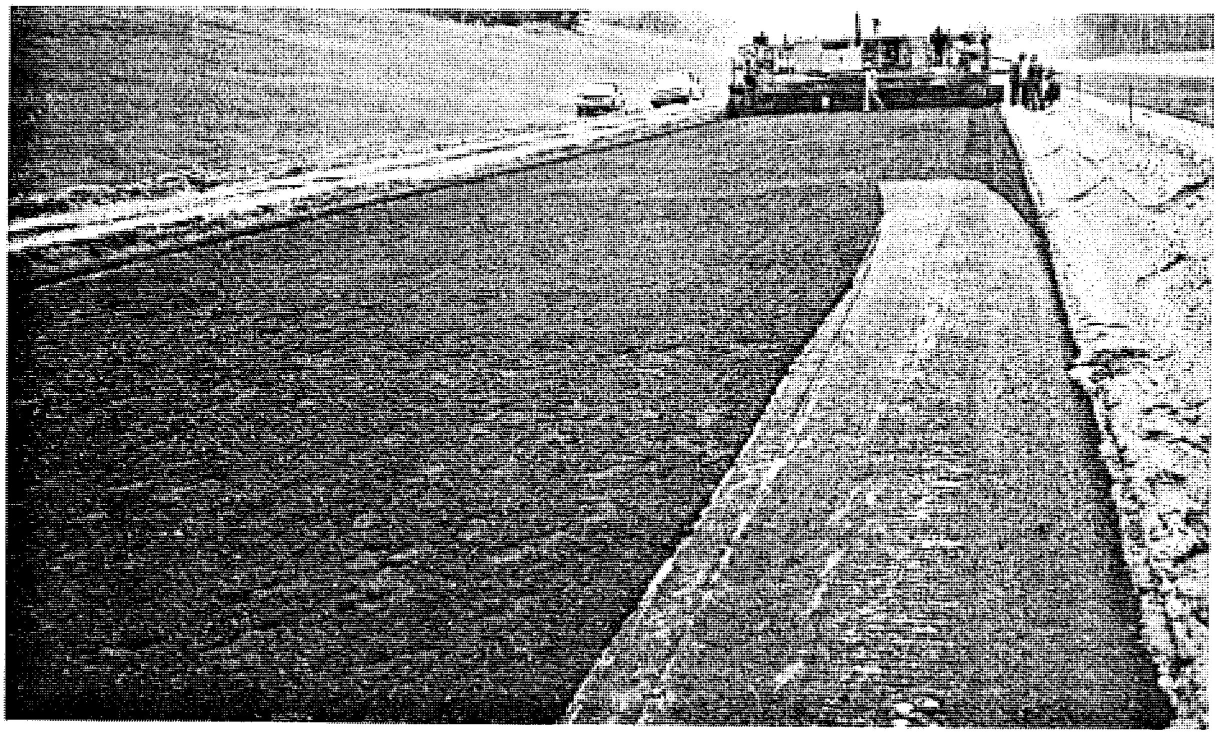


Figure 10. Application of black base with CMI spreader. (Lighter section at right shows result of one pass of 3-ton roller.)

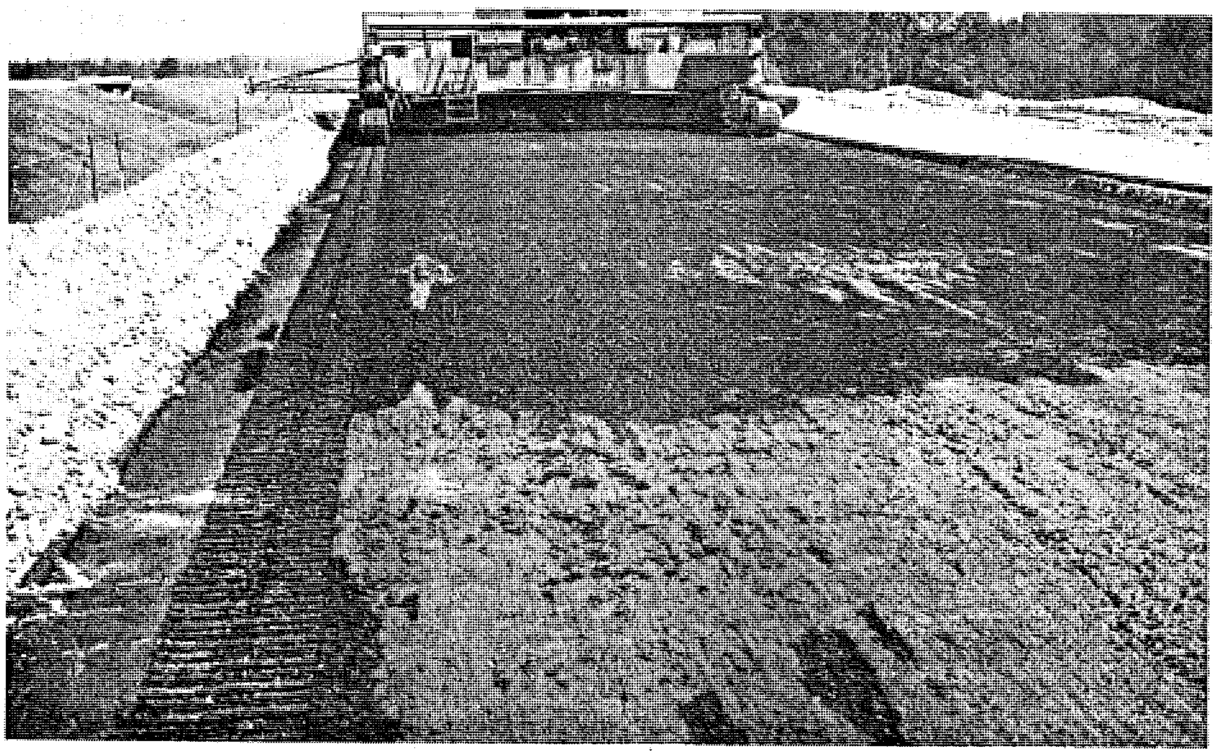


Figure 11. Uneven surface of a black base section being trimmed by the CMI autograder.

TABLE 2
FIELD TEST RESULTS ON SUBGRADE AND SUBBASE SECTIONS

Section	Station No.	Subgrade								Subbase							
		k, ft/day	N_e	Saturation, percent*	$\frac{k}{N_e}$	Dry Density, lb/cu ft	Percent Passing			k, ft/day	N_e	Saturation, percent*	$\frac{k}{N_e}$	Dry Density, lb/cu ft	Percent Passing		
							1-in.	No. 100	No. 200						1-in.	No. 100	No. 200
Eastbound US 10, Section D-1 Station 69+36 - 92+80	70+70	8.6	0.08	76.5	108.0	109.1	98.6	6.5	3.6	5.6	0.09	72.6	62.0	116.3	100.0	7.0	4.2
	71+70	8.6	0.12	66.3	72.0	104.6				10.3	0.05	82.6	206.0	113.0			
	74+20	27.3	0.09	76.3	303.0	106.1	98.8	8.1	2.9	7.3	0.09	73.6	81.0	112.2	100.0	7.1	3.9
	75+20	21.6	0.05	84.3	432.0	113.2				7.3	0.09	70.0	81.0	116.8			
	78+00	19.7	0.08	73.1	246.0	112.6	98.4	6.5	3.4	8.0	0.02	90.6	400.0	115.9	100.0	7.6	4.3
	79+40	16.0	0.07	80.6	228.0	111.1				5.1	0.10	67.7	51.0	113.3			
	81+60	12.9	0.10	71.7	129.0	110.9	100.0	7.2	3.9	7.5	0.08	72.8	94.0	115.5	100.0	7.3	3.8
	84+20	23.0	0.12	65.1	192.0	110.5				47.2	0.05	84.8	944.0	112.7			
	86+00	25.4	0.05	85.0	508.0	106.7	100.0	7.6	4.0	2.3	0.14	54.8	16.0	115.6	100.0	7.3	4.2
	87+20	3.4	0.12	64.1	28.0	114.2				0.4	0.05	76.9	8.0	122.9			
	90+10	25.4	0.05	83.9	508.0	109.6	100.0	6.3	3.3	1.4	0.08	72.1	18.0	118.7	100.0	7.5	4.4
	91+80	15.1	0.10	71.4	151.0	109.6				2.5	0.06	78.1	42.0	114.5			
	$\bar{x}$	17.3	0.09	74.9	242.0	109.7	101.0	7.0	3.5	8.7	0.08	74.7	204.5	115.6	100.0	7.3	4.1
	σ	7.7	0.03	7.5	164.5	3.0	4.5	0.7	0.4	12.5	0.03	9.1	220.8	3.0	0	0.2	0.2
Eastbound US 10, Section A-2 Station 94+17 - 120+25	95+50	16.8	0.11	68.6	153.0	108.3	100.0	8.3	3.6	5.4	0.11	67.1	49.0	112.1	100.0	10.0	3.7
	96+90	12.7	0.10	68.1	127.0	112.2				4.1	0.10	71.4	41.0	110.0			
	99+90	16.5	0.08	75.1	206.0	113.5	100.0	9.2	4.6	0.9	0.09	72.2	10.0	115.7	100.0	6.8	3.5
	101+90	11.0	0.13	62.0	85.0	110.2				10.9	0.10	72.5	109.0	112.3			
	102+60	20.8	0.09	71.3	231.0	110.5	100.0	6.3	3.1	14.4	0.09	72.8	160.0	111.4	100.0	4.9	2.6
	104+70	3.5	0.08	76.4	44.0	112.8				17.0	0.07	78.5	243.0	108.3			
	106+10	17.2	0.07	76.3	246.0	113.6	100.0	7.3	4.6	12.7	0.07	77.2	181.0	114.2	100.0	6.1	3.4
	109+40	17.1	0.08	74.3	214.0	112.6				10.4	0.04	87.0	260.0	116.3			
	111+70	12.1	0.05	81.1	242.0	119.4	100.0	5.1	3.2	21.6	0.08	77.0	270.0	107.0	100.0	5.6	2.5
	112+30	5.6	0.11	60.3	51.0	119.6				9.5	0.13	97.0	73.0	111.5			
	114+60	7.0	0.02	92.6	350.0	119.5	100.0	5.7	3.4	9.5	0.09	76.0	106.0	109.3	100.0	5.4	3.1
	117+80	22.0	0.07	77.1	314.0	117.2				13.5	0.07	78.1	193.0	110.5			
	118+10	7.9	0.05	81.1	158.0	119.2	100.0	14.3	5.3	29.5	0.09	76.4	328.0	107.1	98.5	4.4	1.9
	$\bar{x}$	13.1	0.08	74.2	186.2	114.5	100.0	8.0	4.0	12.3	0.09	77.2	155.6	111.2	99.7	6.2	3.0
	σ	5.9	0.03	8.5	94.5	4.0	0	3.1	0.9	7.5	0.02	7.6	100.2	3.0	0.6	1.9	0.6

* When gravity drained.

TABLE 2 (Cont.)
FIELD TEST RESULTS ON SUBGRADE AND SUBBASE SECTIONS

Section	Station No.	Subgrade								Subbase							
		k, ft/day	N_e	Saturation, percent*	$\frac{k}{N_e}$	Dry Density, lb/cu ft	Percent Passing			k, ft/day	N_e	Saturation, percent*	$\frac{k}{N_e}$	Dry Density, lb/cu ft	Percent Passing		
							1-in.	No. 100	No. 200						1-in.	No. 100	No. 200
Eastbound US 10, Section D-3 Station 120+25 - 145+15	121+00	12.8	0.002	100.0	6400.0	120.7											
	123+40	7.2	0.07	77.7	103.0	117.0	100.0	8.1	5.5	2.4	0.11	63.3	22.0	116.6	100.0	7.2	4.6
	126+20	3.3	0.05	82.8	66.0	115.8				5.5	0.07	77.0	79.0	115.2			
	128+60	11.6	0.09	71.9	129.0	109.8	100.0	8.6	5.2	8.3	0.08	75.8	104.0	112.6	97.4	6.4	3.2
	129+60	10.5	0.07	76.3	150.0	116.3				8.7	0.09	72.1	97.0	111.4			
	132+40	2.7	0.05	83.0	54.0	115.6	100.0	7.8	5.2	6.6	0.07	77.8	94.0	114.1	100.0	7.3	3.8
	134+10	0.9	0.08	73.0	11.0	118.0				3.3	0.09	71.7	37.0	113.3			
	136+80	8.3	0.08	74.2	104.0	112.1	100.0	9.4	5.5	9.5	0.06	80.2	158.0	111.9	100.0	5.8	3.0
	137+80	7.5	0.10	68.4	75.0	116.0				11.4	0.07	79.2	163.0	112.6			
	139+70	23.6	0.04	89.0	590.0	111.9	100.0	7.6	3.6	12.9	0.03	90.1	430.0	111.3	100.0	8.3	3.2
	142+70	4.2	0.10	69.2	42.0	115.5				3.6	0.08	74.0	45.0	115.3			
	144+70	25.9	0.02	92.7	1295.0	110.0	96.1	7.6	3.6	8.7	0.10	67.9	87.0	114.5	100.0	7.1	3.1
	$\bar{x}$	9.9	0.06	79.9	751.6	114.9	99.4	8.2	4.8	7.4	0.08	75.4	119.6	113.5	99.6	7.0	3.5
	σ	7.9	0.03	9.9	1816.1	3.3	1.6	0.7	0.9	3.4	0.02	7.0	112.1	1.7	1.1	0.6	0.6
Eastbound US 10, Section B-4 Station 145+15 - 170+60	145+90	11.5	0.10	74.1	115.0	107.1				4.3	0.08	73.0	54.0	113.2	100.0	11.2	5.7
	147+00	13.3	0.13	65.0	102.0	107.1	100.0	11.8	5.2	3.0	0.10	68.6	30.0	114.4	100.0	8.5	4.7
	149+80	4.3	0.04	88.2	108.0	109.3				11.2	0.09	74.6	124.0	112.7	100.0	6.2	4.1
	151+50	13.4	0.04	91.9	335.0	104.8	100.0	10.1	5.6	31.2	0.06	83.5	520.0	112.0	100.0	5.6	3.3
	154+40	10.4	0.03	91.1	347.0	112.2				9.2	0.09	73.2	102.0	114.1	100.0	6.0	3.9
	155+40	1.7	0.11	69.0	15.0	117.0	100.0	9.8	5.3	19.6	0.07	79.5	280.0	114.1	100.0	4.9	2.9
	157+20	5.0	0.04	86.8	125.0	115.9				10.2	0.07	77.6	146.0	115.7	100.0	6.9	3.1
	159+80	9.6	0.13	64.1	74.0	104.2	100.0	9.3	3.5	34.5	0.09	74.3	383.0	109.4	100.0	5.3	3.0
	161+40	13.7	0.07	78.8	196.0	110.8				8.6	0.09	72.9	96.0	112.9	100.0	7.6	4.4
	164+10	6.8	0.03	90.6	227.0	118.2	90.7	6.9	3.5	6.4	0.07	76.4	91.0	115.6	100.0	6.6	4.2
	165+80	14.5	0.05	82.6	290.0	114.4				16.7	0.09	73.8	186.0	111.5	100.0	5.0	3.0
	167+00	17.1	0.02	92.9	855.0	119.2	100.0	5.8	3.7	9.6	0.09	70.6	107.0	114.9	99.1	5.1	3.3
	169+70	3.5	0.07	75.8	50.0	112.8				8.5	0.06	80.1	142.0	114.6	100.0	7.1	4.6
	$\bar{x}$	9.6	0.07	80.8	218.4	111.4	98.4	9.0	4.5	13.3	0.08	75.2	173.9	113.5	99.9	6.7	3.9
	σ	4.9	0.04	10.4	219.3	5.1	3.8	2.2	1.0	9.8	0.01	4.1	140.5	1.8	0.3	1.8	0.9

* When gravity drained.

TABLE 2 (Cont.)
FIELD TEST RESULTS ON SUBGRADE AND SUBBASE SECTIONS

Station No.	Subgrade k, ft/day	Subgrade N_e	Subgrade Saturation, percent*	Subgrade $\frac{k}{N_e}$	Subgrade Dry Density, lb/cu ft	Subgrade Percent Passing 1-in.	Subgrade Percent Passing No. 100	Subgrade Percent Passing No. 200	Subbase k, ft/day	Subbase N_e	Subbase Saturation, percent*	Subbase $\frac{k}{N_e}$	Subbase Dry Density, lb/cu ft	Subbase Percent Passing 1-in.	Subbase Percent Passing No. 100	Subbase Percent Passing No. 200
Eastbound US 10, Section C-5, Station 170+60 - 195+98																
171+40	7.0	0.001	100.0	7000.0	117.1	93.5	16.6	12.8	6.1	0.09	67.9	68.0	119.7	97.0	7.1	4.2
173+80	15.3	0.10	67.7	153.0	113.3				8.8	0.07	80.2	126.0	109.7			
176+70	13.7	0.10	73.0	137.0	109.0	100.0	17.5	2.9	12.1	0.10	72.1	121.0	108.8	100.0	6.1	2.9
177+20	35.1	0.06	82.7	585.0	107.7				17.8	0.08	77.0	223.0	109.0			
179+30	12.8	0.08	79.0	160.0	105.8	100.0	8.2	3.6	13.3	0.10	73.5	133.0	110.9	97.9	6.1	3.1
182+90	3.2	0.12	61.3	27.0	111.7				11.1	0.05	84.4	222.0	114.5			
184+10	6.3	0.07	79.2	90.0	111.9	100.0	13.4	9.4	8.3	0.14	59.0	59.0	106.2	100.0	5.4	3.2
185+10	13.5	0.06	76.8	225.0	119.7				3.8	0.10	69.6	38.0	111.3			
188+80	3.1	0.02	91.9	155.0	120.1	100.0	15.4	10.3	12.8	0.11	66.7	116.0	110.2	100.0	5.6	3.1
189+50	4.4	0.03	91.8	147.0	116.0				8.1	0.09	72.4	90.0	113.1			
192+90	8.0	0.04	86.4	200.0	120.0	96.4	10.8	5.9	9.1	0.09	72.1	101.0	111.8	98.5	6.2	3.3
193+80	1.2	0.05	84.9	24.0	115.3				11.9	0.09	73.6	132.0	112.3			
$\bar{x}$	10.3	0.06	81.2	741.0	114.0	98.3	13.6	7.5	10.3	0.09	72.4	114.1	111.5	98.9	6.1	3.3
σ	9.2	0.04	10.9	1976.0	4.9	2.8	3.6	4.0	3.7	0.02	6.5	64.1	3.4	1.3	0.6	0.5
Eastbound US 10, Section A-6, Station 195+98 - 222+00																
197+00	7.2	0.10	69.8	72.0	115.3	93.2	20.7	8.2	6.1	0.10	70.7	61.0	111.0	100.0	5.6	2.6
198+40	13.3	0.05	84.4	266.0	114.2				7.2	0.09	72.1	80.0	111.7			
200+40	9.2	0.13	64.3	71.0	108.0	100.0	5.8	3.5	6.8	0.11	67.0	62.0	111.0	96.7	6.2	2.9
202+60	0	---	100.0	---					9.8	0.06	81.0	163.0	116.1			
205+30	11.5	0.06	78.9	192.0	115.6	100.0	7.4	4.5	3.3	0.09	74.0	37.0	109.5	100.0	6.9	3.7
206+90	0	---	100.0	---	111.4				3.6	0.12	63.7	30.0	109.8			
208+60	0	---	100.0	---	117.5	100.0	16.6	9.3	1.3	0.06	82.3	22.0	118.7	97.6	11.2	6.3
213+10	5.9	0.13	58.2	45.0	114.7	100.0	13.5	8.8	3.2	0.09	71.0	36.0	115.4	100.0	7.5	4.1
210+60	3.9	0.10	64.7	39.0	121.1				2.8	0.06	79.8	47.0	116.0			
214+70	11.7	0.10	69.7	117.0	110.7				1.9	0.05	80.6	38.0	114.8			
217+50	3.4	0.08	73.8	43.0	114.1	100.0	7.3	4.3	0.3	0.10	66.7	3.0	117.2	100.0	7.0	3.8
219+70	5.6	0.08	74.8	70.0	112.6				1.9	0.08	73.3	24.0	117.4			
220+20	5.4	0.12	59.8	45.0	115.4	94.3	8.6	4.6	2.8	0.06	79.3	47.0	119.1	93.4	6.6	4.7
$\bar{x}$	7.7	0.10	76.8	96.0	114.2	98.2	11.4	6.2	3.9	0.08	74.0	50.0	114.4	98.2	7.3	4.0
σ	3.5	0.03	15.1	75.8	3.4	3.1	5.6	2.5	2.7	0.02	6.2	39.3	3.4	2.5	1.8	1.2

* When gravity drained.

TABLE 2 (Cont.)
FIELD TEST RESULTS ON SUBGRADE AND SUBBASE SECTIONS

Section	Station No.	Subgrade k, ft/day	Subgrade N_e	Subgrade Saturation, percent*	Subgrade $\frac{k}{N_e}$	Subgrade Dry Density, lb/cu ft	Subgrade Percent Passing 1-in.	Subgrade Percent Passing No. 100	Subgrade Percent Passing No. 200	Subbase k, ft/day	Subbase N_e	Subbase Saturation, percent*	Subbase $\frac{k}{N_e}$	Subbase Dry Density, lb/cu ft	Subbase Percent Passing 1-in.	Subbase Percent Passing No. 100	Subbase Percent Passing No. 200
Westbound US 10, Section C-7 Station 197+15 - 222+00	198+40	0.5	--	100.0	---	119.9				22.7	0.10	74.7	227.0	104.5			
	200+70	2.3	0.15	48.3	15.0	118.3	100.0	17.9	12.4	16.7	0.11	69.8	152.0	107.4	100.0	6.1	2.8
	201+30	0	--	100.0	---	119.3				17.8	0.12	66.0	148.0	106.9			
	203+10	4.0	0.02	94.9	200.0	115.1	100.0	12.0	5.2	16.7	0.09	74.4	186.0	110.6	100.0	6.1	2.9
	205+90	0.2	0.09	62.1	2.0	124.4				11.7	0.14	59.5	84.0	107.4			
	207+40	0	--	100.0	---	122.4	100.0	13.2	9.9	10.9	0.09	73.3	121.0	110.9	97.8	7.7	3.4
	209+20	7.9	0.09	72.4	88.0	110.5				19.4	0.10	72.5	194.0	108.2			
	212+20	1.0	0.08	72.4	13.0	117.3	100.0	15.1	9.7	7.5	0.06	78.6	125.0	112.8	100.0	10.2	3.4
	213+80	0	--	100.0	---	122.7				12.1	0.11	67.0	110.0	110.9			
	215+50	0.5	0.07	74.3	7.0	120.7	100.0	19.7	4.9	4.0	0.10	65.9	40.0	114.9	100.0	7.7	4.9
	217+20	1.5	0.07	76.4	21.0	119.2				13.6	0.14	59.3	97.0	110.2			
	219+40	0	--	100.0	---	118.8	100.0	13.1	8.7	24.6	0.10	73.9	246.0	105.8	100.0	8.0	2.9
	$\bar{x}$	2.2	0.08	81.9	49.4	119.1	100.0	15.2	8.5	14.8	0.11	69.6	144.2	109.2	99.6	7.6	3.4
	σ	2.6	0.04	18.1	72.5	3.7	0	3.0	2.9	6.0	0.02	6.1	60.5	3.0	0.9	1.5	0.8
Westbound US 10, Section A-8 Station 172+06 - 197+15	172+80	11.8	0.06	86.9	197.0	110.7	100.0	8.3	4.6	19.7	0.05	82.3	394.0	119.1	100.0	6.2	3.9
	173+40	2.7	0.09	70.5	30.0	115.0				20.8	0.08	71.0	260.0	117.6			
	175+00	7.6	0.08	75.6	95.0	110.3	100.0	6.3	3.7	15.0	0.09	69.5	167.0	118.3	97.5	6.4	4.3
	177+90	1.5	0.12	60.1	13.0	116.3				19.7	0.04	87.3	493.0	112.1			
	179+10	0.8	0.05	81.9	16.0	121.2	100.0	8.2	5.2	15.3	0.04	87.7	383.0	115.6	94.8	5.1	3.0
	182+20	1.5	0.11	63.2	14.0	116.2				43.0	0.12	67.5	358.0	106.4			
	183+00	9.1	0.05	83.7	182.0	116.0	100.0	7.7	4.7	13.4	0.09	72.9	149.0	110.4	100.0	5.9	3.1
	186+90	12.8	0.06	81.4	213.0	110.9				22.3	0.10	70.7	223.0	111.3			
	188+50	2.4	0.11	65.1	22.0	116.1	100.0	7.3	4.2	26.3	0.05	85.9	526.0	109.6	100.0	4.8	2.8
	190+50	15.4	0.003	99.2	5133.0	116.1				23.5	0.06	81.2	392.0	112.5			
	192+50	23.8	0.08	79.3	298.0	106.3	100.0	4.9	3.0	19.6	0.08	75.2	245.0	113.2	98.6	5.3	3.6
	194+00	10.3	0.06	80.9	172.0	112.9				30.1	0.11	67.2	274.0	110.4			
	196+50	2.2	0.10	69.2	22.0	112.3	100.0	6.7	3.2	26.1	0.07	77.6	373.0	109.7	100.0	4.5	2.0
	$\bar{x}$	7.8	0.08	76.7	1398.0	113.9	100.0	7.0	4.1	22.7	0.08	76.6	325.9	112.0	98.7	5.5	3.3
	σ	6.9	0.03	10.9	492.9	3.8	0	1.2	0.8	7.8	0.03	7.5	117.0	5.1	2.0	0.7	0.8

* When gravity drained.

TABLE 2 (Cont.)
FIELD TEST RESULTS ON SUBGRADE AND SUBBASE SECTIONS

Section	Station No.	Subgrade k, ft/day	Subgrade N_e	Subgrade Saturation, percent*	Subgrade $\frac{k}{N_e}$	Subgrade Dry Density, lb/cu ft	Subgrade Percent Passing 1-in.	Subgrade Percent Passing No. 100	Subgrade Percent Passing No. 200	Subbase k, ft/day	Subbase N_e	Subbase Saturation, percent*	Subbase $\frac{k}{N_e}$	Subbase Dry Density, lb/cu ft	Subbase Percent Passing 1-in.	Subbase Percent Passing No. 100	Subbase Percent Passing No. 200
Westbound US 10, Section D-9 Station 147+00 - 172+00	149+00	12.1	0.003	96.7	4033.0	116.8	97.8	4.3	2.6	14.4	0.10	68.8	144.0	109.9			
	151+30	9.2	0.10	68.6	92.0	114.0				27.6	0.11	69.2	251.0	107.4	100.0	5.1	3.0
	152+80	8.8	0.03	91.5	293.0	117.1	100.0	14.5	4.4	14.9	0.10	70.4	149.0	110.1	97.7	6.2	3.7
	154+10	4.9	0.03	89.1	163.0	118.4				9.8	0.10	68.0	98.0	115.3			
	157+40	6.0	0.07	75.1	86.0	118.9	100.0	7.1	3.7	11.9	0.07	75.8	170.0	118.8	97.8	5.8	3.9
	158+10	18.6	0.07	48.0	266.0	106.7				18.0	0.06	80.6	300.0	115.8			
	161+60	3.9	0.07	79.5	56.0	114.3	100.0	6.0	3.6	15.0	0.09	72.5	167.0	109.8	100.0	7.5	3.0
	163+40	4.5	0.13	62.0	35.0	110.7				31.2	0.11	61.9	284.0	117.7			
	164+10	1.9	0.10	69.6	19.0	117.1	100.0	14.6	9.3	5.7	0.08	73.0	71.0	117.9	98.7	6.4	3.7
	167+20	4.1	0.11	69.0	37.0	109.5				10.5	0.05	84.6	210.0	117.2			
	168+90	12.9	0.10	71.7	129.0	108.0	96.9	6.9	4.0	31.6	0.05	83.6	632.0	111.3	100.0	4.9	3.1
	169+00	16.9	0.07	83.5	241.0	112.0				20.3	0.18	81.8	113.0	111.5			
	$\bar{x}$	8.6	0.07	75.4	454.2	113.6	99.1	8.9	4.6	17.6	0.09	74.2	215.8	113.6	99.0	6.0	3.4
	σ	5.4	0.03	13.6	1131.0	4.2	1.4	4.5	2.4	8.5	0.04	7.1	149.5	3.9	1.1	1.0	0.4
Westbound US 10, Section B-10 Station 120+56 - 147+00	120+60	3.0	0.07	76.7	43.0	116.8	100.0	7.3	4.8	17.4	0.10	72.6	174.0	108.6	97.7	7.3	3.6
	122+70	3.7	0.06	80.0	62.0	115.6	100.0	6.5	2.0	8.3	0.07	76.0	119.0	115.1	97.1	4.7	2.8
	125+80	25.8	0.03	91.9	860.0	105.3				18.9	0.11	78.4	172.0	117.4			
	126+90	26.8	0.07	80.6	383.0	106.7				9.2	0.10	68.0	92.0	115.3			
	128+20	6.9	0.10	68.8	69.0	114.3	100.0	6.3	4.1	17.9	0.08	76.1	224.0	114.2	100.0	5.9	2.8
	131+20	6.1	0.09	66.5	68.0	120.1				17.4	0.10	69.4	174.0	106.6	100.0	6.8	2.7
	132+70	3.3	0.09	70.8	37.0	117.0	100.0	8.1	4.6	15.9	0.10	70.5	159.0	111.8	97.9	6.4	3.3
	134+90	7.3	0.11	66.0	66.0	113.8				15.4	0.02	90.6	770.0	113.4	97.7	6.7	3.6
	137+00	15.1	0.11	67.3	137.0	109.8	100.0	5.0	2.6	17.0	0.10	72.2	170.0	111.3	100.0	5.5	1.9
	139+00	1.6	0.13	59.7	12.0	111.5				10.2	0.11	70.0	93.0	109.4	100.0	8.8	3.4
	140+10	2.6	0.09	67.9	29.0	120.4	100.0	9.2	5.6	21.2	0.09	73.2	236.0	111.5	100.0	10.3	3.6
	143+50	10.6	0.09	64.7	118.0	112.6				4.5	0.11	61.3	41.0	118.2	97.3	12.5	6.3
	144+60	9.5	--	---	---	110.9	100.0	6.7	3.4	26.1	0.001	100.0	26100.0	111.7	100.0	5.6	1.8
	$\bar{x}$	9.4	0.09	65.9	157.0	113.4	100.0	7.0	3.9	15.3	0.08	75.3	2194.2	112.6	98.9	7.3	3.2
	σ	8.4	0.03	20.6	242.2	4.6	0	1.4	1.3	5.9	0.03	10.1	7185.1	3.4	1.3	2.3	1.2

* When gravity drained.

TABLE 2 (Cont.)
FIELD TEST RESULTS ON SUBGRADE AND SUBBASE SECTIONS

Section	Station No.	Subgrade k, ft/day	Subgrade N_e	Subgrade Saturation, percent*	Subgrade $\frac{k}{N_e}$	Subgrade Dry Density, lb/cu ft	Subgrade Percent Passing 1-in.	Subgrade Percent Passing No. 100	Subgrade Percent Passing No. 200	Subbase k, ft/day	Subbase N_e	Subbase Saturation, percent*	Subbase $\frac{k}{N_e}$	Subbase Dry Density, lb/cu ft	Subbase Percent Passing 1-in.	Subbase Percent Passing No. 100	Subbase Percent Passing No. 200
Westbound US 10, Section C-11 Station 94+07 - 120+56	95+50	25.4	0.03	91.1	847.0	111.9	100.0	7.3	3.3	7.8	0.08	73.5	98.0	113.2	98.0	7.2	4.6
	97+50	37.4	0.09	76.0	416.0	103.2				9.2	0.04	87.1	230.0	115.5			
	98+20	17.7	0.01	95.1	1770.0	113.2	100.0	6.2	3.6	12.5	0.09	71.9	139.0	112.7	100.0	6.2	3.2
	99+60	27.8	0.07	80.0	397.0	106.7				11.1	0.05	84.6	222.0	115.9			
	101+40	29.7	0.05	86.3	594.0	111.1	94.6	4.9	2.3	23.2	0.007	96.7	3314.0	115.0	100.0	5.9	3.3
	103+80	22.2	0.06	82.1	370.0	110.6				25.4	0.03	89.6	847.0	114.7			
	104+40	21.2	0.08	73.8	265.0	114.2	100.0	16.7	3.9	19.3	0.02	93.8	965.0	114.0	98.1	6.6	4.0
	107+10	13.1	0.08	74.0	164.0	113.7				1.8	0.12	63.7	15.0	113.7			
	108+70	1.8	0.08	73.5	23.0	116.8	100.0	9.1	5.5	13.1	0.05	83.3	262.0	106.5	100.0	5.9	2.8
	111+80	2.5	0.11	62.6	23.0	116.0				8.0	0.12	62.9	67.0	111.9			
	113+80	1.9	0.11	61.8	17.0	118.4	100.0	11.9	7.6	7.8	0.09	71.1	87.0	116.4	100.0	5.9	3.6
	115+00	6.4	0.02	94.1	320.0	119.2				4.9	0.07	76.7	70.0	116.7			
	117+30	3.8	0.08	75.4	48.0	116.4	100.0	18.0	4.7	5.2	0.08	75.0	65.0	114.0	96.8	5.1	3.2
	118+90	4.3	0.03	90.2	143.0	118.6				15.6	0.05	84.0	312.0	115.8			
	$\bar{x}$	15.4	0.06	79.7	385.5	113.6	99.2	10.6	4.4	11.8	0.06	79.6	478.1	114.0	99.0	6.1	3.5
	σ	12.1	0.03	10.7	465.2	4.6	2.0	5.1	1.7	7.0	0.04	10.5	866.0	2.6	1.3	0.7	0.6
Westbound US 10, Section B-12 Station 67+96 - 92+70	69+90	12.2	0.06	81.8	203.0	111.7	100.0	5.4	3.3	16.9	0.12	67.5	141.0	113.9	100.0	6.0	2.4
	71+10	22.8	0.07	80.0	326.0	109.1				32.9	0.12	70.5	274.0	101.1			
	73+70	0	---	100.0	---	119.6	100.0	11.0	7.7	3.5	0.13	57.6	27.0	115.0	100.0	7.6	4.0
	74+30	4.0	0.07	78.0	57.0	112.6				19.7	0.11	69.8	179.0	107.3			
	77+90	0	---	100.0	---	119.6	100.0	10.0	5.9	14.2	0.10	71.7	142.0	107.1	96.7	5.3	2.5
		1.1	0.07	74.9	16.0	117.9				6.8	0.06	79.5	113.0	114.8			
	79+00	2.5	0.10	68.3	25.0	114.8	100.0	7.5	3.7	12.9	0.08	74.9	161.0	111.4	100.0	6.5	3.3
	83+00	7.1	0.04	88.3	178.0	113.1				2.5	0.10	66.7	25.0	117.2			
	84+10	2.8	0.09	70.5	31.0	113.6	100.0	7.8	4.6	2.2	0.07	75.8	31.0	117.4	100.0	7.3	5.0
	88+00	2.8	0.10	69.7	28.0	111.2				12.6	0.10	71.4	126.0	109.2			
	89+70	6.2	0.09	71.9	69.0	112.9	100.0	6.2	3.1	8.7	0.08	75.6	109.0	109.6	100.0	6.6	3.1
	91+80	9.9	0.04	87.3	248.0	111.7				9.0	0.10	66.9	90.0	114.4			
	92+70	6.6	0.03	90.6	220.0	114.2	100.0	7.4	4.3	3.4	0.07	77.2	49.0	114.6	100.0	6.4	3.9
	$\bar{x}$	7.1	0.07	81.6	127.4	114.0	100.0	7.9	4.7	11.2	0.10	71.2	112.9	111.8	99.5	6.5	0.9
	σ	6.2	0.03	10.9	110.1	3.2	0	2.0	1.6	8.6	0.02	5.8	71.2	4.7	1.2	0.8	3.5

* When gravity drained.

In general, all subbase sections, except A6, are well drained and with only a few exceptions meet drainage requirements. Because the subgrades in most cases have good drainability, the k/N_e ratio required of the subbase can be smaller than 55.2 and still provide adequate drainage since the k/N_e value of 55.2 is based on the assumption that the subgrade is impervious. In addition, subbase drains were placed in the more poorly drained areas of each section to ensure adequate subbase drainage. The only exception is in section A6, for which only 600 ft of subbase drain were placed in a roughly 1,200-ft section of poorly drained subbase so that long-term relative performance characteristics may be observed. Dry density and gradation data were collected for reference use only.

From every other test site (approximately every 400 ft) samples were collected for laboratory determination of moisture-tension characteristics of each material. These test results are summarized in Figure 12. The figure indicates the pore size distribution or water holding capacity of each section. Generally, A, B, and D sections appear to be uniform and of low water holding capacity. C sections are built on subgrades that tend to vary a little more in water holding capacity. In general, these data indicate that the entire project is constructed on sand subgrade and sand subbase materials that are uniformly graded and have similar pore-size distribution.

After construction of the subbase layer of the ATPM test sections (Type B), samples were randomly selected to determine if the subbase material was coarse enough to act as a filter layer for the ATPM base. Because of the cost of making special filter material and because water should not move from the subbase to ATPM as it would in typical filter situations the filter design method recommended in Ref. (5) was used as a guideline to see if a potential problem may exist. It was found that the subbase nearly meets the filter criteria so that no filter layer would be required to keep the subbase material from clogging the ATPM voids. These data are summarized in Table 3.

During construction samples of the ATPM and black base materials were collected from each sample site for laboratory testing. The only characteristics measured for the ATPM sections were the permeability values and these are summarized in Table 4. These data show that the permeability of the ATPM bases is in excess of 4,000 ft per day which is fast enough to ensure that the base will rapidly remove all surface infiltrated water. Samples from black base sections are to be tested in the future to determine stiffness modulus and tensile strength properties.

After the aggregate bases were shaped and compacted, samples were collected from each test site for laboratory determination of grain size distribution and permeability. The results, summarized in Table 5 show that

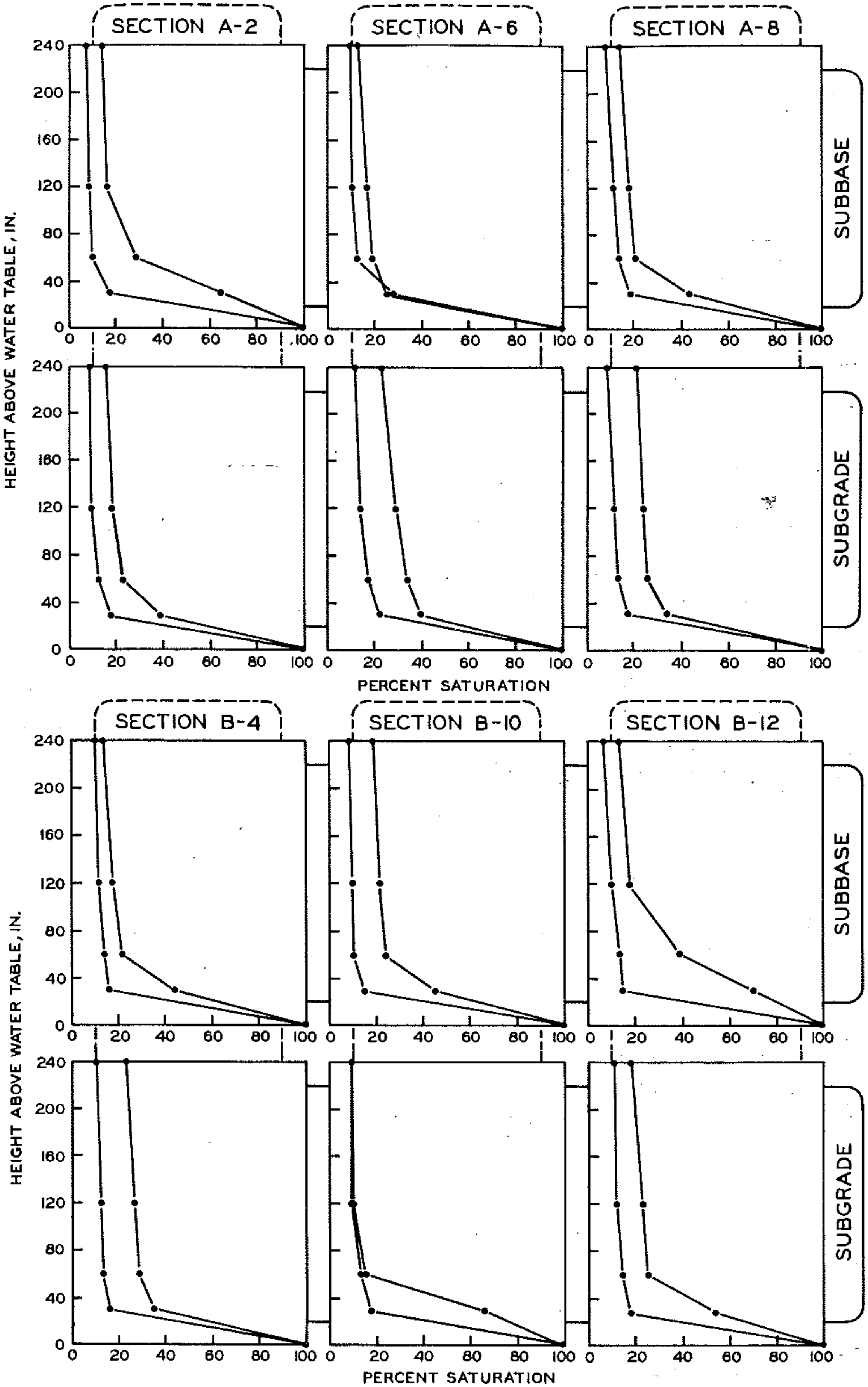


Figure 12. Moisture characteristic curves illustrating the maximum to minimum percent saturation limits for samples tested in the designated layer and section.

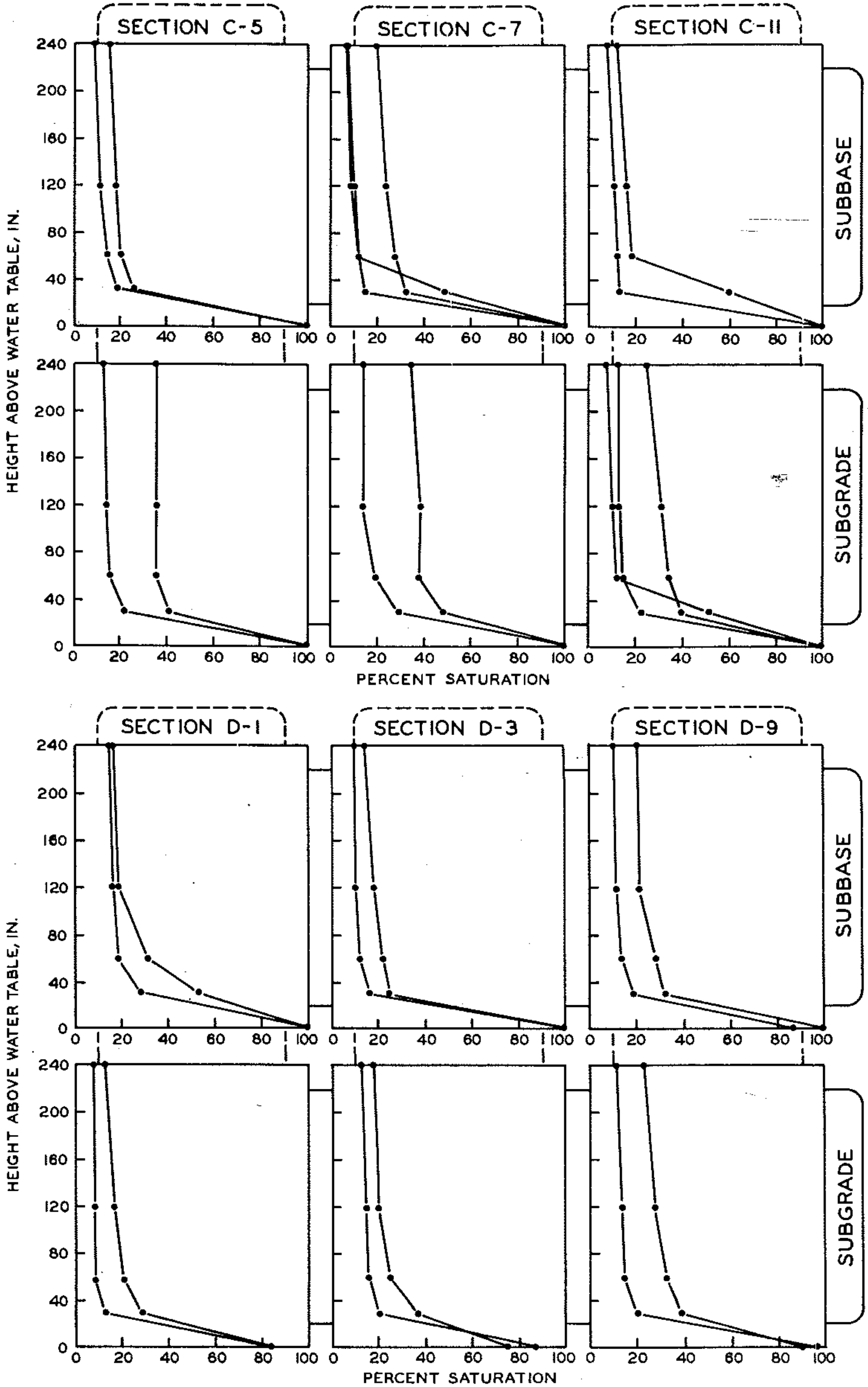


Figure 12 (Cont.). Moisture characteristic curves illustrating the maximum to minimum percent saturation limits for samples tested in the designated layer and section.

TABLE 3

SUMMARY OF GRAIN SIZE DATA USED FOR ATPM FILTER LAYER DESIGN

Section B-4 Subbase					Section B-10 Subbase					Section B-12 Subbase				
Station	D60/D10	D85	D50	D15	Station	D60/D10	D85	D50	D15	Station	D60/D10	D85	D50	D15
145+90	3.5	1.30	0.35	0.16	120+60	3.2	2.00	0.50	0.20	69+90	2.5	0.58	0.33	0.17
147+00	2.8	1.40	0.40	0.18	122+70	3.1	2.70	0.48	0.22	73+70	2.6	0.60	0.33	0.18
149+80	3.1	1.40	0.42	0.19	128+20	2.9	2.20	0.41	0.19	77+90	2.6	0.58	0.36	0.18
151+50	3.0	1.07	0.42	0.19	131+20	2.7	0.85	0.36	0.18	80+60	2.6	0.89	0.37	0.17
154+40	3.1	1.60	0.44	0.21	132+70	2.5	1.20	0.40	0.21	84+10	3.0	1.95	0.42	0.18
155+40	2.9	1.75	0.44	0.22	134+90	2.5	1.20	0.39	0.21	89+70	2.7	0.90	0.38	0.17
157+20	2.9	1.40	0.42	0.20	137+00	2.6	0.90	0.40	0.19	92+70	3.0	1.10	0.40	0.18
159+80	2.9	1.15	0.42	0.21	139+40	2.3	0.62	0.31	0.18	Requirements*	1.5><4.0	>1.22	>0.52	>0.30
161+10	3.0	1.05	0.40	0.18	140+10	2.3	0.57	0.30	0.17					
164+10	3.1	1.90	0.43	0.20	143+50	4.3	1.30	0.32	0.16					
165+80	3.0	1.15	0.42	0.20	144+50	2.5	0.58	0.36	0.19					
167+00	2.9	1.25	0.43	0.22	Requirements*	1.5><4.0	>1.22	>0.52	>0.30					
169+70	3.2	1.70	0.42	0.18										
Requirements*	1.5><4.0	>1.22	>0.52	>0.30										

* Requirements are based on the following filter design criteria:

D15F ≤ 5 x D85S and
D15F ≤ 20 x D15S and
D50F ≤ 25 x D50S

where F = ATPM
S = Subbase (from table)

Mean ATPM particle sizes
D15F = 6.1 mm
D50F = 13.0 mm

TABLE 4

PERMEABILITY DATA FOR ASPHALT TREATED POROUS MATERIAL (ATPM) AT DESIGNATED STATIONS

Westbound US 10 - Section B-12 (Station 67+96 - 92+70)

Station	69+90	71+10	73+70	74+30	77+90	79+00	80+60	83+00	84+10	88+00	89+70	91+80	92+70	$\bar{x}$	σ
k, ft/day	4,179	8,833	6,996	7,473	8,176	7,698	6,434	8,963	5,830	6,827	5,535	6,122	6,247	6,870	1,361

Westbound US 10 - Section B-10 (Station 120+56 - 147+00)

Station	126+90	128+20	131+20	132+70	134+90	137+00	139+00	140+10	143+50	144+60	$\bar{x}$	σ
k, ft/day	5,389	6,303	6,013	5,876	4,675	4,459	4,327	5,313	7,108	7,559	5,702	1,088

Eastbound US 10 - Section B-4 (Station 145+15 - 170+60)

Station	145+90	147+00	149+80	151+50	154+40	155+40	157+20	159+80	161+10	164+10	165+80	167+00	169+70	$\bar{x}$	σ
k, ft/day	6,354	6,408	5,248	7,573	7,020	6,097	5,506	7,038	7,539	7,810	7,148	7,361	8,688	6,907	960

TABLE 5
GRAIN SIZE DISTRIBUTION AND PERMEABILITY DATA

	Station No.	Aggregate Base									
		k, ft/day	N_e	Saturation, percent*	$\frac{k}{N_e}$	Dry Density, lb/cu ft	Percent Passing				
							1-in.	3/4-in.	3/8-in.	No. 8	No. 200
Eastbound US 10, Section A-2 Station 94+17 - 120+25	95+50	0.7	0.06	72.7	12	130.9	100	99.3	84.2	61.3	5.9
	96+90	0.0	--	100.0		134.8	100	98.3	79.4	53.1	6.7
	99+90	0.0	--	100.0		137.6	100	95.3	75.9	49.1	6.4
	101+90	0.0	--	100.0		135.3	100	99.1	82.3	54.8	6.8
	102+60	0.0	--	100.0		134.8	100	97.0	76.4	49.3	6.5
	104+70	2.6	0.06	75.0	43	128.2	100	97.0	77.2	49.9	6.1
	106+10	0.0	--	100.0		130.6	100	98.2	76.2	49.9	6.2
	109+40	0.0	--	100.0		135.9	100	98.1	82.8	56.1	9.0
	111+70	0.0	--	100.0		138.4	100	96.7	80.4	52.6	6.5
	112+30	0.0	--	100.0		136.3	100	96.8	76.2	49.3	7.3
	114+60	0.0	--	100.0		134.4	100	96.5	75.6	51.3	5.6
	117+80	1.4	0.02	90.0	70	133.5	100	97.0	78.1	52.7	5.7
	118+10	0.0	--	100.0		134.4	100	96.1	79.6	53.6	6.2
	$\bar{x}$	0.4	0.05	95.2		134.2	100	97.3	78.8	52.5	6.5
	σ	0.8	0.02	9.9		2.9	0	1.2	2.9	3.5	0.9
Eastbound US 10, Section A-6 Station 195+98 - 222+00	197+00	0.0	--	100.0		132.5	100	96.3	74.2	47.4	5.6
	198+40	1.1	0.01	95.0	110	134.4	100	95.1	71.0	47.8	6.9
	200+40	0.0	--	100.0		135.9	100	95.5	76.7	49.7	6.4
	202+60	0.0	--	100.0		135.1	100	98.7	79.4	51.4	5.9
	205+30	0.0	--	100.0		135.9	100	97.8	78.2	51.1	5.2
	206+90	0.0	--	100.0		134.7	100	97.5	80.2	52.5	5.2
	208+60	0.0	--	100.0		135.9	100	98.3	81.9	54.9	6.5
	210+60	0.6	0.002	100.0	300	137.6	100	96.5	72.3	47.4	6.4
	213+10	2.2	0.01	95.0	220	134.0	100	95.0	70.3	45.6	5.6
	214+70	0.0	--	100.0		135.3	100	96.8	81.7	56.2	6.8
	217+50	0.5	0.03	84.2	17	135.3	100	96.4	72.0	46.2	6.5
	219+70	0.0	--	100.0		135.5	100	94.4	75.5	49.6	5.6
	220+20	0.0	--	100.0		134.5	100	96.0	75.8	50.5	6.1
	$\bar{x}$	0.3	0.01	98.0		135.1	100	96.5	76.1	50.0	6.1
	σ	0.7	0.01	4.6		1.2	0	1.3	4.0	3.2	0.6
Westbound US 10, Section A-8 Station 172+06 - 197+15	172+80	0.0	--	100.0		137.2	100	98.8	79.2	51.9	6.3
	173+40	0.0	--	100.0		137.0	100	99.8	82.2	53.8	6.0
	175+00	0.0	--	100.0		135.1	100	97.4	77.2	51.1	4.2
	177+90	0.0	--	100.0		135.4	100	96.7	75.2	50.7	6.1
	179+10	0.3	0.03	84.2	10	134.6	100	98.2	81.0	52.7	6.6
	182+20	0.0	--	100.0		133.7	100	98.8	81.7	52.4	6.4
	183+00	0.0	--	100.0		134.4	100	98.6	76.3	49.1	5.8
	186+90	0.0	--	100.0		135.7	100	99.3	80.5	52.4	6.4
	188+50	0.1	0.03	84.2	3	134.6	100	98.1	78.6	51.4	5.9
	190+50	0.8	0.05	73.7	16	134.7	100	98.3	81.0	53.5	6.3
	192+50	1.8	0.03	85.0	60	133.7	100	97.5	77.2	52.3	5.7
	194+00	0.0	--	100.0		135.3	100	97.9	85.1	55.4	6.7
	196+50	0.7	0.04	81.0	18	131.8	100	97.9	79.5	53.6	6.5
	$\bar{x}$	0.3	0.04	92.9		134.9	100	98.3	79.6	52.3	6.1
	σ	0.5	0.009	9.7		1.4	0	0.8	2.7	1.6	0.6

* When gravity drained.

TABLE 5 (Cont.)
GRAIN SIZE DISTRIBUTION AND PERMEABILITY DATA

Station No.	Aggregate Base									
	k, ft/day	N_e	Saturation, percent*	$\frac{k}{N_e}$	Dry Density, lb/cu ft	Percent Passing				
						1-in.	3/4-in.	3/8-in.	No. 8	No. 200
Eastbound US 10, Section C-5, Station 170+60 - 195+98										
171+40	0.0	--	100.0		133.9	100	98.5	82.6	57.5	6.3
173+80	0.0	--	100.0		136.5	100	95.5	82.7	55.0	6.3
176+70	0.0	--	100.0		135.9	100	97.1	80.2	53.8	7.3
177+20	0.8	0.01	94.7	80	135.2	100	97.9	76.3	48.1	6.0
179+30	0.0	--	100.0		135.5	100	97.3	76.1	48.8	6.3
182+90	0.0	--	100.0		135.0	100	97.3	80.0	53.2	6.7
184+10	0.9	0.03	86.4	30	130.1	100	100.0	82.4	61.5	5.1
185+10	0.0	--	100.0		135.6	100	98.2	81.0	52.7	6.5
188+80	0.0	--	100.0		132.3	100	96.7	78.1	52.7	6.1
189+50	0.0	--	100.0		130.6	100	96.9	80.8	54.9	6.5
192+90	0.0	--	100.0		136.4	100	96.9	76.2	49.9	6.5
193+80	0.0	--	100.0		135.0	100	98.0	78.2	51.3	6.1
$\bar{x}$	0.1	0.02	98.4		134.3	100	97.5	79.6	53.3	6.3
σ	0.3	0.01	4.1		2.2	0	1.1	2.5	3.7	0.5
Westbound US 10, Section C-7, Station 197+15 - 222+00										
198+40	0.0	--	100.0		135.2	100	97.8	80.1	53.8	6.5
200+70	0.7	0.03	85.0	23	133.7	100	97.7	81.0	54.2	6.4
201+30	0.5	0.01	94.7	50	135.7	100	99.0	77.9	51.4	5.8
203+10	0.0	--	100.0		134.5	100	96.1	79.2	54.8	5.9
205+90	0.6	0.03	84.2	20	135.5	100	96.4	77.9	52.3	6.0
207+40	0.0	--	100.0		134.6	100	98.0	82.1	56.0	6.7
209+20	0.0	--	100.0		134.8	100	96.5	76.3	52.3	6.4
212+20	0.7	0.01	94.7	70	135.1	100	96.7	77.7	50.9	6.7
213+80	0.0	--	100.0		137.4	100	98.1	78.5	50.8	6.5
215+50	0.0	--	100.0		134.6	100	97.7	81.1	54.3	6.5
217+20	0.0	--	100.0		136.6	100	94.7	76.1	49.6	6.4
219+40	0.0	--	100.0		133.3	100	97.5	76.9	50.7	6.9
$\bar{x}$	0.2	0.02	96.6		135.1	100	97.2	78.7	52.6	6.4
σ	0.3	0.01	5.9		1.1	0	1.1	2.0	2.0	0.3
Westbound US 10, Section C-11, Station 94+07 - 120+56										
95+50	0.0	--	100.0		136.4	100	93.6	68.0	43.5	5.2
97+50	0.0	--	100.0		138.1	100	96.1	76.9	50.2	5.2
98+20	0.4	0.02	90.0	20	134.0	100	96.7	78.7	49.4	5.8
99+60	0.6	0.05	73.7	12	135.7	100	97.2	80.4	53.5	6.5
101+40	0.0	--	100.0		133.6	100	97.2	78.9	50.4	6.5
103+80	0.2	0.04	81.0	5	136.0	100	95.7	73.2	48.1	5.5
104+40	0.7	0.03	85.7	23	132.3	100	98.8	79.6	54.5	6.0
107+10	0.4	0.03	84.2	13	135.9	100	96.7	75.8	50.3	5.9
108+70	0.3	0.03	85.7	10	132.9	100	96.3	77.8	52.0	6.4
111+80	0.0	--	100.0		134.2	100	96.5	77.4	48.9	6.5
113+80	0.0	--	100.0		137.1	100	97.6	72.1	46.3	5.9
115+00	0.6	0.03	85.0	20	134.3	100	96.9	77.6	51.9	6.2
117+30	2.1	0.04	78.9	53	136.0	100	96.4	73.9	47.5	5.6
118+90	0.7	0.05	73.7	14	134.7	100	96.5	81.1	54.7	6.0
$\bar{x}$	0.4	0.03	88.4		135.1	100	96.6	76.5	50.1	5.9
σ	0.6	0.01	10.0		1.6	0	1.1	3.6	3.2	0.4

* When gravity drained.

the dense graded aggregate bases are essentially impervious and should normally be 100 percent water saturated with the exception of section C11, in which a little more than half the section should be able to drain to less than 90 percent saturation. The gradation data indicate that in some cases the aggregate base material is finer than permitted by the specifications.

After construction of the pavement and shoulders, 23 moisture access tubes were installed at various locations (Fig. 13) in order that seasonal moisture distribution in base, subbase, and subgrade layers could be monitored and to study the effect that surface water infiltration has on moisture distribution. Moisture contents can be read at desired intervals to a depth of 68 in. using a Troxler Nuclear Moisture Probe.

INITIAL OBSERVATIONS OF PERFORMANCE

Most of the rain that falls on exposed ATPM surfaces accumulates in the ATPM drains, causing outlets to flow full during and for some time after a significant rainfall. The large volume of this outflow caused severe erosion, resulting in gullies 3 or 4 ft deep at some outlet locations. Special provisions should be provided to accommodate the large volumes of drain water that will come from ATPM base pavement from the time the ATPM is installed until it is finally covered with the pavement and shoulder surfaces.

It was assumed that once the pavement and shoulders were constructed, the joint seal materials would permit little if any surface water to infiltrate into the base. Observation of ATPM drain outlets indicates that large volumes of water are removed by the ATPM base during and for a short time after each rain. Apparently there is considerably more surface water infiltration taking place than was originally expected. The greatest source of infiltrated water is believed to be at the longitudinal pavement-shoulder joint.

Shallow subbase drains also carry a considerable volume of water during periods of rain; therefore, slope protection at outlets is necessary. A problem observed with one ATPM drain, as well as with several of the subbase drains, is that considerable erosion is taking place adjacent to some of the outlets that have been observed to carry no water. It is assumed that the joints are mismatched near the outlet and that the drain water is seeping along the outlet pipe causing extensive erosion which could lead to expensive repairs. It should be possible to avoid this problem by installing the drains and outlets at the same time and by close inspection of "L" and butt joints to ensure that they remain intact when backfilled.

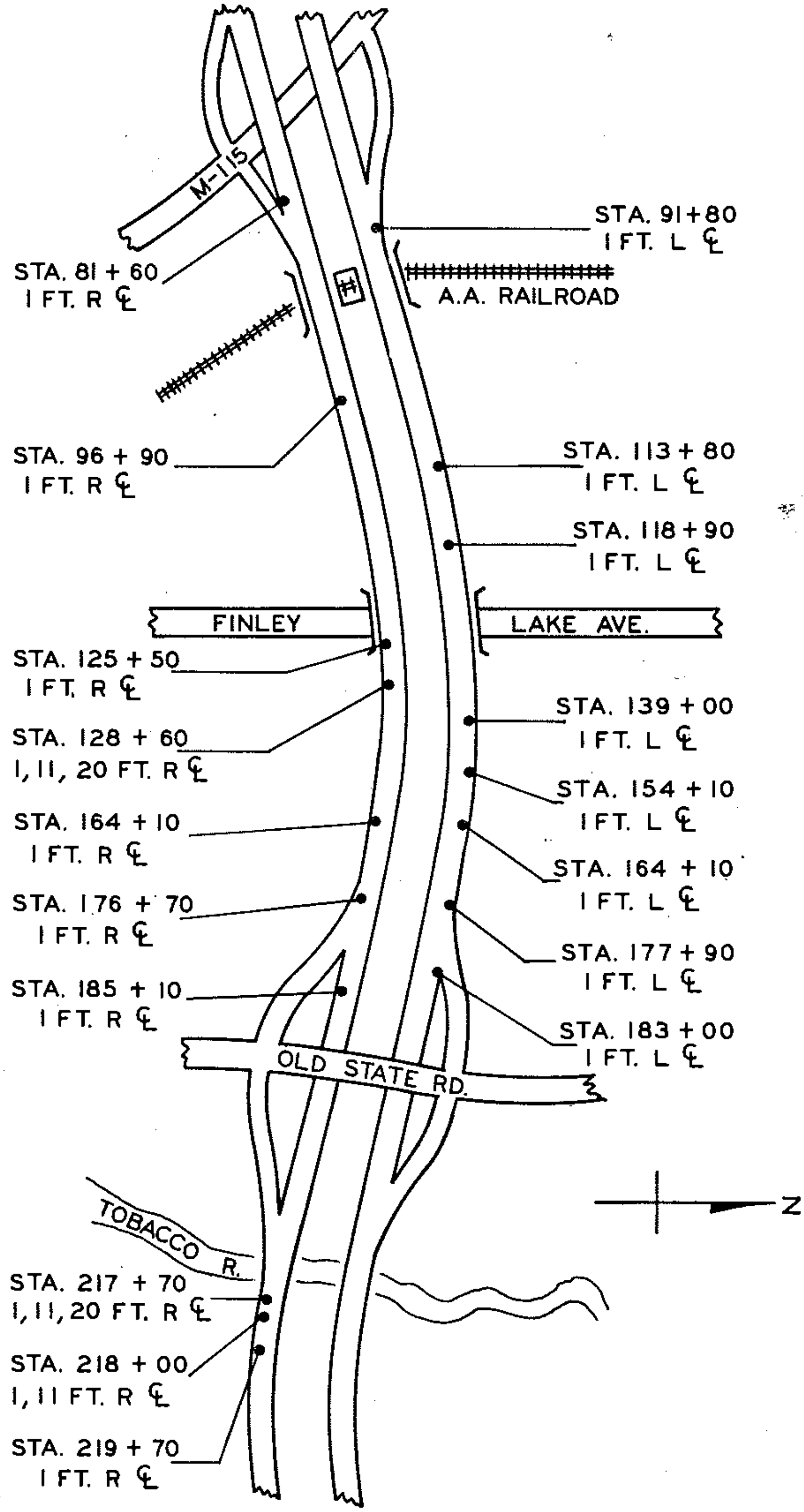


Figure 13. Location of nuclear gage access tubes.

The subbase drains in the black base sections have not been observed to carry water at any time. This indicates this type of base, so far, has acted effectively as a barrier against infiltration of surface water into the subbase layer. However, it has been noted on a superelevated section that water infiltrating the higher longitudinal pavement-shoulder joint appears, in at least one of the three sections, to be seeping either under the pavement between the pavement-base interface and then back out the lower longitudinal pavement-shoulder interface, or water from the upper longitudinal joint is flowing to the lower joint through transverse joint cracks (Fig. 14). This problem will be carefully observed in the future to see what, if any, effect it may have on performance.

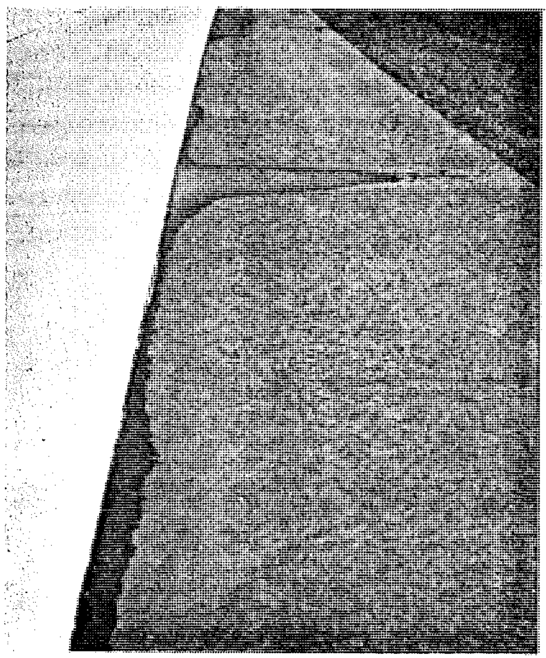


Figure 14. Water seeping from lower longitudinal joint onto shoulder.

SUMMARY AND CONCLUSIONS

Test results collected to document foundation properties indicate the subgrade and subbases are generally well drained and that the subbases should be less than 90 percent saturated when gravity drained. Aggregate bases are, in most cases, essentially impervious and should be more than 90 percent saturated when gravity drained. Dry density and gradation data were collected for reference use only.

The experimental foundation features; subbase drains, ATPM, and black base, all were constructed without serious problems and could easily be used for standard pavement construction.

The subbase drains have already proved effective in removing the large volume of water that infiltrates the pavement surface especially at the longitudinal pavement-shoulder joint. Subbase drains should be considered as a standard pavement addition because they provide an inexpensive method of removing water that tends to saturate the subbase layer.

The ATPM base proved easy to handle, extremely effective in removing infiltrated surface water, provided a stable platform on which to pave, and appears to be performing very well.

The black base has maintained its structural integrity with no signs of cracking so far.

The control and short-slab plain concrete load transfer pavement sections were constructed on standard aggregate bases and test results indicate their foundations are as good, if not better, than typical standard rigid pavement foundations constructed on granular subgrades. From a pavement foundation standpoint, the control sections should perform at least as well as other Michigan standard, jointed, rigid, pavement construction.

REFERENCES

1. "Experimental Short Slab Pavements," MDSHT Work Plan No. 34, March 1974.

2. Chiunti, M. A., "Experimental Short Slab Pavements (Construction Report)," MDSHT Research Report No. R-1016, July 1976.

3. Novak, E. C., "Development and Evaluation of a Field Drainability Test Method," MDSHT Research Report No. R-1001, June 1976.

4. Hsia, F., "Subbase Drainage Criteria," MDSHT Research Report No. R-991, March 1976.

5. Spalding, R., "Selection of Materials for Sub-Surface Drains," Road Research Laboratory, RRL Report LR-346, 1970.