REPORT #74-015-7783

PROJECT 7783

BRIDGE DECK PROTECTIVE SYSTEMS

FIRST INTERIM REPORT

June 12, 1974

prepared by:

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ABSTRACT

This report describes the progress made to date on a project designed to test several promising bridge deck protective systems. Four waterproofing membranes are under test and additional installations of other systems are planned. The membranes are being evaluated by visual inspection and by means of moisture detecting instrumentation placed beneath the membranes on the test bridges. The results so far must be considered tentative but appear to indicate that an asbestos modified asphalt system and a hot applied liquid system are performing better than two preformed sheet systems. In terms of ease of construction, however, there was almost unanimous preference for the preformed sheet systems. The installations, instrumentation, and performance of these membranes are discussed in detail in this report.

BACKGROUND

As a result of a serious spalling problem on many of the concrete bridge decks in the state, New Jersey is participating in a FHWA sponsored study of various bridge deck protective systems. The emphasis in the New Jersey research is being concentrated on waterproofing membranes, particularly those suitable for maintenance applications. Other methods under consideration but not presently in test include galvanized or epoxy coated reinforcing steel and latex-modified mortar toppings.

As is well known, spalling is attributed to corrosion of the top mat of reinforcing steel due to the penetration of water and de-icing salts. Waterproofing membranes would solve the problem by preventing water and salts from ever entering the concrete. Galvanizing and epoxy coatings would solve the problem by protecting the surface of the steel. There are still other approaches, such as cathodic protection, which will not be included in this study.

METHODS OF EVALUATION

The membrane systems are evaluated both by visual inspection and by means of moisture detecting electrodes. The visual evaluation includes a subjective rating of the ease of construction as well as subsequent inspections to check for any obvious deterioration due to traffic. The waterproofing characteristics are evaluated by taking periodic measurements on electrodes which were placed at various locations on the decks when the membranes were installed.

A schematic drawing of the moisture detecting electrodes is shown in Figure I. The electrodes consist of thin copper tape, 1/2 inch wide by 10 feet long by 1.5 mils thick. These electrodes are first attached to polyethylene tape and then placed in pairs on the surface of the deck. Wire leads with waterproof high-temperature insulation are run from the electrodes to a terminal box at one end of the bridge.

Normally, about 10 pairs of these strips were placed on each test deck. Some were placed at critical locations such as the gutter line, the end of the bridge, or next to any joints. Others were located randomly on the deck, some in the wheelpaths and some between the wheelpaths, and one (control) was usually placed on the approach slab at the end of the bridge where there was to be bituminous pavement but no membrane.

To determine the existing wetness condition of the decks at the locations of the copper strips, electrical resistance readings are taken between the two strips of each pair by means of an ordinary ohm-meter. Calibration tests have shown that completely dry pavement would produce readings of at least 20,000 ohms and as high as several million ohms. Readings in the range from 20,000 ohms down to about 2,000 ohms are considered uncertain insofar as the presence of moisture is concerned. Below 2,000 ohms, moisture is almost certainly present and, below approximately 500 ohms, it is believed that both salts and moisture are present. The readings are taken on a periodic basis and, when possible, shortly after a heavy rain because it is thought that this would be the most likely time to detect any leaks in the membranes.

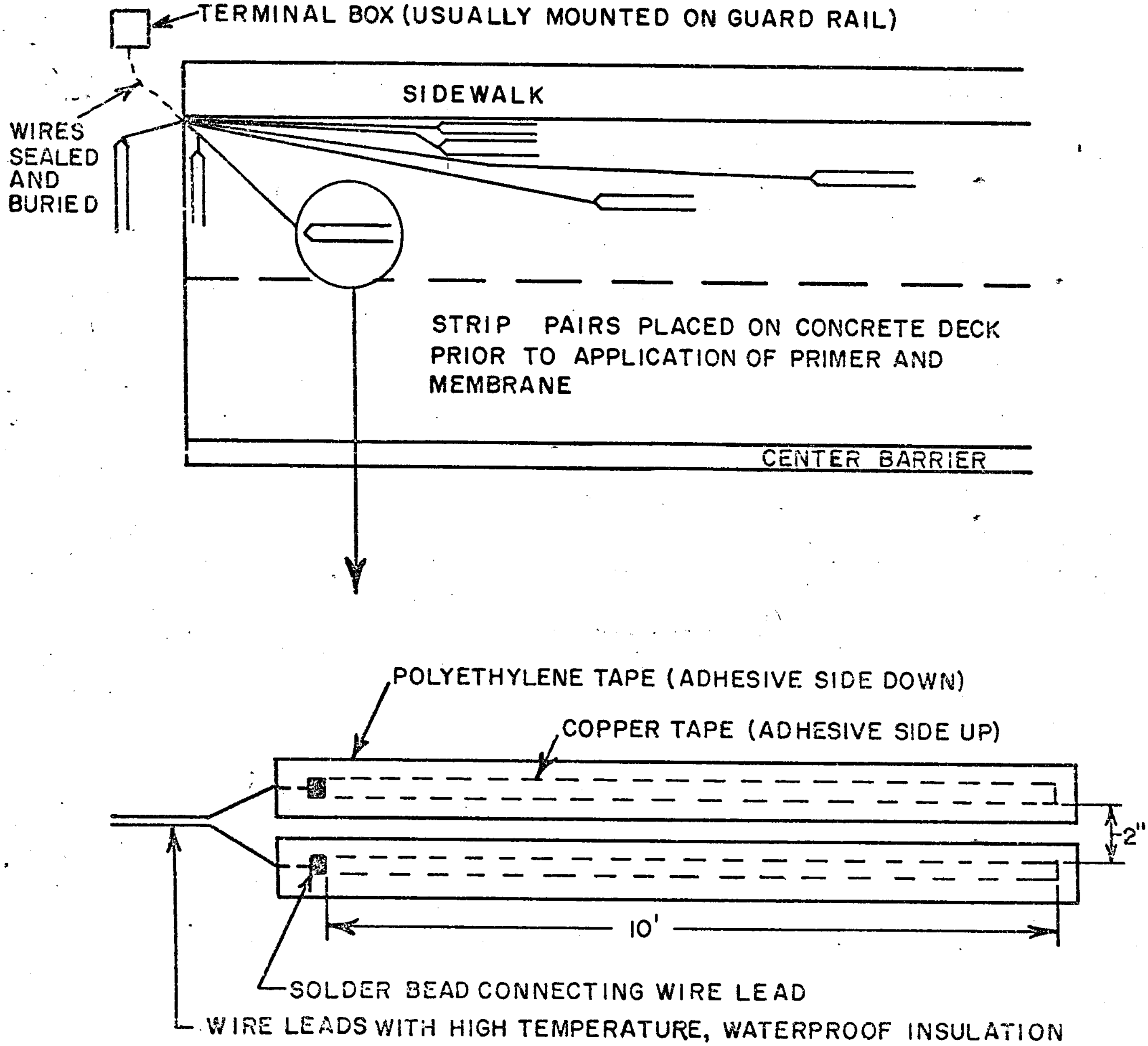


Figure I: Schematic Of Moisture Detection System

In regard to the precision of the ohm-meter readings, it is recognized that it would be desirable to know how much variability might ordinarily be present in order to establish when a reading could be judged significantly greater than 20,000 ohms or significantly less than 2,000 ohms. However, because of the complex nature of the type of resistance reading that is being taken, plus the uncertainty of how to maintain an unchanging control, as well as the fact that the critical levels of 2,000 and 20,000 are somewhat arbitrary points which are believed to differentiate generally wet concrete from generally dry concrete, it was judged impractical to attempt to develop a precision statement for this method of testing.

This monitoring system is satisfactory for waterproofing membranes but is not appropriate for the other experimental systems such as coated reinforcing steel or latex modified mortar. When these systems are tested, some other means of evaluation will have to be considered such as the copper half-cell potential measuring device (reported by Moore in "Detection of Bridge Deck Deterioration," Texas Transportation Institute, 1973).

SYSTEMS UNDER TEST

To date, four membrane-type systems have been installed as part of this study. A fifth product, Husky Deck by the Husky Oil Company, was installed by the Bureau of Maintenance but with such difficulty that it was judged unsatisfactory and excluded from further testing. The four systems which were successfully applied are (1) an asbestos-modified asphalt mix by Johns-Manville, (2) a hot-applied liquid rubberized asphalt system by Uniroyal, (3) a rolled-on preformed sheet by Royston, and (4) a similar system by W. R. Grace. The following will summarize the more pertinent details of each installation:

MEMBRANE #1

Manufacturer: Johns-Manville

Type: Asbestos Modified Asphalt Mix (15% asphalt, 6% asbestos)

Locations: Bridge #1227155, Route 130 over Pennsylvania Railroad (northbound)

Bridge #1227156, Route 130 over Route 522 (southbound)

Size of Decks: Approximately 34' x 163' and 34' x 58', respectively

Installation Dates: 7-12-72 northbound, 7-14-74 southbound

Weather: Clear, dry, 85°

Normal In-Place Cost: Approximately $3.00/s.y.

Paver Used: Barber-Greene, Metal Tracks

Rate of Application: Slightly slower than normal paving

Labor Forces: New Jersey Department of Transportation

Research Instrumentation: Copper Strips

Because of the composition of this mix, a placement temperature of 350°F is recommended by the manufacturer. Due to a delay in placing the instrumentation, plus the fact that the paver was cold at the start, the material was placed at a temperature of 325° or less. As a result, bare gaps occurred in the mat as it was put down by the paver, especially when it was attempted to control the thickness at 1/2". A fairly uniform mat was put down for a short stretch when it was accidentally placed at 1" thick. Because it was cooler than desired, the material tended to "ball" together and was difficult to rake out to a uniform thickness.

On the second day of paving, on the southbound lanes of the bridge over Route 522, a portion of the material in the final truck was discovered to be insufficiently mixed. Since it was too late to obtain another load, this material was mixed in the paver as much as possible and then appeared to lay down normally. Its subsequent performance seems to indicate that the mixing was adequate.

MEMBRANE #2

Manufacturer: Uniroyal

Type: Hot-applied liquid rubberized asphalt system

Locations: Bridge #1607156, Route 46 over Erie-Lackawanna Railroad, inner lane, westbound

Bridge #1607158, Route 46 over Paulison Avenue, inner lane, westbound

Size of Decks: Approximately 24' x 140' and 24' x 54', respectively

Installation Date: 7-19-72 (installed at night)

Weather: Clear, Dry, 80°F

Normal In-Place Cost: Approximately $6.30/s.y.

Special Equipment Used: Double-jacketed heated kettle, squeegees, cement dust

Rate of Application: Approximately one hour for a single lane 54' long

Labor Forces: Outside Contractor

Research Instrumentation: Copper strips

Paver: Rubber-tracked type

This material was heated to a temperature of 425°F in a double-jacketed kettle, poured onto the deck, and squeegeed to a thickness of approximately 1/16". Cement dust was applied after approximately 20 minutes and the material was solidified and ready for paving after 30-40 minutes.

Due to the roughness of the deck after extensive repairs had been made, the actual thickness of the poured membrane varied from 1/16" to 1/4" or more. This excessive thickness is believed to be the cause of the formation of several "bleed-through" spots which appeared after the overlay was placed. These gradually wore away in time and, after about two weeks of traffic, were no longer visible.

Some operational problems were experienced with the kettle during the treatment of the second deck over the Erie-Lackawanna Railroad. It is not known at this time whether or not this affected the integrity of the membrane placed on this deck.

MEMBRANE #3

Manufacturer: Royston

Type: Preformed Sheet (Bridge Membrane #10)

Location: Bridge #1117150, Route 64 westbound (to Princeton) over Pennsylvania Railroad

Size of Deck: Approximately 24' x 105'

Installation Date: 10-16-72

Weather: Windy, fairly dry, 50°F

Normal In-Place Cost: Approximately $5.00/s.y.

Labor Forces: New Jersey Department of Transportation

Rate of Application: Approximately three hours for two lanes

Equipment Required: Paint rollers and trays, propane torch, chalk line, linoleum knife (or equivalent)

Research Instrumentation: Copper strips

Paver: Metal tracks

The primer was rolled on with paint rollers and dried within a half hour or less. It was necessary to avoid contacting existing bituminous pavement (or patches) with this primer because it has a softening effect on bituminous concrete.

The Royston membrane is slightly thicker and heavier than the Grace material (Membrane #4). It did not wrinkle as much but it bonded less strongly when first rolled out by hand. Once down, it seemed quite secure. It requires sealing with a hand torch at the edges of the deck and also at transverse laps. The metal tracks of the paver did not appear to damage it.

About one week after the membrane and wearing course were installed, a very small popout of the overlay material was observed. It was discovered that the overaly was thinner than planned at this point due to an attempt to smooth out some of the irregularities in the approaches to the deck. The problem was not felt to be related to the membrane itself and it was corrected by adding another thin layer of wearing course over the whole bridge.

A second installation of the Royston membrane was made on four bridge decks on Route 17. Bridge #0214158, northbound over the New York State and Western Railroad, was instrumented in the same manner as the previous bridges but, unfortunately, vandals destroyed the terminal box after only one series of readings had been taken. Future evaluation of this bridge will have to be by visual inspection or, possibly, by coring.

An interesting aspect of this second Royston installation is that it was applied at temperatures substantially below the recommended minimum temperature of 50°F. This was a contract job, traffic conditions required that it be done at night, and the schedule was such that the membraning could not be done until early November. As a result, the temperatures were in the low 30's when the membrane was applied. In spite of this, no particular problems were encountered. The construction progressed normally and appears to have been satisfactory.

MEMBRANE #4

Manufacturer: W. R. Grace

Type: Preformed sheet (Heavy Duty Bituthene)

Location #1: Bridge #1117150, Route 64 eastbound (to Hightstown)

Size of Deck: Approximately 24' x 105'

Installation Date: 10-17-72

Weather: Partly cloudy, 60°F, the deck was wet early in the morning but the surface was dry by 10:00 a.m.

Location #2: Bridge #0214158, Route 17 southbound over New York State and Western Railroad

Size of Deck: Approximately 24' x 155'

Installation Date: 11-7-73 (installed at night)

Weather: Dry, temperature in mid-30's

Normal In-Place Cost: Approximately $5.00/s.y.

Labor Force: New Jersey Department of Transportation for Location #1
Outside Contractor for Location #2

Rate of Application: Approximately three hours for two lanes

Equipment Required: Paint rollers and trays, chalk line, linoleum knife, tubes of mastic

Research Instrumentation: Copper strips

Paver: Metal tracks

The primer was rolled on with paint rollers and dried in less than an hour. The Grace material (Bituthene) is slightly thinner and lighter and easier to handle than the Royston membrane. It wrinkled slightly more (causing bubbles) but its initial bond was stronger when rolled out by hand. Larger bubbles were cut open and patched quite easily. It was deeply marked but not cut by the steel tracks of the paver.

Immediately after paving, prior to rolling, unexpected reflection cracks opened up along several longitudinal seams at Location #1. This may have been related to the bead of sealer contained along the edge of the material but the Grace representative was not sure. These cracks appeared to knit together when rolled and were nearly invisible at the completion of the job. This did not occur at Location #2.

Like Membrane #3, a small popout occurred near one end of the bridge at Location #1. The overlay was found to be thin and these lanes were given another thin layer of wearing course.

At Location #2, the Grace material, like the Royston material, was installed at night with temperatures in the mid-30's, slightly colder than the recommended minimum temperature of 40°F. As with the Royston membrane, this seemed to have no adverse effect on either the installation or the performance.

RESULTS

There are at least three ways in which the resistance readings listed in Appendix I could be evaluated. These are (1) average all the readings for each deck, (2) count the number of definitely satisfactory (above 20,000) readings for each deck, and (3) count the number of definitely unsatisfactory (below 2,000) readings for each deck.

Method (1), utilizing the averages of the readings, is judged to be inappropriate because the few extremely high readings which commonly occur can cause the average to be misleadingly large. Method (2) and Method (3) appear to be satisfactory and will both be used because we are interested in maximizing the satisfactory readings as well as minimizing the unsatisfactory readings.

Before tabulating the results, it is necessary to impose a restriction on the data. Since all membrane systems appear to permit the intrusion of water along the gutter line (as evidenced by frequent very low readings), those systems with a greater number of strips placed in the gutter line might appear to perform more poorly than those with fewer gutter-line strips. In order to make a fair comparison, only data from interior strips are used to obtain the rankings listed in Table I.

TABLE I

Method	Description	Ranking (best to worst)	
(2)	Calculate percentage of definitely satisfactory non-gutter-line readings (greater than 20,000 ohms)	Johns-Manville Uniroyal Grace Royston	70% 41% 40% 25%
(3)	Calculate percentage of definitely unsatisfactory non-gutter-line readings (less than 2,000 ohms)	Johns-Manville Uniroyal Royston Grace	1.5% 9.0% 25% 35%

It is worthwhile to look not only at the relative rankings but at the percentages in Table I. At this time, the Johns-Manville material appears to be clearly in first place by either Method (2) or Method (3). The reversal of the Grace and Royston systems by these two methods is due to the fact that the Grace results are more variable, having a greater percentage of both satisfactory and unsatisfactory readings. This can also be seen in the histograms in Appendix II.

It should be re-emphasized that the precision of these measurements is unknown and that these results should be regarded only as a general indication of the relative performance of these products. All four are still regarded as tentatively acceptable for future construction.

EASE OF INSTALLATION

Based on the comments of Maintenance personnel who worked with these materials and Maintenance, Bridge, and Research engineers who witnessed the installations, there is a definite preference for the ease and simplicity of the rolled-on preformed sheet materials (Royston and Grace). These installations went smoothly, even with unskilled labor. Next in preference was the Johns-Manville asbestos-asphalt system, although both timing and inadequate mixing are potential problems with this system. If the mix becomes too cool, excessive hand work may be required to rake it out to a uniform thickness. Last in preference was the Uniroyal hot applied liquid system because both special equipment and trained operators are required.

FUTURE PLANS

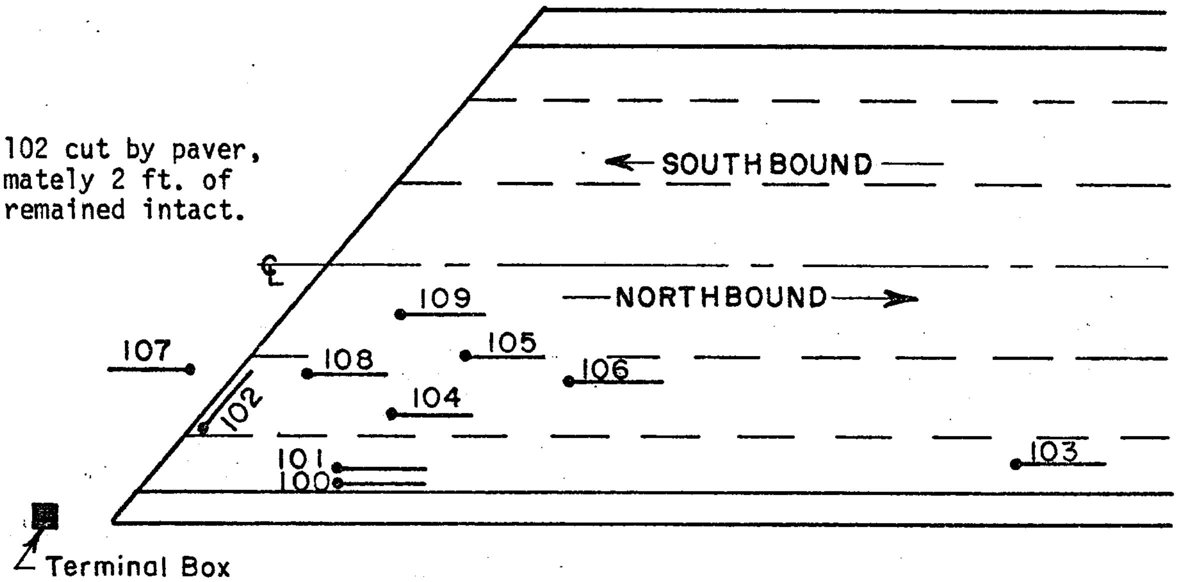
At the time of this writing, both epoxy coated reinforcing steel and the Dow SM-100 latex modified mortar system are scheduled to be tried during the coming construction season. One other preformed sheet type membrane is under consideration and there is also a possibility that galvanized reinforcing steel may be included.

APPENDIX I

ROUTE 130 BRIDGE OVER PENNSYLVANIA RAILROAD

JOHNS-MANVILLE ASBESTOS MODIFIED ASPHALT

Number 102 cut by paver, approximately 2 ft. of strips remained intact.

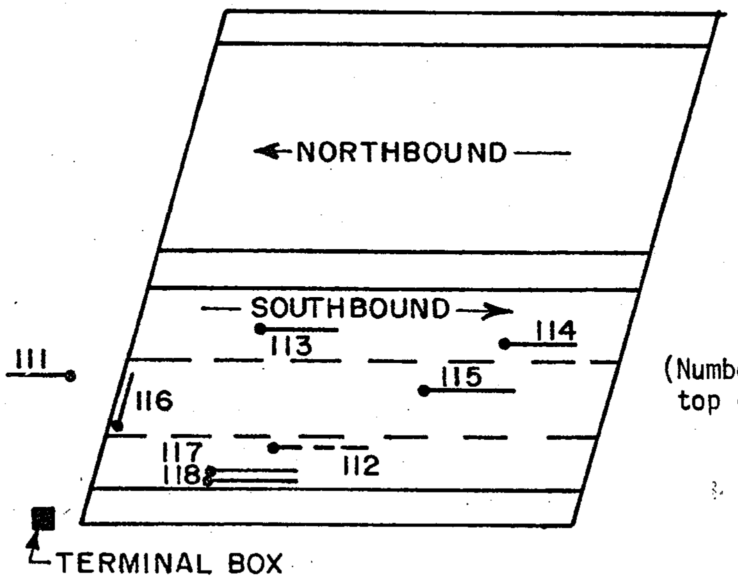


	AVERAGE RESISTANCE READING PER STRIP--OHMS									
	STRIP NUMBERS									
DATE	100	101	102	103	104	105	106	107	108	109
AFTER PAVING 7/14/72	230	125,000	235,000	16,000	7500	4900	5750	2200	245,000	13,000
8/1/72	140	22,000	5,325,000	295,000	56,000	23,500	15,000	1650	3,250,000	115,000
8/18/72	150	11,000	1,600,000	290,000	50,000	15,000	23,000	2400	530,000	60,000
8/29/72	130	3200	2,535,000	125,000	35,000	13,000	17,500	1150	390,000	29,000
9/14/72	125	6500	1,545,000	185,000	38,000	5500	45,000	1000	95,000	25,000
9/26/72	310	7100	820,000	180,000	23,000	4400	33,000	1450	68,000	21,000
10/27/72	335	3100	385,000	6450	80,000	2350	37,500	1700	82,500	16,500
11/13/72	570	1525	50,500	7800	63,500	3300	29,000	3350	61,500	19,250
12/18/72	1550	2850	62,500	32,000	170,000	28,500	175,000	27,000	132,500	[illegible]
2/21/73	515	2550	16,000	4750	7200	3400	7050	1700	29,000	5850
10/15/73	700	290	22,000	4550	2750	1100	1950	2600	19,000	2550
12/20/73	15,000	4950	3900	11,100	4950	2600	3700	2250	19,500	5500
3/29/74	295	438	38,000	2575	2075	3575	2850	3100	29,000	5000

APPENDIX I

<u>ROUTE 130 BRIDGE OVER COUNTY ROUTE 522</u>

JOHNS-MANVILLE ASBESTOS MODIFIED ASPHALT



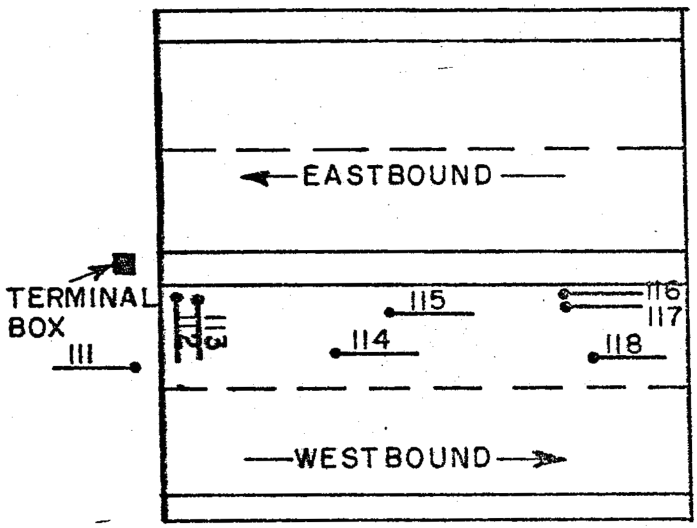
(Number 112 placed on top of membrane)

	AVERAGE RESISTANCE READING PER STRIP--OHMS							
	STRIP NUMBERS							
DATE	111	112	113	114	115	116	117	118
BEFORE PAVING 7/14/72	190,000	—	180,000	180,000	180,000	190,000	190,000	160,000
AFTER PAVING 7/14/72	160,000	23,000	105,000	190,000	215,000	210,000	67,500	1900
8/1/72	85,000	23,500	240,000	125,000	95,000	1,300,000	240,000	2150
8/18/72	48,000	37,000	140,000	60,000	45,000	560,000	180,000	925
8/29/72	80,000	90,000	210,000	110,000	75,000	425,000	205,000	975
9/14/72	50,000	50,000	200,000	70,000	50,000	270,000	205,000	1150
9/26/72	44,000	60,000	230,000	75,000	48,000	230,000	100,000	1100
10/27/72	77,500	310,000	575,000	137,500	97,500	201,500	6750	1425
11/13/72	44,000	52,000	700,000	160,000	108,000	123,000	6750	3300
12/18/72	132,500	300,000	1,650,000	420,000	245,000	135,000	35,500	28,000
2/21/73	49,000	36,000	475,000	132,500	96,000	39,000	4200	2900
10/15/73	1900	2,700,000	60,000	37,500	27,000	6900	1450	675
12/20/73	3750	3,600,000	32,000	23,250	23,000	16,000	15,000	15,000
3/29/74	3800	97,500	140,000	80,000	80,000	7500	950	725

APPENDIX I

ROUTE 46 BRIDGE OVER PAULISON AVENUE

UNIROYAL HOT-APPLIED LIQUID RUBBERIZED ASPHALT

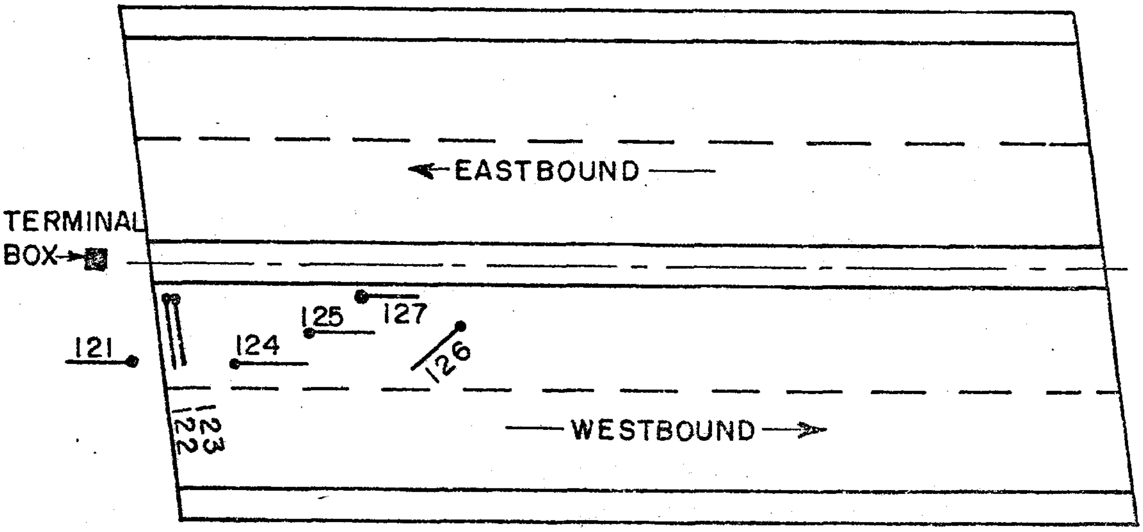


	AVERAGE RESISTANCE READING PER STRIP--OHMS							
	STRIP NUMBERS							
DATE	111	112	113	114	115	116	117	118
7/24/72	12,250	2000	105,000	217,500	100,000	140,000	130,000	24,000
8/1/72	7500	3000	73,500	625,000	285,000	250,000	210,000	14,000
8/21/72	4400	4200	54,000	390,000	190,000	67,000	130,000	6100
8/29/72	4500	4300	55,000	290,000	75,000	120,000	110,000	6000
9/14/72	5700	5900	75,000	360,000	95,000	75,000	80,000	7500
9/26/72	2050	3000	58,000	180,000	51,000	45,000	52,000	34,000
10/27/72	3200	5250	85,000	330,000	66,000	83,000	81,000	11,000
11/13/72	3950	8650	48,000	635,000	43,500	51,000	93,000	14,750
12/18/72	5150	19,000	160,500	1,625,000	119,000	62,000	295,000	22,500
2/21/73	6250	10,650	66,000	975,000	38,500	4200	107,500	16,000
10/15/73	600	1000	5600	149,000	8850	1350	52,500	10,000
1/2/74	1300	3000	9200	530,000	45,000	136,500	95,000	35,000
3/28/74	2000	2000	5100	1,200,000	9500	500	45,500	15,000

APPENDIX I

ROUTE 46 BRIDGE OVER ERIE-LACKAWANNA RAILROAD

UNIROYAL HOT-APPLIED LIQUID RUBBERIZED ASPHALT

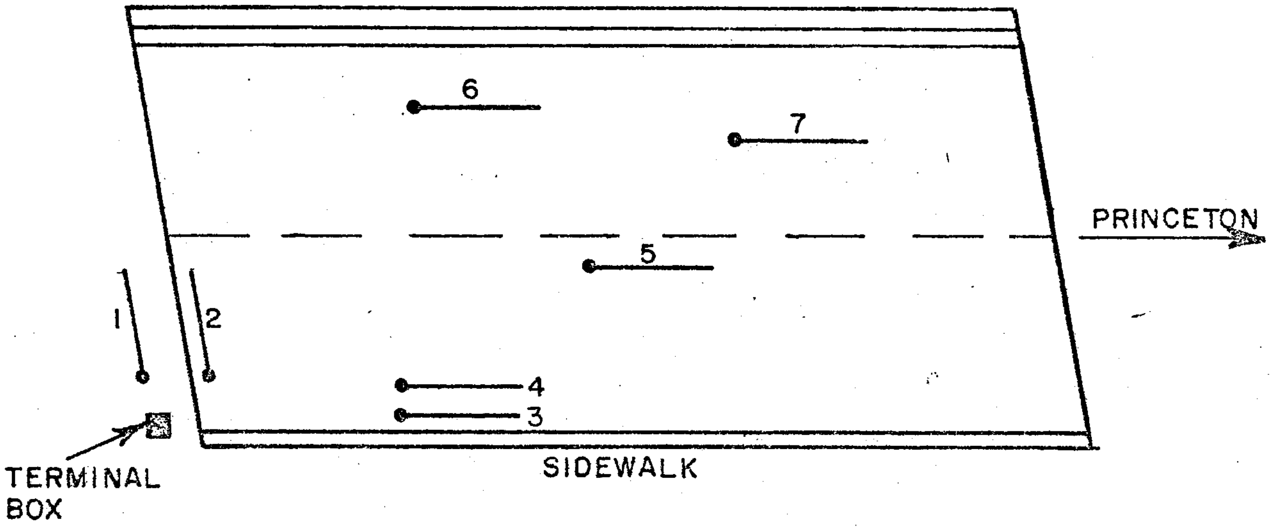


	AVERAGE RESISTANCE READING PER STRIP--OHMS						
	STRIP NUMBERS						
DATE	121	122	123	124	125	126	127
7/24/72	19,000	3400	19,000	1650	4300	5650	1800
8/1/72	17,000	4500	31,000	2100	5200	5500	1000
8/21/72	24,000	4200	23,500	2600	4200	3900	110
8/29/72	36,000	4000	25,000	3500	3800	5000	1300
9/14/72	41,000	4800	36,000	4100	3900	5000	620
9/26/72	34,000	1850	49,000	2100	1075	1950	230
10/27/72	52,500	2550	41,500	8000	1950	2700	655
11/13/72	52,500	5300	42,000	13,250	3550	5150	595
12/18/72	83,000	12,000	775,000	31,000	5150	14,500	6000
2/21/73	45,000	6400	15,000	13,500	6400	9750	3800
10/15/73	25,500	2100	29,000	2250	225	500	210
1/2/74	520,000	2650	405,000	155,000	150,000	155,000	150,000
3/28/74	28,000	1900	27,250	5000	1700	2600	1450

APPENDIX I

PRINCETON JUNCTION BRIDGE WESTBOUND (TO PRINCETON)

ROYSTON BRIDGE MEMBRANE NUMBER 10

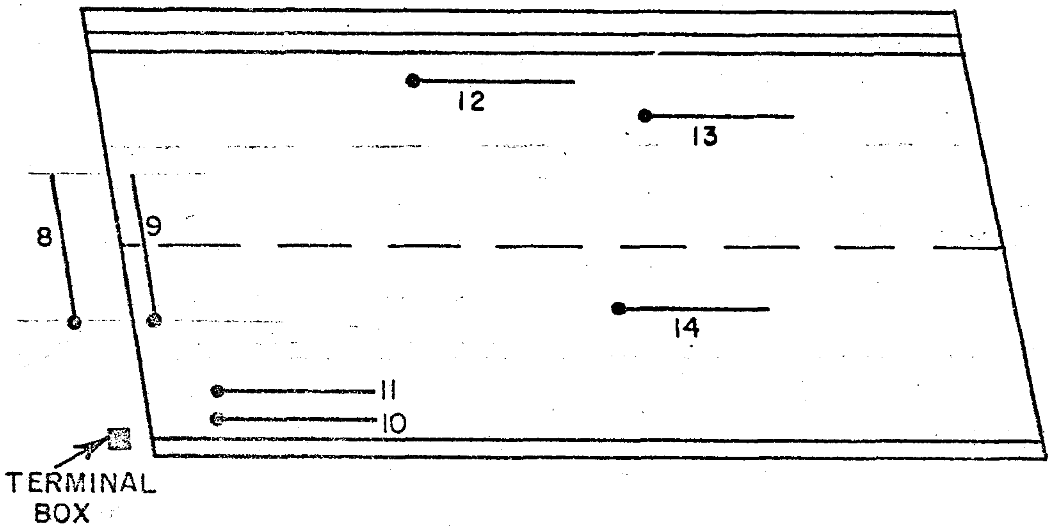


	AVERAGE RESISTANCE READING PER STRIP--OHMS						
	STRIP NUMBERS						
DATE	1	2	3	4	5	6	7
10/27/72	10,600	13,250	60,000	50,000	285,000	125,000	4850
11/13/72	4150	1645	12,300	38,000	5125	6800	4150
12/19/72	2900	945	17,500	34,000	22,000	37,500	10,500
2/21/73	1450	540	7150	12,000	4300	5150	1900
10/17/73	2800	1900	2300	2100	375	2350	150
12/20/73	2350	3650	4450	4300	1750	5050	235
3/29/74	412	4600	1975	2900	3550	3425	1480

APPENDIX I

PRINCETON JUNCTION BRIDGE EASTBOUND (TO HIGHTSTOWN)

W. R. GRACE HEAVY DUTY BITUTHENE

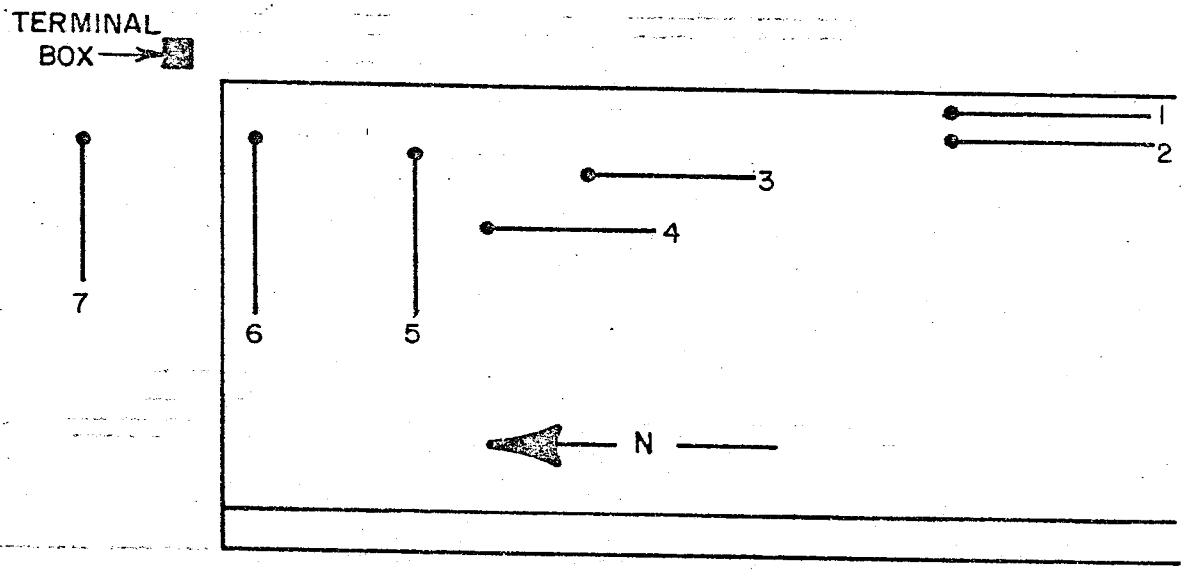


	AVERAGE RESISTANCE READING PER STRIP--OHMS						
	STRIP NUMBERS						
DATE	8	9	10	11	12	13	14
10/27/72	285,000	2950	17,500	10,750	34,500	75,000	100,000,000
11/13/72	80,500	1745	20,000	9400	19,700	1025	25,425,000
12/19/72	800,000	1625	27,500	16,000	16,000	9000	100,000,000
2/21/73	280,000	550	7250	4450	3200	675	27,500,000
10/17/73	50,000	105	195	165	185	950	9500
12/20/73	1,475,000	169	500	365	315	1000	28,000
3/29/74	125,000	150	375	240	302	875	15,750

APPENDIX I

ROUTE 17 BRIDGE NORTHBOUND

ROYSTON BRIDGE MEMBRANE NUMBER 10

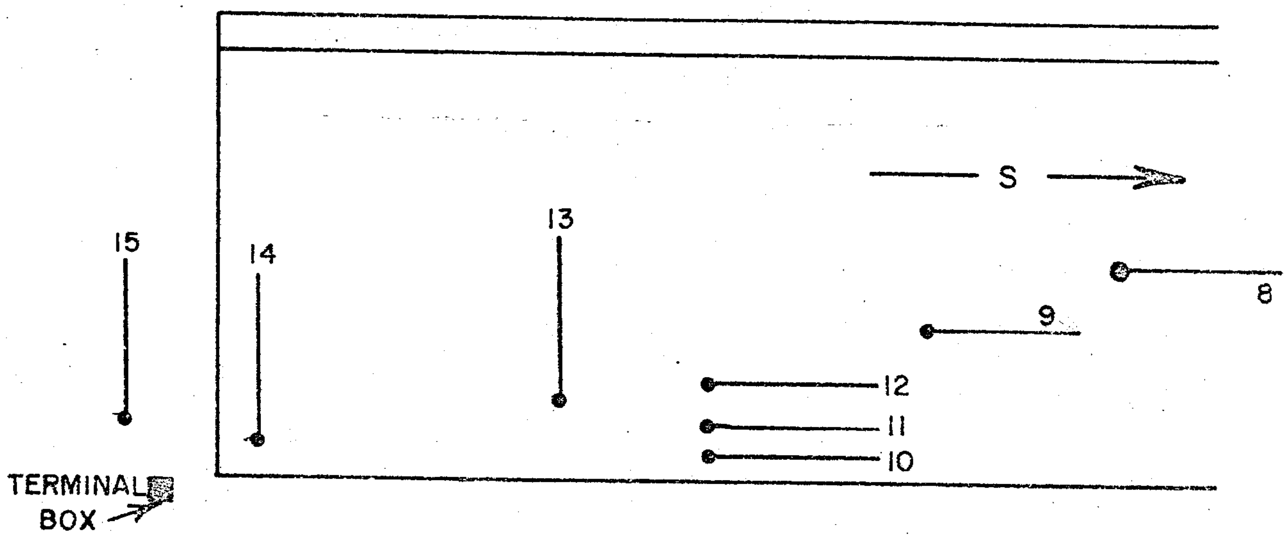


	AVERAGE RESISTANCE READING PER STRIP--OHMS						
	STRIP NUMBERS						
DATE	1	2	3	4	5	6	7
1/2/74	175	275	4250	135,000	100,000,000	3700	14,900
3/28/74	Terminal box vandalized, no further readings possible.						

APPENDIX I

ROUTE 17 BRIDGE SOUTHBOUND

W. R. GRACE HEAVY DUTY BITUTHENE



	AVERAGE RESISTANCE READING PER STRIP--OHMS							
	STRIP NUMBERS							
DATE	8	9	10	11	12	13	14	15
1/2/74	1600	49,000	2000	600	675	2250	3250	82,500
3/28/74	260,000	512	360	230	80	2100	10,250	1500

APPENDIX II

Relative Frequency of Ohm-Meter Readings Plotted on Logarithmic Scale

(Non-Gutter-Line Readings)

JOHNS-MANVILLE ASBESTOS-MODIFIED ASPHALT

	Range (Ohms)	Bridge over PRR	Bridge over Route 522
WET	100 - 157		
	158 - 250		
	251 - 397		
	398 - 630		
	631 - 999		
	1,000 - 1,584	X	
UNCERTAIN	1,585 - 2,511	XXX	
	2,512 - 3,980	XXXXXXXXX	
	3,981 - 6,309	XXXXXXXXXX	
	6,310 - 9,999	XXXXX	
	10,000 - 15,848	XXXXX	
DRY	15,849 - 25,118	XXXXXXXXXXX	XXXX
	25,119 - 39,810	XXXXXXXXXX	XXXXX
	39,811 - 63,095	XXXXX	XXXXXXXX
	63,096 - 99,999	XXXXXX	XXXXXXXXXX
	100,000 - 158,488	XXX	XXXXXXXX
	158,489 - 251,188	XXXXX	XXXXXXXX
	251,189 - 398,106	XXX	XX
	398,107 - 630,956	X	XXX
	630,957 - 999,999		X
	1,000,000 - 1,584,893		
	1,584,894 - 2,511,886		X
	2,511,887 - 3,981,072	X	XX
	3,981,073 - 6,309,573		
	6,309,574 - 9,999,999		
	10,000,000 - AND OVER		

APPENDIX II

Relative Frequency of Ohm-Meter Readings Plotted on Logarithmic Scale

(Non-Gutter-Line Readings)

UNIROYAL HOT-APPLIED LIQUID RUBBERIZED ASPHALT

	Range (Ohms)	Bridge Over Paulison Avenue	Bridge Over Erie-Lackawanna RR
	100 - 157		
	158 - 250		X
	251 - 397		
WET	398 - 630		X
	631 - 999		
	1,000 - 1,584		X
	1,585 - 2,511		XXXXXXX
	2,512 - 3,980		XXXXXXXX
UNCERTAIN	3,981 - 6,309	XX	XXXXXXXXXXX
	6,310 - 9,999	XXX	XXX
	10,000 - 15,848	XXXXX	XXX
	15,849 - 25,118	XXX	
	25,119 - 39,810	XXX	X
	39,811 - 63,095	XXX	
	63,096 - 99,999	XXX	
	100,000 - 158,488	XXX	XXX
	158,489 - 251,188	XXX	
	251,189 - 398,106	XXXXX	
DRY	398,107 - 630,956	XX	
	630,957 - 999,999	XX	
	1,000,000 - 1,584,893	X	
	1,584,894 - 2,511,886	X	
	2,511,887 - 3,981,072		
	3,981,073 - 6,309,573		
	6,309,574 - 9,999,999		
	10,000,000 - AND OVER		

APPENDIX II

Relative Frequency of Ohm-Meter Readings Plotted on Logarithmic Scale

(Non-Gutter-Line Readings)

ROYSTON BRIDGE MEMBRANE NO. 10

	Range (Ohms)	Both Bridges (Primarily Princeton Junction)
WET	100 - 157	X
WET	158 - 250	X
WET	251 - 397	X
WET	398 - 630	
WET	631 - 999	
WET	1,000 - 1,584	X
UNCERTAIN	1,585 - 2,511	XXX
UNCERTAIN	2,512 - 3,980	XX
UNCERTAIN	3,981 - 6,309	XXXXXXX
UNCERTAIN	6,310 - 9,999	X
UNCERTAIN	10,000 - 15,848	X
DRY	15,849 - 25,118	X
DRY	25,119 - 39,810	X
DRY	39,811 - 63,095	
DRY	63,096 - 99,999	
DRY	100,000 - 158,488	XX
DRY	158,489 - 251,188	
DRY	251,189 - 398,106	X
DRY	398,107 - 630,956	
DRY	630,957 - 999,999	
DRY	1,000,000 - 1,584,893	
DRY	1,584,894 - 2,511,886	
DRY	2,511,887 - 3,981,072	
DRY	3,981,073 - 6,309,573	
DRY	6,309,574 - 9,999,999	
DRY	10,000,000 - AND OVER	X

APPENDIX II

Relative Frequency of Ohm-Meter Readings Plotted on Logarithmic Scale

(Non-Gutter-Line Readings)

GRACE HEAVY DUTY BITUTHENE

	Range (Ohms)	Both Bridges (Primarily Princeton Junction)
	100 - 157	
	158 - 250	
	251 - 397	
WET	398 - 630	X
	631 - 999	XXX
	1,000 - 1,584	XX
	1,585 - 2,511	XXX
	2,512 - 3,980	
UNCERTAIN	3,981 - 6,309	
	6,310 - 9,999	XX
	10,000 - 15,848	X
	15,849 - 25,118	
	25,119 - 39,810	X
	39,811 - 63,095	X
	63,096 - 99,999	X
	100,000 - 158,488	
	158,489 - 251,188	
	251,189 - 398,106	X
DRY	398,107 - 630,956	
	630,957 - 999,999	
	1,000,000 - 1,584,893	
	1,584,894 - 2,511,886	
	2,511,887 - 3,981,072	
	3,981,073 - 6,309,573	
	6,309,574 - 9,999,999	
	10,000,000 - AND OVER	XXXX