FIELD EVALUATIONS OF WATERPROOF MEMBRANE SYSTEMS FOR BRIDGE DECKS 1972-1974

by

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SUMMARY

Waterproof membrane systems are being studied by many agencies from the standpoint of their effectiveness in protecting the reinforcing steel in concrete bridge decks against corrosion. Trial applications and evaluations of six such systems, including both preformed sheet and liquid membranes, were made in Virginia during the period from 1972 through 1974. These field evaluations included observations of the installation procedures and assessments of the subsequent waterproofing effectiveness of the systems through electrical resistivity measurements. While none of the systems could be considered an unqualified success, four of the systems showed promise, with modification of the application techniques used in the study, of providing the desired degree of long-term protection.

Specific details of the application techniques and performances of each of the membrane systems are presented as is an evaluation of the effectiveness of earlier epoxy resin sealcoats.

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INTRODUCTION

It is generally agreed that corrosion of the top reinforcing steel in a concrete bridge deck in the presence of chloride ions that have entered the concrete through its pores or cracks is a primary cause of spalling of the deck. In many areas the correction of spalling is a major maintenance expense, and much effort is being devoted to its prevention. One of several schemes being evaluated as a means of preventing corrosion of the steel is the installation of a waterproof membrane on the top surface of the deck. Trials of bridge deck membranes are being conducted by many transportation agencies, and among these are nationwide investigations under the auspices of the Federal Highway Administration (NEEP No. 12) and the Transportation Research Board (NCHRP Project 12-11).

The emphasis on the use of waterproof membrane systems has caused a proliferation in the number of systems available to the highway engineer since 1972. Some of the new membranes are very promising; they appear to offer better protection and the potential of greater economy than earlier systems such as the coal tar epoxy sealcoat widely used in Virginia. For these reasons, a limited program of field trials of promising membrane systems was proposed by the Virginia Highway and Transportation Research Council in 1972.

PURPOSE AND SCOPE

The purpose of the subject study was to evaluate a number of new membrane systems and to compare their application procedures and subsequent performances with those of the epoxy resin sealcoats. It was initially envisioned that the study would be limited to products which showed promise of success based on their trial by other agencies, but trials of experimental membranes were later included. While the determination of an effective system was a primary goal, the research was also intended to provide the Department of Highways and Transportation with sufficient background information to allow the adoption of the findings of more extensive studies being conducted by other agencies.

The project began in July 1972, with a survey of the waterproofing systems then used by the Department, followed by evaluation of the six membrane systems listed below.

1. Heavy Duty Bituthene — 3 installations.
2. Protecto Wrap — 2 installations.
3. Witmer System — 1 installation.
4. Polytok Membrane 165 — 1 installation.
5. Chevron's System — 1 installation.
6. Two-Coat Coal Tar Epoxy Sealcoat — 1 installation.

The performances of the membranes at these nine installations were evaluated using the electrical resistivity test procedure developed by Spellman and Stratfull of California.(1) Only limited laboratory tests were performed.

THE ELECTRICAL RESISTIVITY TEST

The electrical resistivity test, reported in 1971, remains virtually the only way to evaluate the effectiveness of a membrane in place on a bridge deck. The resistance is measured in the circuit shown in Figure 1, in which an ohmeter is connected to the deck reinforcement and to a copper plate and sponge on the wetted deck surface. Water, with a wetting agent added, is applied to the surface of the overlay and given time to permeate the asphaltic concrete, and a reading is taken. If the membrane, which must be of a dielectric material, is completely waterproof, the resistance will be infinite. Holes in the membrane, which allow the passage of water, reduce the resistance. On the basis of laboratory tests Spellman and Stratfull initially established a value of 500,000 ohms per square foot (0.09 m^2) as being indicative of an effective membrane. At this writing there appears to be a widely held, but unwritten, opinion that values above 200,000 ohms per square foot (0.09 m^2) are acceptable.

Because of several factors that can cause significant errors in the readings, proper application of the electrical resistivity test requires considerable judgment. The most critical factor appears to be the size of the wetted area in the asphaltic concrete overlay. Conventionally, the wetted area is assumed to be equal to the area of the copper plate, and the resistance reading is reported in relation to the area of the plate. Obviously, however, the resistance is read over the entire wetted area, and care must be used in minimizing the spread of water on the surface of and within the asphaltic concrete layer. The overlay must be dry initially, but it is difficult to determine when this condition is met. In order to approach the desired dryness, a period of about one week without rain was allowed before the readings in this study were taken.

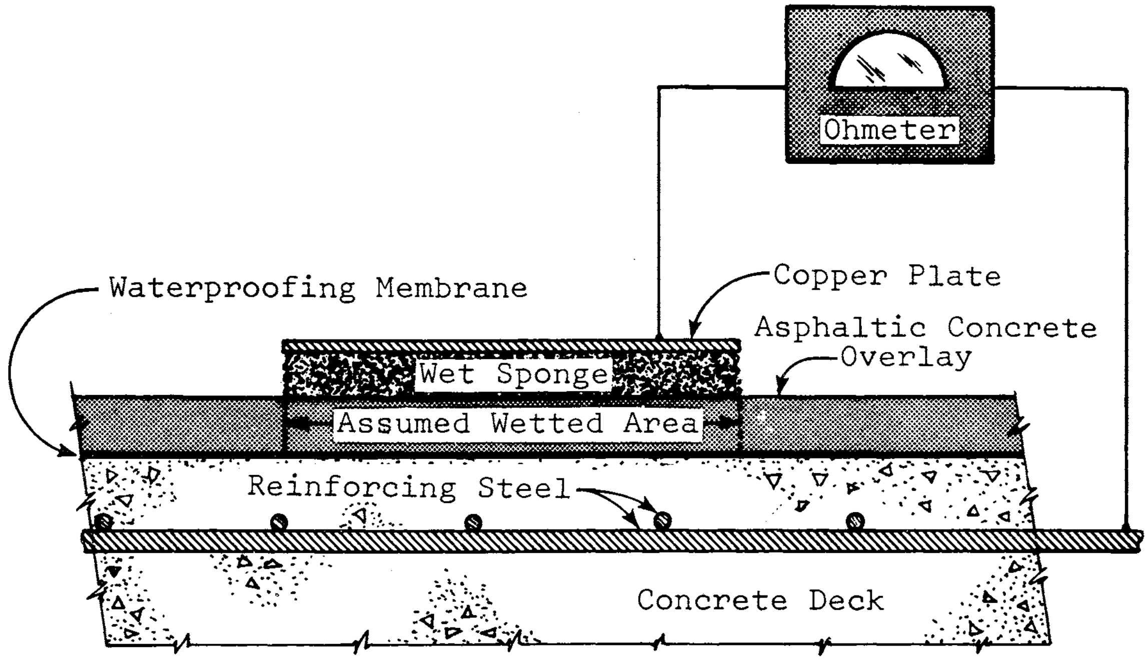

Figure 1. Assumed circuit for the electrical resistivity test.

Although difficulty is seldom encountered, care must also be exercised in selecting a proper connection to the reinforcing steel, because the connection can influence the resistivity readings. It is also important that no part of the wetted area touch bare concrete at the edge of the membrane. Several other factors that can significantly affect the reliability of the readings have been cited in a recent "Paving Information Bulletin" published by Phillips Petroleum.[2] Among these were the distance between the electrodes, the specific resistivity of the wetting agent, and the quantity of residual soluble salts in the overlay or the concrete.

The factors cited previously indicate the need for care in obtaining resistance readings. Newly placed membranes should be evaluated as soon as possible after paving, preferably before rain has fallen, to avoid the effects of moisture in the overlay. Reliable data can be obtained on new installations, but as pointed out in a recent FHWA notice, the interpretation of resistivity data taken on in-service decks requires both experience and judgment.[3] The pattern of resistance values at various points on the decks, as well as the values themselves, were found to be important in the interpretation of the data taken in this study.

EVALUATION OF MEMBRANES IN USE IN 1972

The Virginia study began with an assessment of those waterproofing systems in use in 1972. The then applicable specifications allowed two systems: Class I, a coal tar epoxy resin applied at a rate of one gallon per 30 square feet (1.36 ℓ/m^2), upon which grit was applied at a rate of 11 to 15 pounds per square yard (6.0-8.1 kg/m^2); and Class II, a built-up multilayer system consisting of three layers of fiberglass alternated with four moppings of asphalt, applied at a total rate of not less than 16 gallons per 100 square feet (6.5 ℓ/m^2), on a previously primed deck.[4] Both the Class I and Class II systems were generally protected by an asphaltic concrete overlay. A few variant systems had also been placed on an experimental basis.

Unfavorable experiences with the Class II system had resulted in an overwhelming predominance of the Class I epoxy system, to the extent that it could be considered the Virginia standard. In fact, conditions did not allow the testing of a Class II system, which in the majority of cases was used on prestressed concrete box superstructures that were not suited to the resistivity tests. The effectiveness of those systems tested during the summer of 1972 is described below; a short discussion of systems similar to the Class II system is also included.

Class I — Coal Tar Epoxy Resin Sealcoats

Twenty-three bridges waterproofed through the use of an epoxy sealcoat with grit and an asphalt wearing course were evaluated. Most of the decks were sealed with a single coat of epoxy, but some had areas with a double coating. The results of the electrical resistivity tests are shown in two forms in Figures 2 and 3.

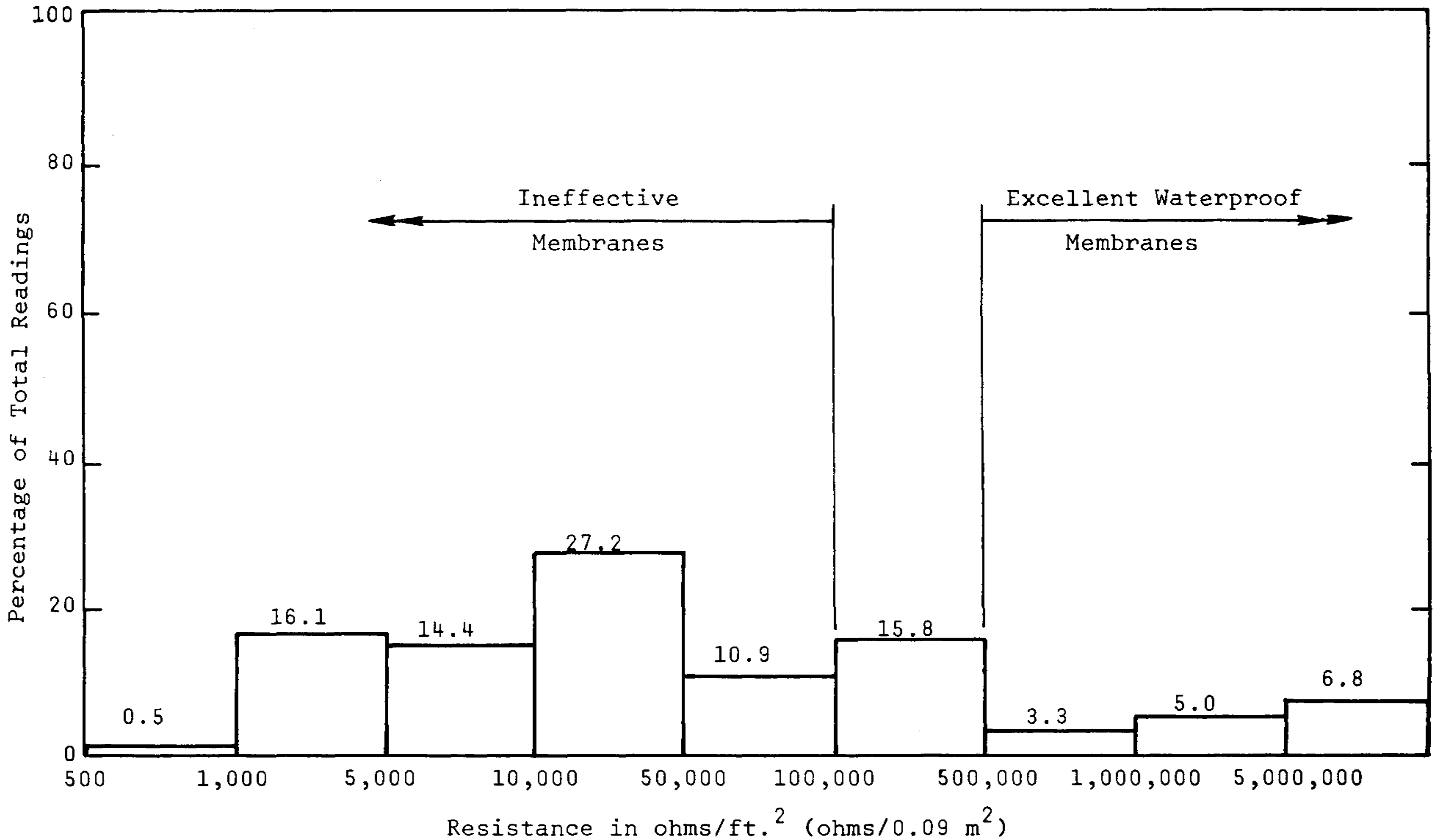

Figure 2. Distribution of resistivity readings from 23 bridges with coal tar modified epoxy resin sealcoats.

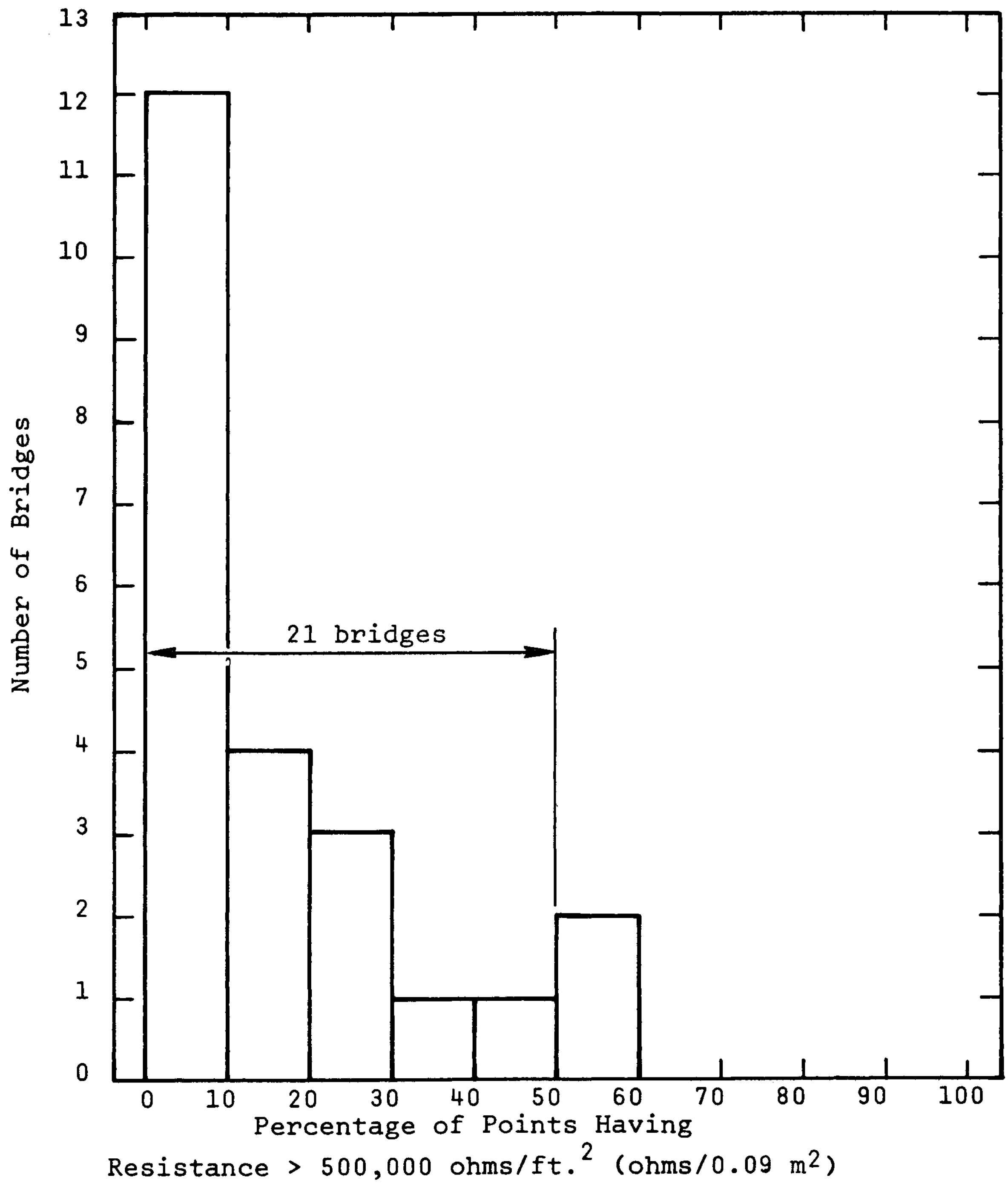

Figure 3. Percentage of points with effective waterproofing on 23 bridges with coal tar modified epoxy resin sealcoats.

Figure 2 is a plot of the percentages of all of the resistivity readings from the 23 bridges falling in several arbitrarily selected ranges of resistance in ohms per square foot. It is important to note that 69.1 percent of the readings were below 100,000 ohms per square foot (0.09 m^2), which is indicative of an ineffective waterproof membrane, while only 15.1 percent were above 500,000 ohms per square foot (0.09m^2), which is considered to be indicative of an excellent waterproofing system.(1) Thus, in general, the epoxy sealcoats did not appear to be providing satisfactory protection.

Figure 3 provides an indication of the effectiveness of the epoxy resin sealcoats on individual bridges. Here, the percentage of points at which effective waterproofing was indicated is plotted versus the number of bridges. Thus, for example 12 bridges each had 0 to 10 percent of their readings above 500,000 ohms per square foot (0.09 m^2), based on a 5-foot (1.52 m) coordinate grid system in most cases. It is important to note that of the 23 bridges tested only two had epoxy resin sealcoats that could be considered more than 50 percent effective. The best of these had only 57 percent of the readings above 500,000 ohms per square foot (0.09 m^2). Similar data, not shown, based on the failure criteria indicated that 17 bridges had 50 percent or more readings below 100,000 ohms.

Thus it appears, on the basis of electrical resistivity measurements, that a single application of an epoxy resin sealcoat does not provide effective waterproofing. Similar results were found later in the study when single coatings of an epoxy system without grit were tested, and the findings are consistent with those of a nationwide survey conducted by the Federal Highway Administration.(5) Those deck areas with double coatings of epoxy, while not uniformly satisfactory, yielded higher resistance readings.

Coal Tar Emulsion Sealcoats

Sealcoats consisting of a single coating of a coal tar emulsion were tried in a few instances prior to the summer of 1972 in an attempt to find an economical waterproofing system. Resistivity tests on two structures with such membranes gave unimpressive results. The great majority of the readings were below 100,000 ohms per square foot (0.09 m^2), and use of the system has been discontinued.

Class II — Asphalt-Fiberglass Multilayer Membrane

The Class II waterproofing system has not been popular in Virginia because of application difficulties and the possibility of the membrane sliding under traffic. No representative installation was found for testing, but the results of studies of similar systems by other agencies are available.

A report from the Federal Highway Administration's National Experimental and Evaluation Program Project Number 12 stated that the performance of a similar coal tar-fiberglass layered system "varies between good and bad depending on construction practice."(5) Tests of similar systems using hot mopped asphalt and coal tar emulsion performed in Vermont indicated that the membranes were not waterproof before paving, but the pavement and membrane systems initially were waterproof in both cases.(6) However, neither system was recommended for further use as a bridge deck membrane, possibly because neither exhibited good flexibility and elongation at low temperatures.

Summation

There is ample evidence that a single layer epoxy membrane cannot be considered waterproof, and that the coal tar emulsion system appears similarly weak. Further testing of a double layer epoxy system in which the first layer was applied without grit will be described in more detail later, but this system also failed. The poor electrical resistivity results plus the inherent expense of the epoxy systems argue strongly for trials of the newer membranes described later. While no firm data on the Class II layered system are available, the national consensus cannot be considered promising.

TESTS OF NEW MEMBRANE SYSTEMS

Heavy Duty Bituthene (W. R. Grace & Co.)

Installations

1. Route 340 over Harners Run, Augusta County, Deck area 2,535 s.f. (235.5 m^2), September 1972.

2. Route 19 over Little River, Tazewell County, Deck area 6,525 s.f. (606.2 m^2), August 1973.

3. (a) Route 64 (EBL) over Burcher Road, City of Newport News, Deck area 7,560 s.f. (702.4 m^2), July 1974.

   (b) Route 64 (WBL) over Burcher Road, City of Newport News, Deck area 7,560 s.f. (702.4 m^2), August 1974.

Description

Heavy Duty Bituthene is a prefabricated sheet membrane consisting of a woven mesh sandwiched between a layer of adhesive grade rubberized asphalt and a layer of non-tacky bituminous compound, and has a total thickness of 65 mils (1.7 mm). It is produced in rolls 3 feet (0.9 m) wide by 60 feet (18.3 m) long interwound with a release paper.

Application Procedure

The steps in a typical application of the Bituthene system are shown in Figures 4-8. The deck surface (Figure 4) was cleaned of all soil, loose debris, and accumulations of oil or grease. This required only a light brush sandblasting, after which the deck was blown clean. Bituthene primer was then applied to the decks and the faces of the wheel guards (Figure 5) and allowed to cure to a non-tacky state. Application of the sheet membrane began with the placement of short strips at the wheel guards (Figure 6) in order to provide a shingling of subsequent laps toward the low points of the deck. The membrane was extended up the face of the wheel guards for a distance equal to the depth of the overlay. Subsequent strips of the membrane were unrolled by pulling the release paper (Figure 7). After placement of the membrane its free edges were sealed with mastic and it was rolled lightly with a garden roller to ensure proper contact with the deck surface (Figure 8). Finally a 1½-inch (3.8 cm) thick asphaltic concrete overlay meeting the requirements of Table 1 was placed directly on the membrane. The treatment of the filled expansion joints in the deck consisted of placing 8-12 inch (20-30 cm) strips of the membrane along their lengths, covering them with the uncut deck membrane, and paving continuously across them.

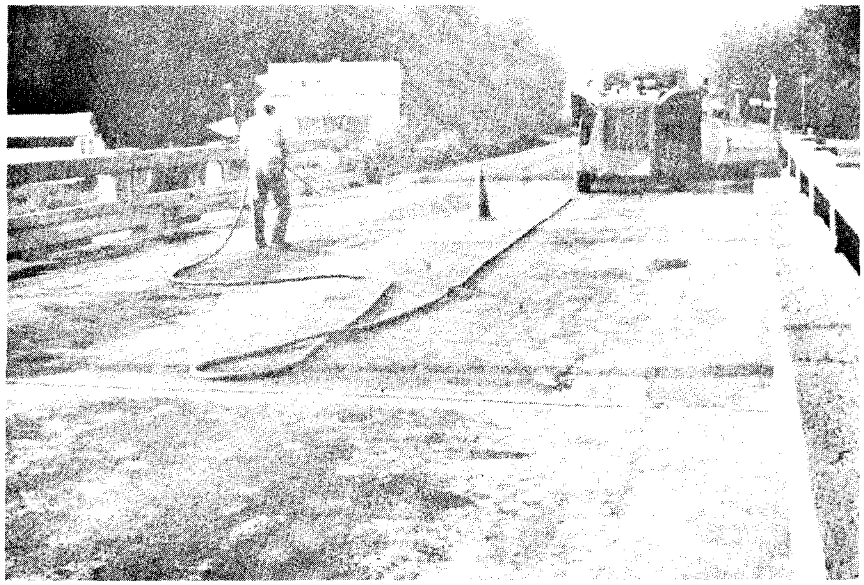

Figure 4. Deck surface prepared for application of Bituthene membrane

Figure 5. Application of Bituthene primer.

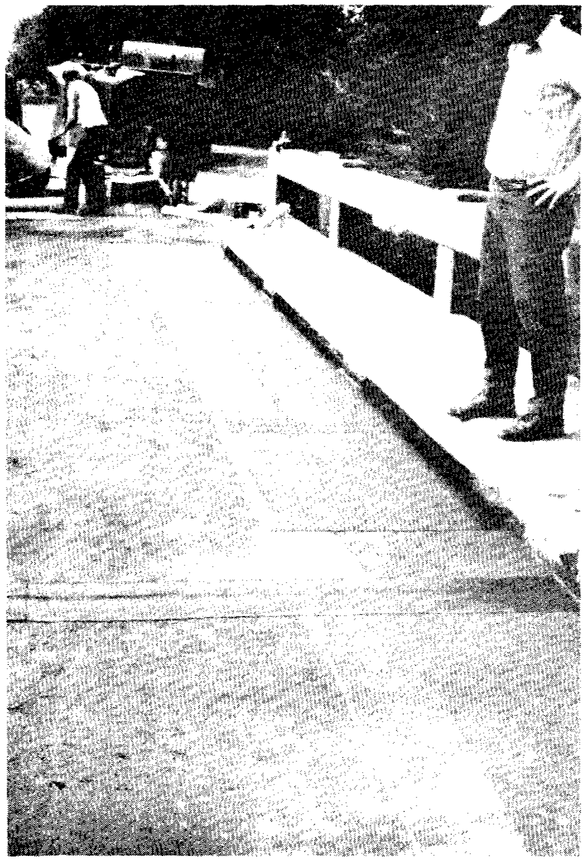

Figure 6. Placement of short strips of Bituthene membrane along curb.

Figure 7. Unrolling of sheet membrane by pulling release paper.

Table 1

Specification Requirements for Type S-5 Bituminous Concrete Mixture Used to Overlay Bridge Deck Membrane Systems(4)

PERCENTAGE BY WEIGHT PASSING SQUARE MESH SIEVES*						
1/2 in.	3/8 in.	No. 4	No. 8	No. 30	No. 50	No. 200
12.7 mm	9.5 mm	6.4 mm	3.2 mm	0.8 mm	0.5 mm	0.1 mm
100	80-100		35-55	15-30	7-22	2-10
PERCENT BITUMINOUS MATERIALS: 5.0 - 8.5						
MIX TEMPERATURE (AT PLANT): 225 - 300°F 107 - 149°C						

*Numbered sieves are those of the U. S. Standard Sieve Series.

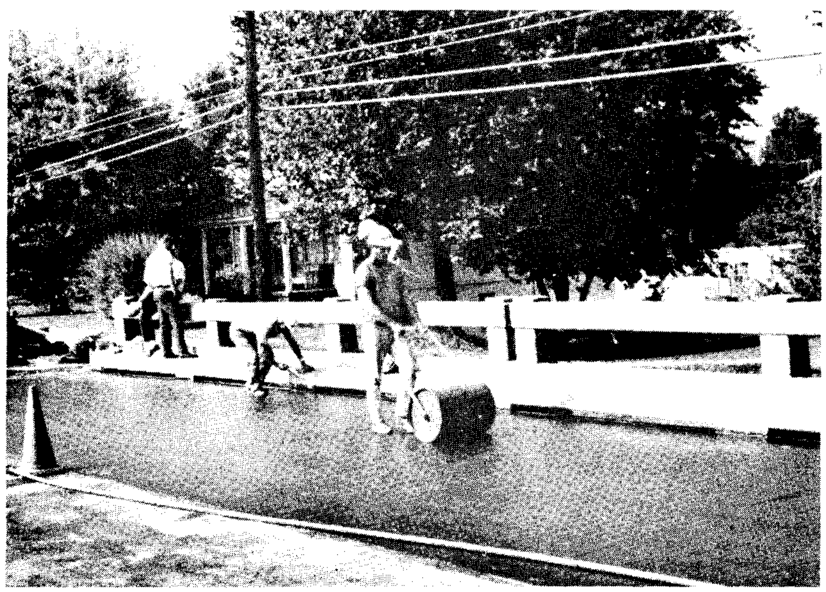

Figure 8. Rolling of the membrane to assure contact with the deck.

Evaluation

The application of a Heavy Duty Bituthene membrane, while more difficult than that of other systems because of its strong adhesion, is relatively easy to master. Pieces of the material must not be allowed to double over and care must be used in unrolling the material since it cannot easily be removed from the deck. In spite of the obvious need for careful placement of the membrane, each of the four installations was completed in one day by inexperienced personnel with the guidance of representatives of the manufacturer.

Hot weather can render the application more difficult as the adhesion of the membrane to the backing paper is increased. Sizeable blisters are also formed beneath the membrane during warm weather, but no distress resulting from the blisters has been noted. Paving has proved to be the most critical phase in the placement of any of the newer membrane systems. The asphaltic concrete overlay must be placed before the bridge is opened to traffic, but the quantity of material required is not large. Coordination of the paving operation is, therefore, difficult, but care must be exercised to avoid damaging the membrane.

With proper care, good initial results can be attained. The Route 340 bridge over Harners Run was first tested on October 2, 1972, at which time only 4 out of 120 points on a 5 x 5 foot (1.5 x 1.5 m) grid had resistivity readings below 500,000 ohms per square foot (0.09 m^2). Two of these initial readings occurred in an area at which the asphalt overlay was thin. However, resistivity readings taken on August 31, 1973, approximately one year after installation,had the pattern shown in Table 2. It can be seen that while the readings remain generally high in the shoulder areas, they have dropped to unsatisfactory levels in the wheel path areas. The readings at the centerline, while somewhat higher, are also unsatisfactory. The structure was considered dry at the time of testing; there was good provision for drainage and no rain had fallen for ten days.

This characteristic pattern of low resistivity readings in the traffic lanes was noted on all of the other applications and it was apparent, though not as severe, in the case of the Burcher Road bridges approximately two months after installation. The cause of the deterioration has not been determined with certainty. Attempts to remove the overlay from the Little River bridge were hampered by the excellent bond of the asphalt to the membrane. It did appear, however, that some of the membrane constituents had migrated into the rather coarse asphalt overlay. Similar problems were noted in the case of the two Protecto-Wrap installations described in the next section of this report.

Table 2

Array of Resistivity Readings, ohms x 10^{-3}
Per Square Foot (0.09 m^2) Taken on a 5 x 5 ft. (1.5 x 1.5 m)
Grid, Rte. 340 Bridge Over Harners Run, 8/31/73

	Curb	Wheelpath	Wheelpath	℄	Wheelpath	Between Wheelpaths	Curb
	1	2	3	4	5	6	7
1	1.80	0.012	0.01	2.00	0.07	0.02	20.00
2	4.00	0.02	0.03	2.00	0.06	0.02	20.00
3	.30	0.03	0.05	0.70	0.02	0.02	20.00
4	1.08	0.02	0.08	0.07	0.02	0.02	20.00
5	.30	0.03	0.03	0.14	0.03	0.04	0.65
6	5.00	0.02	0.02	0.19	0.07	0.03	20.00
7	1.10	0.02	0.05	0.12	0.03	0.05	20.00
8	.80	0.02	0.03	0.11	0.03	0.02	1.50
9	.40	0.02	0.03	0.13	0.06	0.03	0.70
10	.64	0.04	0.06	0.18	0.22	0.04	3.00
11	20.00	0.05	0.03	0.28	0.06	0.04	1.20
12	20.00	0.04	0.02	0.03	0.07	0.04	20.00
13	5.00	0.04	0.02	0.11	0.05	0.02	1.25
14	10.00	0.03	0.02	0.12	0.05	0.03	0.46
15	.28	0.02	0.04	0.06	0.05	0.35	0.82
16	1.50	0.03	0.02	0.03	0.05	20.00	0.35
17	20.00	0.04	0.04	0.10	0.02	20.00	0.71
18	20.00	0.03	0.06	0.11	0.10	20.00	0.32
19	.80	0.03	0.08	0.04	20.00	20.00	1.25
20	.60	0.04	0.05	0.09	20.00	0.22	0.69

The rather simple treatment of the deck expansion joints worked well on the short, rigid concrete beam spans of the Harners Run Bridge, in which little movement would be expected. However, cracking and raveling of the overlay has occurred over the joints between the longer spans of the Burcher Road Bridges. Additional consideration will have to be given to the treatment of the joints in all but the shortest spans if Bituthene and, possibly, other newer membrane systems are used.

Costs

The recent costs of installing the Bituthene membranes with 165 pound (74.8 kg) asphalt overlays on the two Burcher Road bridges, including materials, equipment and labor, were $1.04 per square foot (0.09 m^2) for the eastbound lane structure and $0.97 per square foot (0.09 m^2) for the westbound lane structure. Both installations were made by state maintenance forces.

Protecto Wrap M-400

Applications

(1) Route 81 (SBL) over Route 260, Shenandoah County, Deck area 8,232 s.f. (764.8 m^2), October 1972.

(2) Route 19 over Indian Creek, Tazewell County, Deck area 6,020 s.f. (559.3 m^2), August 1972.

Description

Protecto Wrap M-400 is a prefabricated sheet membrane composed of a non-woven synthetic fiber between layers of coal tar modified with synthetic resins, with a total thickness of approximately 70 mils (1.8 mm). It is generally available in rolls 30 inches (0.7 m) and 60 inches (1.5 m) in width and 50 feet (15.2 m) long. One side of the membrane has a polyethlene separator sheet which is removed after placement.

Application Procedure

The application of a Protecto Wrap membrane, shown in Figures 9-12, was similar to that for the Bituthene membrane described previously. The deck, which had been cleaned of all loose material, and the faces of the wheel guard were primed with Protecto Wrap No. 80 primer (Figure 9), and allowed to dry to a tack-free condition.

Figure 9. Application of Protecto-Wrap membrane.

Figure 10. Unrolling of Protecto-Wrap membrane.

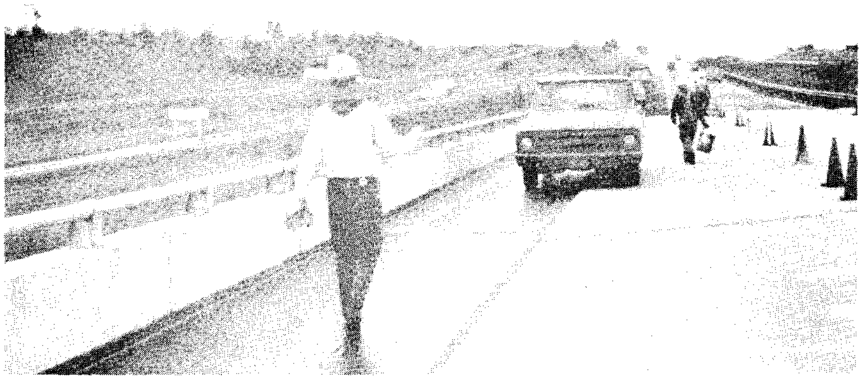

Figure 11. Rolling with light truck to set the laps between adjacent membrane sheets.

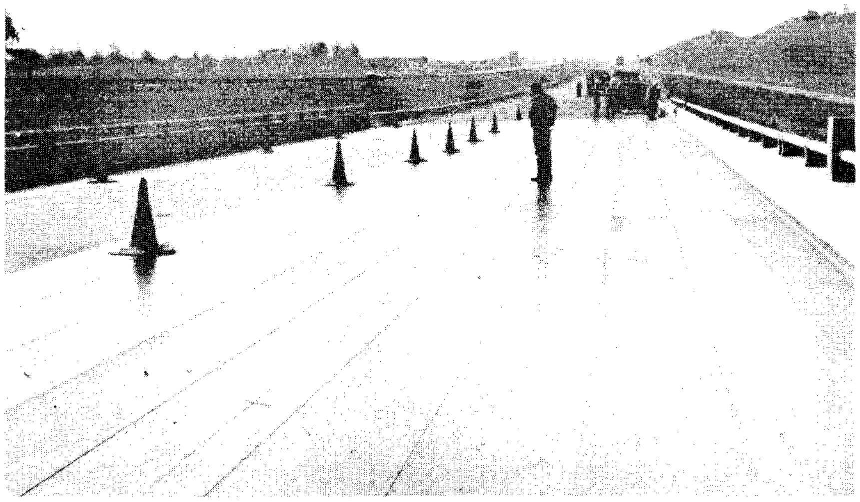

Figure 12. View of completed Protecto-Wrap membrane before paving.

Placement of the membrane began at the curb and at the low end of the bridge. The sheets were unrolled as shown in Figure 10 and lapped a minimum of 3 inches (7.62 cm) at the sides and ends of the preceding strips. A light truck was used to set the laps between rolls (Figure 11). Expansion joints were coated with mastic and the membrane was cut over the joint after placement. Finally the polyethylene separator sheet was removed (Figure 12) and the membrane was paved.

Evaluation

The Protecto Wrap membrane is easily applied. Because the membrane is not of an extremely adhesive nature, it can be adjusted once it has been placed. Some difficulty was noted in unrolling the 5-foot (1.5 m) wide rolls used on the Tazewell County bridge, but this may have been a temporary defect in the materials. Although more personnel were required, in that case, to unroll the material, the work proceeded with efficiency. The placement of the Protecto Wrap membrane is easily mastered.

Placement of the asphaltic concrete overlay requires care to avoid damage to the Protecto Wrap membrane, as with other systems. Some damage was noted during the paving operations on the Route 19 bridge. This difficulty could have been avoided had the paving operations proceeded more slowly, but the bridge overlay was only a small part of a large resurfacing contract on Route 19. It should be noted that only a tracked paver was available rather than a rubber tired machine recommended by the manufacturer.

Weather conditions did not allow the obtaining of initial readings on either bridge, and poor drainage of the deck of the Route 81 bridge prevented any meaningful resistivity evaluations. Resistivity measurements made on the Route 19 membrane about one year after placement showed a pattern similar to that described previously for the Bituthene membrane; the readings were low in the traffic areas and higher at the edges of the roadway.

Raveling of the asphaltic concrete overlay over the filled expansion joints (Figure 13) was noted in both installations. An attempt to attain better protection of the deck by leaving the membrane intact over the joint failed through raveling within two months, and this practice should be discontinued. Loss of the overlay was subsequently noted in areas where the membrane had been cut over the joint in accordance with the manufacturer's recommendations. The adhesion of the overlay to the membrane is not strong enough to prevent raveling, so treatment of the overlay at the joints should receive consideration.

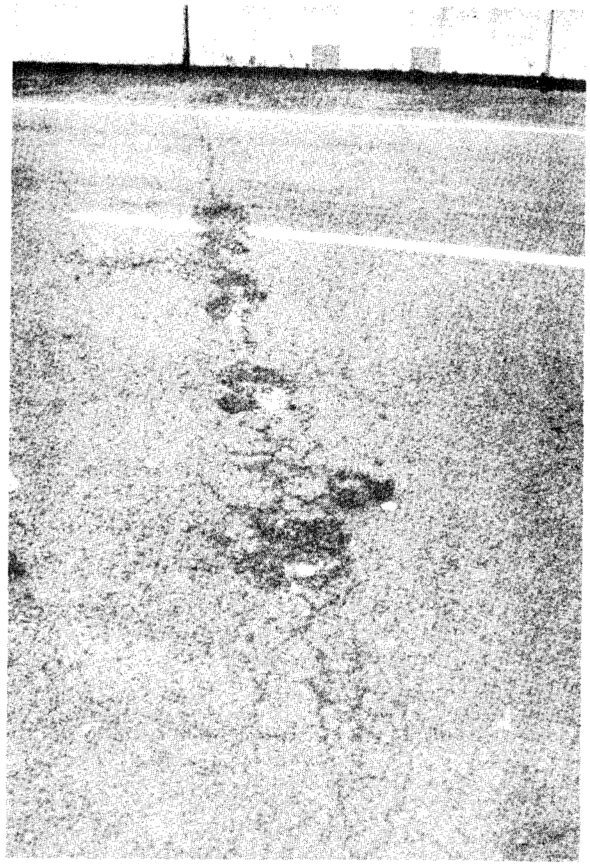

Figure 13. Raveling of asphaltic concrete overlay over deck expansion joints.

Cost

The cost of the installation on the Route 81 bridge was \$1.12 per square foot (0.09 m^2), including materials, equipment and labor.

Witmer Bridge Decking Membrane System (Witco Chemical)

Applications

(1) Route 250 over C & O Railroad, Albemarle County, Deck area 5,965 s.f. (554.2 m^2), June-July 1974.

Description

The Witmer Bridge Decking Membrane System is a two-component, bitumen extended, polyurethane elastomer, applied cold in liquid form in two coats to attain a minimum total thickness of 60 mils (1.5 mm).

Application Procedure

Both coats of the Witmer membrane were applied by squeegees.

The deck, which was surface dry and free of dust, dirt, grease or oil, was primed by squeegee with a mixture of 1 part of each of the two components and 1 part of solvent (Figure 14). After the prime coat had cured sufficiently to permit access, approximately three hours later, the second coat, composed of one part of each of the two components, with sufficient solvent for proper flow, was applied. The second application was allowed to cure for 24 hours before paving. No protective board or roofing sheet was applied to the membrane before paving, although the manufacturer's literature stated that "ideally" a layer of protection board was recommended.

Evaluation

Installation of the Witmer membrane is basically a simple process, although attention must be given to maintaining the proper rate of application. The only difficulty encountered in placing the liquid was the formation of a great many bubbles (Figure 15) in the first coat. These were probably due to the hot weather, temperatures over 90° F (32° C), and, possibly, the presence of air entrapped in the liquid during mixing. Unfortunately, it was impossible to compact the asphaltic concrete overlay because of poor bond between it and the membrane. As a result, the overlay failed quickly under traffic (Figure 16). Attempts to achieve bond through the use of a cutback asphalt tack coat and, later, the dusting of the tacky membrane with sand, were to no avail. Laboratory tests in which the specified overlay material and the membrane were placed on concrete cylinders and compacted in a Marshall mold disclosed no significant bond unless a piece of roofing sheet was placed on the tacky membrane. It appears that use of some sort of protective layer, placed while the membrane is still tacky, is mandatory to provide bond between the courses.

Figure 14. Application of Witmer liquid membrane with squeegees.

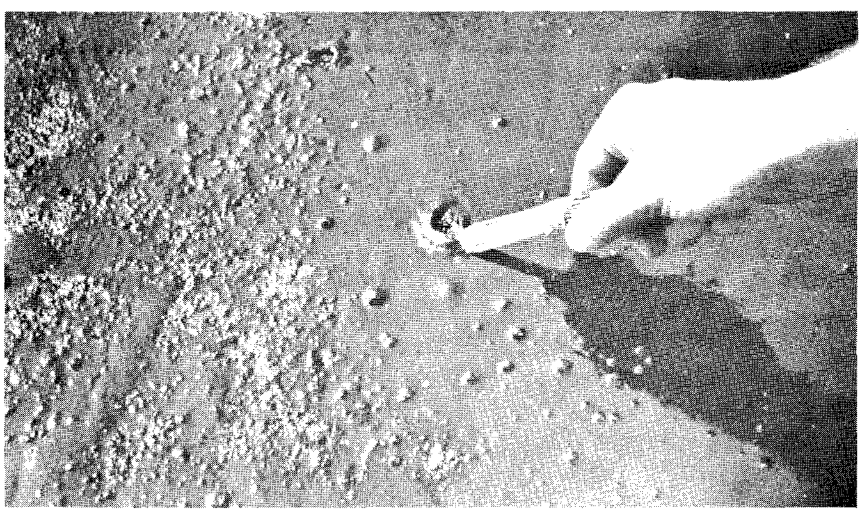

Figure 15. Bubbles in first coat of Witmer membrane.

Figure 16. Failure of asphaltic concrete overlay on Witmer membrane.

Resistivity tests taken on the membrane after the application of the second coat, but before paving, indicated that a waterproof barrier existed; all readings were above 500,000 ohms per square foot (0.09 m^2). Slight damage to the membrane in the truck wheelpaths was seen during paving, but subsequent resistivity readings were below 500,000 ohms per square foot (0.09 m^2) in many areas across the deck. Some of the loss in effectiveness may have been due to the effect of bubbles in the membrane.

Further use of the Witmer membrane without a proper protective layer on the membrane is not recommended. Such a layer, which might possibly be only a compatible roofing sheet, would, most importantly, provide sufficient bond to allow successful paving, but it might also improve the system as a waterproof barrier.

Because of the paving problems the Witmer membrane was removed and the two-coat coal tar modified epoxy system described in the next section was substituted for it.

Costs

The application of the Witco membrane installed by a contractor was initially bid at $1.78 per square foot (0.09 m^2). Additional work caused by the paving difficulties was negotiated on a work order basis.

Two-Coat Coal Tar Modified Epoxy Resin Membrane

Applications

(1) Route 250 over C & O Railroad, Albemarle County, Deck area 5,965 s.f. (554.2 m^2), July 1974. (Replaced previously described Witmer membrane.)

Description

Coal tar modified epoxy resin sealcoats have been widely used in Virginia for several years. As described previously, resistivity tests have indicated that these sealcoats, most of which were composed of a single application of epoxy with sand cast on the surface, were inadequate as waterproof barriers. It was desired to test a two-coat application in which sand is cast only on the second coat. The average rate of application, including both coats, was 0.5 gallon per square yard (0.7 ℓ/m^2), or 1.67 gallons per 30 square feet, (2.3 ℓ/m^2), as opposed to the rate of 1 gallon per 30 square feet (1.4 ℓ/m^2) specified for a single-coat application.

Application Procedure

Application of the epoxy membrane was routine. The surface of the deck was scarified to remove the preceding membrane, sandblasted, and blown clean, and the epoxy was applied with squeegees. Sufficient time, about three hours, was allowed for curing of the first coat before placement of the second. Sand was applied only to the surface of the second coat.

Evaluation

A large number of bubbles (Figure 17) were apparent in the first coating of epoxy, which was applied early in the day during hot weather, with temperatures approaching 90° F (32° C). The bubbles were covered by the second coat, and resistivity measurements taken before paving indicated that the double coating was completely waterproof. Resistivity readings taken after paving showed a drop in effectiveness; approximately half of the readings were below 200,000 ohms per square foot (0.09 m^2). The drop in resistivity readings was probably caused by bursting of the bubbles in the membrane under the heat of the overlay asphalt. The extent of the bubbles might have been lessened, and the performance of the overlay improved, had the first coat of epoxy been applied late in the day, during a falling temperature cycle.

Figure 17. Bubbles in first coat of coal tar epoxy sealcoat.

Costs

No reliable cost data were developed for the membrane on the C & O bridge, because the price was negotiated through a work order. However, a similar application by the same contractor on a 11,655 square foot (1,082.8 m^2) deck in Northern Virginia was bid at \$1.78 per square foot (0.09 m^2).

Polytok Membrane 165 (Carboline Company)

Applications

(1) Route 250 over Rivanna River, Albemarle County, Deck area 11,455 s.f. (1,064.2 m^2), September 1974.

Description

Polytok Membrane 165 is a two-component, modified polyurethane elastomer, applied cold in liquid form by spray or squeegee at a 40 mil (1.0 mm) film thickness, topped by 50 pound (23 kg) asphalt impregnated roofing sheet. Solvent can be added if required for easier application.

Application Procedure

Figures 18 and 19 show the application of the Polytok membrane. The liquid membrane was applied as a single coat by spray (Figure 18) and in two coatings by squeegee when the spray equipment malfunctioned. The membrane was allowed to dry to a tacky condition, usually in about one full hour, after which the roofing sheet was placed (Figure 19) and rolled with a garden roller to ensure firm contact with the membrane. Adjacent strips of the roofing sheet were butted together at their edges. The joints at the ends of the continuous spans of the bridge were raised to the level of the top of the overlay.

Evaluation

Although the application of the Polytok membrane is relatively simple, in itself, the waterproofing of the Rivanna River bridge extended over a period of weeks, primarily because of equipment malfunctions. The spray equipment required that the polyurethane and catalyst be mixed using an electric drill before pumping, so there was little time savings over a squeegee application. Air was entrapped in the liquid during mixing, and blisters were noted in the wet membrane. No detrimental effects of the blisters were apparent in the final system, however.

Considerable difficulties were encountered in the paving operation. Although it was not clearly expressed, the manufacturer preferred a tracked paver to the rubber tired paver that was available. During the initial paving operation it was noted that the asphalt roofing sheet was shearing at the edge of the main paver wheels (Figure 20), and at times, possibly when the asphalt delivery truck drivers braked their vehicles, the membrane was torn from the deck. The damaging of the membrane was finally averted by loading the hopper of the paver only half full of asphalt and having the delivery truck pull off.

Initial resistivity readings recorded after the previously described precautions were taken were well above 500,000 ohms per square foot (0.09 m^2) at all but one of 47 points, indicating that, with due care, satisfactory results can be attained. Long-term evaluations are, of course, not yet available.

Costs

Placement of the Polytok Membrane 165 on the deck of the Rivanna River Bridge by a contractor cost $1.78 per square foot (0.09 m^2). The price may be too high to be representative, as only one bid was received, and the contractor had had no previous experience with the material.

Figure 18. Spray application of Polytok liquid membrane.

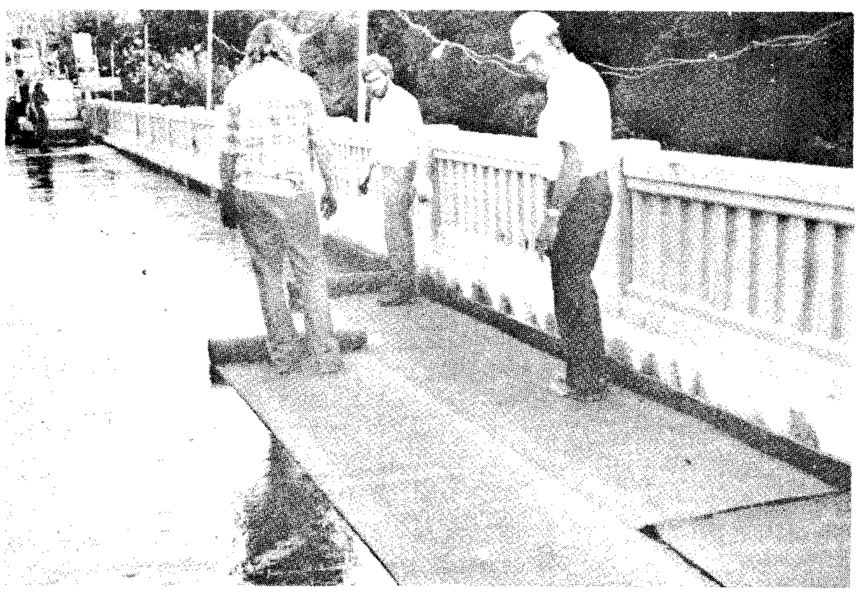

Figure 19. Placement of roofing sheet on Polytok membrane.

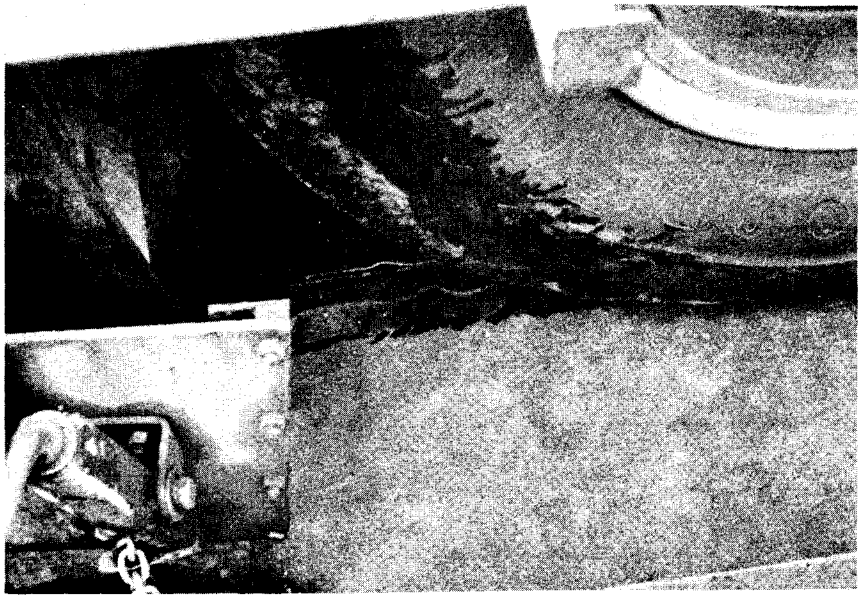

Figure 20. Shearing of roofing sheet under main paver wheels.

Chevron's Bridge Deck Membrane System (Chevron Asphalt Company)

Applications

(1) Route 58 over Route 95, Greensville County, Deck area 10,800 s.f. (1,003.4 m^2), September 1974.

Description

Chevron's Bridge Deck Membrane System is a two-component asphalt-urethane elastomer applied cold in liquid form. It is sprayed on the deck to an average thickness of 100 mils (2.5 mm); the minimum specified thickness is 80 mils (2.0 mm).

Application Procedure

Figures 21 and 22 show the application of the Chevron system to the Route 58 bridge. The deck, which was sound and cleaned of all loose debris, was heated to a temperature at least 30° F (17° C) above ambient using a propane fired infrared heater (Figure 21).

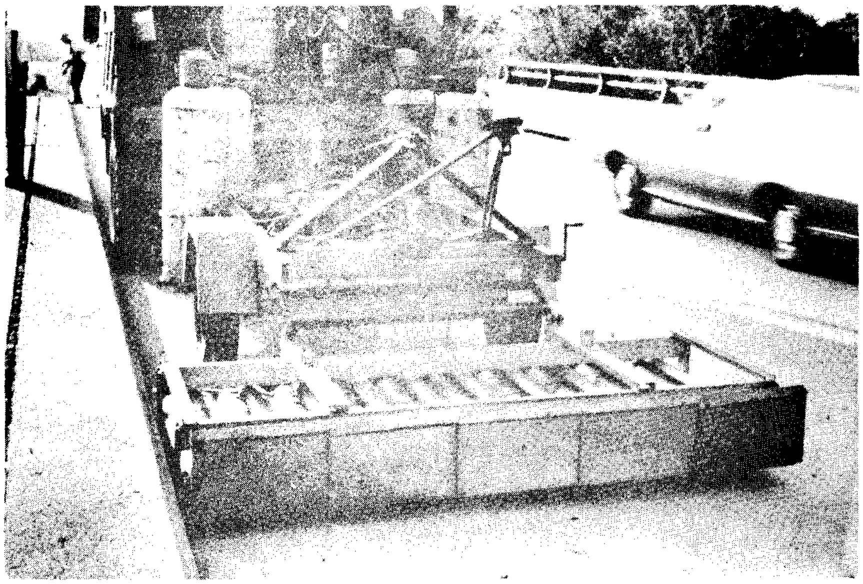

Figure 21. Infrared heater and truck mounted spray equipment used in applying Chevron's membrane system.

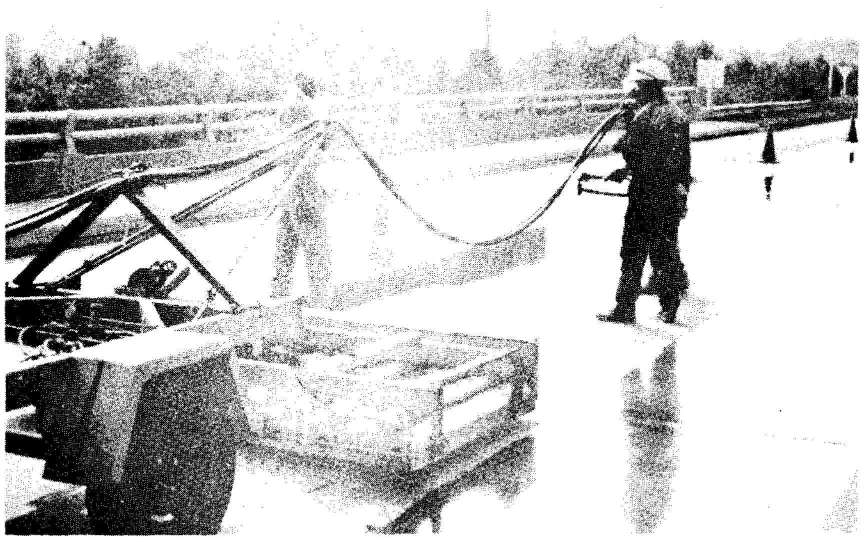

Figure 22. Spray application of Chevron's membrane system.

Truck mounted spray equipment developed by Chevron mixed the two components of the membrane which was applied to the deck within five minutes after heating. The rate of application of the spray equipment was coordinated with the rate of forward movement of the heater to ensure the proper rate of application of the liquid membrane. Boards placed at the side of the lane (Figure 22) were moved forward in stages with the heater to mark the area to be sprayed for the workmen and to keep them a fixed distance behind the heater. The spray operator continued to spray the given area until the heater moved forward, at which time the last board was moved. The membrane was allowed to cure overnight, primed with an uncut liquid asphalt, and paved.

Evaluation

Application of the Chevron system was somewhat more involved than those of the other liquid systems because of the heating and spraying requirements, but these operations were found to yield a blister-free membrane. The heating of the deck allows placement of the membrane under falling temperatures, which minimizes the effect of vapor pressure in the deck, and the mixing of the components in the lines avoids the entrapment of air. Blisters were noted only when small patches of sand, which held moisture, were accidentally left on the deck and when the liquid membrane was mixed in a pail and applied by squeegee. Based on the one experimental application, spreading of the premixed material by squeegee on a heated deck would not seem advisable.

Difficulties were encountered in maintaining operation of the spray equipment, which had been developed for laboratory use, but these should be remedied eventually. Unfortunately, failure of the bond of the asphaltic concrete overlay to the membrane occurred in portions of two of the four traffic lanes within five months after installation. It appears that proper bond has not been attained at the interface of the asphaltic concrete and the comparatively smooth surface of the cured urethane elastomer.

Initial resistivity readings, taken after the membrane and overlay had been open to traffic only one day, were excellent. The readings taken at points on an 8 x 8 foot (2.4 x 2.4 m) grid in one lane ranged from three million ohms per square foot (0.09 m^2) to infinity, the majority being infinity. The excellent performance of the Chevron system in this regard indicates that further study of the previously cited problem of bonding the asphaltic overlay to the membrane would be worthwhile.

Cracking of the overlays was noted over the expansion joints, but no raveling of the asphaltic concrete has been noted.

Costs

The cost of the Chevron membrane application by state forces, including materials, equipment and labor, was $1.25 per square foot (0.09 m^2).

DISCUSSION

The trials of six membrane systems have shown that with due care four of the systems, Bituthene, Protecto Wrap, Polytok and Chevron, can be installed and paved over with no initial loss of waterproofing effectiveness. None of the epoxy systems have shown similarly good results after paving, nor did the Witmer membrane. The drop in resistance readings after paving would appear to be due to the bursting of bubbles in these liquid systems when the hot asphalt overlay is applied. Field observations showed a strong tendency to the formation of bubbles in liquid systems in which the components were stirred together, possibly due to the entrapment of air. The formation of bubbles was nearly eliminated in the case of the Chevron system, but poor adhesion of the asphaltic concrete overlay has emerged as a problem. The good initial performance of the Bituthene and Protecto Wrap systems and the poor performance of the epoxy seal-coats is in line with the experience of other states.[5,6] Long-term evaluations are available only on the two sheet membrane systems.

Unfortunately, the two sheet membrane systems, Bituthene and Protecto Wrap, appear to require an additional protective layer over the membrane to provide long-term stability and, possibly, to prevent penetration by aggregate in the overlay. The cause of the drop in resistivity values over a period of one year or less from those taken just after paving is difficult to ascertain, but it would seem to be related to the effect of traffic. A pattern of high readings at the low shoulder areas and low readings in the wheel paths would not be expected if the asphaltic concrete overlay were moist. Attempts to remove the overlay from atop the membrane were inconclusive, but it appeared that some of the components of the membrane may have migrated into the overlay. At this writing the addition of a protective layer between the membrane and the overlay seems advisable. Such added protection would also aid in preventing damage to the membrane during paving.

A small variety of protective layer materials have been used by states other than Virginia. Among these are the use of a 1/2 inch (13 mm) layer of sand asphalt, asphalt board, and 65 pound (30.4 kg) roofing sheet.[5,7,8] An additional protective layer, P-100 Protection Sheet, is also being marketed by the Protecto Wrap Company. Of these, the 65 pound (30.4 kg) roofing sheet, presently required on a limited basis in Virginia, may be the simplest alternative.(9) Its use on future sheet membrane applications is recommended.

The four initially effective membrane systems were relatively easily applied, and all required less effort in surface preparation than do the more rigid epoxy systems. This fact, coupled with the good initial resistivity evaluations, indicates the need for continued trials of membrane systems to find one that offers long-term effectiveness.

Other methods of deck protection are available, including epoxy coated or galvanized reinforcing steel, construction of the deck in two courses to ensure a proper cover of high quality concrete over the steel, and the provision of cathodic protection for the steel. Trials of these techniques, which are suitable for use at the time of construction, would provide an alternative to the use of membranes. Virginia's policy of using membranes in maintenance operations should be viewed realistically. The permanence of a completely effective membrane is assured only if the concrete does not contain sufficient salt to support corrosion. Application of a membrane to a deck in which spalling has occurred and been patched is probably, in fact, only "buying time".

The critical phase of the membrane application has proven to be the placement of the asphaltic concrete overlay. Proper care in and control of the paving operation is essential to prevent damage to the membrane and assure satisfactory performance of the overlay itself. Coordination with a paving contractor is often difficult because only a small quantity of material is required, sometimes at an isolated location.

All of the new membrane systems can be damaged by abuse during paving. As much as possible, the manufacturer's recommendations should be followed as to procedures and the type of paving machine, wheel or track, to be used. Unfortunately a selection of the type of paver is not always possible in rural areas, and, in such a case, great care is required in the use of available equipment. Damage to the membrane can be averted by requiring that the hopper of the paver be loaded only approximately half-full and having the dump truck pull away. While this is a departure from normal paving operations, it is not considered a difficult requirement because of the relatively small material quantities involved.

Control of the paving operation must not be abandoned. The asphaltic concrete should meet the requirements of Table 1, and the manufacturer's recommended application temperatures, most of which are more limited than those shown in the table. Proper compaction of a bridge overlay may also require a delay between the passes of the roller. The thickness of the overlay should be at least 1½ inches (38 mm) before the roadway is open to traffic.

A final consideration in the design of a membrane system is the treatment of the expansion joints in the deck. While epoxy sealcoats can be paved over at the joints with cracking but no loss of the overlay, this is not the case with some of the newer systems. The best solution would be to raise the joints to the level of the top of the overlay, but this is expensive and time-consuming. A simpler, but untried, solution might be to saw the overlay over the joint to provide crack control.

FUTURE WORK

The initial field tests covered in this report left several important questions unanswered. While much of the needed information should become available through the work of other agencies, continued trials of new and modified membrane systems should be continued by the Virginia Department of Highways and Transportation, and long-term data should be obtained on the more recent applications covered in this report. Research personnel will assist in these evaluations and report the findings.

CONCLUSIONS

The following conclusions are based on the field evaluations described previously. Qualifications, if any, are also noted.

1. Epoxy sealcoats, designated as Class I waterproofing in the Virginia Specifications,[10] do not appear to be effective on the basis of electrical resistivity tests.

2. Four relatively new membrane systems, Bituthene, Protecto Wrap, Polytok 165, and Chevron's system, provide good initial protection, if due care is used in installation. Long-term evaluations have not been made of the latter two of these products. The further qualifications shown in conclusions 3 and 4, below, should also be noted.

3. The two prefabricated sheet membrane systems, Bituthene and Protecto Wrap, appear to require an additional compatible protective layer over the membrane for long-term stability, based on interpretation of electrical resistivity results. Such a protective layer would also provide a desirable degree of protection during paving operations.

4. Modification of the application procedure used in conjunction with Chevron's membrane system will apparently be required to improve the adhesion between the asphaltic concrete overlay and the membrane. The excellent initial effectiveness shown by Chevron's system warrants further study of the adhesion problem.

5. Further use of the Witmer membrane system without a protective layer is not advisable, because of difficulties resulting from poor bond between the membrane and the asphaltic concrete overlay. The elimination of the adverse effect of bubbles in the liquid membrane on its initial effectiveness must also be considered.

6. Placement of the 1½ inch (38 mm) asphaltic concrete overlay, a required part of the waterproofing systems evaluated, is the critical operation in the application procedure. Care in and control of the paving operation is essential to the satisfactory overall performance of the system.

7. Treatment of the expansion joints in bridge decks must receive consideration if the membrane systems considered in this study are used, in order to prevent possible loss of the asphalt overlay through raveling. Raising the joints to the level of the top of the membrane is an ideal solution; sawing a groove over the length of the joint may suffice for structures in less than critical locations.

8. Premixing of two-component liquid systems through the use of a paddle appears to entrap air which forms bubbles in the membrane to the detriment of its effectiveness. The use of a pump system in which the components are mixed in the lines is preferable.

RECOMMENDATIONS

The field evaluations conducted by the Virginia Department of Highways and Transportation have not fully resolved the problem of effectively protecting bridge decks through the use of waterproofing membranes. Questions such as the long-term effectiveness of those systems evaluated and the measures required to obtain high quality remain unanswered. However, some information has been developed, and the following recommendations are offered as a result of the work to date.

1. The Virginia Department of Highways and Transportation should begin using the newer membrane systems in lieu of the currently specified epoxy sealcoats. Electrical resistivity data taken in this study indicate that the epoxy sealcoats do not provide a waterproof barrier.

2. While it is acknowledged that the long-term effectiveness of the systems evaluated must be determined, the four systems listed below now appear to warrant further use, based on their good initial performance.

   (1) Heavy Duty Bituthene — Future applications should include a protective layer acceptable to the Department and the manufacturer for protection during paving and for long-term stability.

   (2) Protecto Wrap — The use of a protective layer, cited previously, should be included, for the same reasons.

   (3) Polytok 165 — The long-term effectiveness of this system has not yet been evaluated.

   (4) Chevron's System — The further use of this system must include modifications to improve the bond between the membrane and the asphaltic concrete overlay.

3. Further trials of new systems and long-term evaluations of those systems shown above should be performed.

4. Any bridge deck membrane application should be viewed as a whole system, no part of which can be neglected. Due care must be provided in the application of the membrane, in the control of the placement of the asphaltic concrete overlay, which must be of sufficient thickness, and in the treatment of the expansion joints to ensure an effective installation.

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