NATIONAL EXPERIMENTAL & EVALUATION PROGRAM

BRIDGE DECK PROTECTIVE SYSTEMS

WORK PLANS #4-#11 INITIAL REPORT

REPORT 73-1

January 1973

Barton EMP I 91-3 (19)

Barton-Derby EMP I 91-3 (20)

VERMONT DEPARTMENT OF HIGHWAYS

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INTRODUCTION

With few exceptions, between the years of 1960 and 1971, the Vermont Department of Highways used a two coat application of tar emulsion to seal newly constructed concrete bridge decks. Maintenance problems over the past few years have proven with little doubt that the tar emulsion system was not satisfactory. For this reason in 1971, the Department began active participation in the National Experimental & Evaluation Program - Bridge Deck Protective Systems. The purpose of the Federal Highway Administration sponsored program is to apply and evaluate products which are designed to protect concrete bridge decks from the deterioration caused by the intrusion of deicing chemicals and moisture. Reports summarizing the information gathered by the participating Highway Departments will be issued by the Federal Highway Administration.

The information in this report covers the application of eight different membrane products on twelve Interstate 91 bridges in the Barton-Derby area. Included also in the summary is a brief discussion of the membrane treatments applied on seven other bridge decks in 1971 and early 1972.

Surveillance of the bridge decks will continue at least twice yearly until valid conclusions can be obtained on the effectiveness of the protective treatments.

WORK PLAN #4 - INITIAL REPORT

BON-LASTIC MEMBRANE

PROJECT

Barton EMP I 91-3 (19)

PROJECT LOCATION

In the County of Orleans, Vermont, beginning at the point of intersection with Vt Rte 16 southerly of Barton Village and extending northerly approximately 5.417 miles.

WORK LOCATION

I 91 southbound bridge over State Aid Highway #2 at station 2171+53 - 2172+53, 5.2 miles south of the US Rte 5 Interchange at Orleans.

CONTROL SECTION

I 91 northbound bridge over State Aid Highway #2. See data on pages 11 to 15.

BRIDGE CONSTRUCTION DATA

Type of Structure - Simple span

Span Length - 100'

Overall Length - 102'

Curb to Curb Width - 39.33'

Skew - 7^{o}

Horizontal Curvature - 2^{o} 45'

Grade - + 2.84%

Superelevation - 13/16"/ft

DECK CONSTRUCTION DATA

Date Poured - August 16, 1971

Weather Conditions - Clear 25% Humidity No breeze

Temperature - $75^{o}F$

Deck Thickness - 8"

Concrete Cover Over Reinforcing Steel - 2" - 2 1/8" 2 1/16" average

Concrete - Class AA

DECK CONSTRUCTION DATA - cont'd

Cement - Type I 6½ bags per c.y.

Aggregate Size - 3/4" maximum

Air Entraining Admixture - Darex 7 oz per c.y.

Retarding Admixture - None

Pour Sequence - South to north

Finishing Method - Capitol finishing machine on outside beams

Surface Texture - Broomed finish

Curing - Plastic cover with sprinkler hose on high side of deck

Concrete Test Results:

Percent Air - Low 6¼% High 7¼% 6.6% average on 18 tests

Slump - Low 2 3/4" High 3½" 3.2" average on 18 tests

Modulus of Rupture - Average 768 psi at 28 days

DECK CONDITION

Surface Texture - Moderate broom finish

Cracks - None detected

Miscellaneous - Asphalt droppings were scattered over the deck from trucks hauling the bituminous base course for the roadway.

Steel Corrosion Readings - Initial readings taken on the deck averaged 0.10 volts, indicating no active corrosion.

PROTECTIVE TREATMENT

Product - Bon-Lastic Membrane
A two part coal tar pitch polyurethane elastomer manufactured by
The Robson Corporation
Box 67
Oxford, Maryland 21654

Test Results - None

RECOMMENDED APPLICATION PROCEDURE

Remove all contaminants from the concrete surface. Sandblast or acid etch to remove laitance as required. Sweep the surface clean and allow to dry. Apply the specified one part E. P. Urethane Primer by roller or spray at the rate of 250 square feet per gallon. Allow primer about three hours to dry. Combine one part

RECOMMENDED APPLICATION PROCEDURE - cont'd

by volume Bon-Lastic part A with one part by volume part B and mix thoroughly. Apply the polyurethane by squeegee or spray at the rate of 45 square feet per gallon for a film thickness of 36 mils. Check coverage frequently to insure that thickness is uniform. While the polyurethane is still tacky, roll a 30 pound roofing felt over it, butting edges. Use a roller to insure contact with the liquid polyurethane. Place bituminous wearing course as required.

DECK PREPARATION PRIOR TO MEMBRANE APPLICATION

Hammers, chisels and a grass edging tool were used to remove most of the larger asphalt droppings which were scattered across the deck during the application of the bituminous base course on the adjacent roadway. The deck was then washed clean. A blower unit was used to remove dust on the day the membrane application began.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humidity	
	7/24/72		Temperature recorded in shade. 100% cloud cover.
10:45	73°	64	Began applying the E. P. Urethane primer with longhandled paint rollers.
11:45	72°	63	Prime coat complete except for 6" width along the lower curb where moisture was present. 17.5 gallons of primer was used on 4200 s.f. of concrete for an application rate of 240 sf/gal.
2:30	76°	62	Began applying Bon-Lastic Membrane with squeegees along westerly curb. 390 s.f. covered with 8.5 gal for an application rate of 46 sf/gal (35 mils).
2:45	76°	63	Work area hit by a light rain shower. A 10 gal batch of polyurethane mixed minutes earlier was wasted since it could not be placed on the wet deck. Most of the rain which fell on the liquid polyurethane remained on the surface of the material and was worked off the surface with paint rollers.
4:30	76°	53	Light sprinkle rewet work area.
	7/31/72		25 to 75% cloud cover.
10:00	72°	35	One set of copper foil strips was placed adjacent to the easterly curb.
10:55	78°	33	Began applying second coat along westerly curb.
11:30	80°	34	Mixing third 10 gal batch. Beads or ridges of the polyurethane left by the squeegee are being smoothed out with a paint roller to obtain a uniform thickness.
12:10	80°	37	40 gallons applied on 1836 s.f. for application rate of 46 sf/gal (35 mils). Bubbles and pinholes can be seen in the membrane coating.
1:35	82°	28	70 gallons applied on 3130 s.f. for application rate of 44.7 sf/gal (36 mils).
2:30	84°	26	Coverage complete except for second coat along easterly curb. A total of 100 gallons was applied on 4244 s.f. for an overall coverage of 42.4 sf/gal which amounted to a film thickness of 39 mils.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION - cont'd

Time	Temp	% Humidity	
	8/1/72		50 to 60% cloud cover.
2:30	83°	44	Began mixing 10 gal batch. Approximately 5 lineal feet by 1 inch in width of foamed polyurethane was cut away from the curb on the low side of the deck. Material had foamed due to excessive thickness.
2:55	84°	34	10 gallons applied for a second coat along the easterly curb at the rate of 43 sf/gal.

TABLE 1

Bubbles and Pinholes - Bon-Lastic Membrane

All locations checked were one square foot in area opposite guard rail post number 10 on the westerly side of the deck. Posts were numbered south from the northerly end.

Curb Offset	Application Rate (sf/gal)	Pinholes	Bubbles
2'	46 & 54 (2 coats)	74	21
4'	46 & 54 (2 coats)	102	14
6'	46	64	0
8'	46	41	6
10'	38	94	19
12'	38	60	15
14'	40	44	16
16'	40	16	6
18'	41	26	5
20'	41	31	6
22'	40	12	0
32'	43	48	17
36'	38 & 43 (2 coats)	60	8
38'	36 & 43 (2 coats)	3	0

The 14 areas checked had an average of 49 pinholes and 10 bubbles per square foot. However, electrical resistance readings and testing with hydrocloric acid did not indicate that any of the bubbles or pinholes were open to the concrete surface.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 472 sy @ $4.50/sy = $2,124.00

Bituminous Concrete - Two 1 inch thick courses
78 tons @ $7.00/ton = $ 546.00

Type IV bituminous mix (95-100% passing the 3/8" sieve) used on all bridge decks.

DISCUSSION

Representatives of the Robson Corporation were on the project to supervise the application of Bon-Lastic Membrane. A discussion ensued on the merits of using roofing sheet as part of the membrane system. The manufacturer explained that the roofing sheet was designed to provide three services. First, it helps to establish a uniform thickness. Second, it offers the Bon-Lastic Membrane some protection against cuts or tears caused by construction traffic or the paving equipment. Third, it helps to establish a bond between the polyurethane membrane and the bituminous concrete. Without such bond, there would be a possibility that the pavement might "creep" over a period of time. After reviewing the difficulties encountered in paving over Polytok Membrane 165, a polyurethane system which included roofing sheet (page 43), the manufacturer agreed to try the Bon-Lastic Membrane without the roofing sheet. To adjust for this change in the system, the manufacturer requested that the application rate be changed from the original specified coverage of 45 square feet per gallon (36 mils) to a coverage of 42 to 33 square feet per gallon (40 to 50 mils). They also requested that the membrane be allowed to cure for one week prior to the pavement application rather than the normal procedure of allowing the pavement to be placed the same day the system is completed.

A clear 78% solvent, E. P. Urethane primer was applied on the concrete first with paint rollers at the rate of 240 square feet per gallon. The purpose of the primer was to seal pores and indentations in the surface of the concrete and thereby reduce the number of pinholes or bubbles which might otherwise occur. The primer appeared to penetrate into the concrete leaving a varnished look on the surface. Most areas were dry to the touch within one hour.

Five gallon units of Bon-Lastic parts A and B were thoroughly mixed and applied by

squeegee along the westerly curb. Ridges and areas with an excess of material were levelled by rolling the polyurethane with a long handled paint roller as recommended by the manufacturer. Close control over the membrane thickness was necessary because excessive thickness of the polyurethane causes the material to foam or expand. This results in a network of air cells forming in the membrane.

Before application could begin on the second ten gallon batch, a light rain began falling on the work area. Because the material is very sensitive to moisture, it could not be placed on the wet concrete and consequently was wasted. Water which remained on the area already treated was worked off the liquid membrane by rolling the treated areas with long handled paint rollers. The company representatives were somewhat surprised that the rain did not have a more detrimental effect on the membrane. Water would normally cause the polyurethane to foam or expand, much the same as would excessive thickness.

Inspection of the treated area after it had cured disclosed some surface bubbles and pinholes, none of which appeared to be open to the concrete.

Unsatisfactory weather conditions prevented the completion of the system for one week. Application at that time was made over 472 square yards. This included the complete deck and three feet onto each approach slab, the procedure used on all of the experimental deck membranes. The only difficulty encountered was in obtaining a uniform thickness over the entire area. Paint rollers were again used to level the material and help eliminate thick areas. Application rates were checked for each ten gallon batch of material. They ranged between 36 square feet per gallon (47 mils) and 54 square feet per gallon (25 mils) with the light application occurring on the second coat along the westerly curb. The average coverage for the entire coat was 42.4 square feet per gallon which amounted to a dry film thickness of 39 mils.

The second coat was placed along the easterly curb a day later, as recommended by the manufacturer. Prior to the application it was noted that the polyurethane had foamed at several locations adjacent to the curb where an excess of material had collected. This was due in part to material which had been squeegeed on the granite curb flowing back down on the deck again. Approximately five lineal feet of membrane averaging one

inch in width was cut from the concrete. The strips ranged from 65 to 330 mils in thickness and contained air cells up to 1/8" in diameter. Visual inspection of the cellular structure of the sample did not disclose whether the air cells were inter connected. However, when samples were later immersed in water, they disclosed absorption rates of from 4.3 to 102 percent. A 28 to 33 mil thick sample cut from the deck also revealed a very fine cellular structure under close observation.

Spot checks of the membrane system revealed an average of 49 pinholes and 10 bubbles per square foot (see table I , page 5). Areas treated before noon had an average of 81 pinholes and bubbles per square foot while areas treated after 12:00 P.M. had an average of 35 pinholes and bubbles. A greater increase in air temperature just prior to and during the morning application with the resulting escape of air and or water vapor from the concrete was believed to be the cause of the difference in the number of pinholes and bubbles. Most of the pinholes were 1/16 inch in diameter or less. Concrete appeared to be visible at the bottom of a few of the pinholes but spot checking with hydrocloric acid did not disclose any effervescence of the concrete. When some of the larger bubbles were broken open, the primed concrete could be seen, but once again checking with acid did not reveal any unprotected concrete. Electrical resistance readings taken on the membrane averaged 480,000 ohms per square foot. This also indicates that the concrete was protected even in areas with numerous pinholes and bubbles.

The overall appearance of the membrane upon completion was quite good. The polyurethane displayed a firmness which gave the impression that it could withstand the compressive load of the pavement and traffic while it also appeared to have sufficient flexibility to bridge any cracks in the concrete. The material also exhibited good bond to the epoxy mortar and granite curb, making what appeared to be a very effective seal at this critical point.

The first one inch course of bituminous pavement was placed with a rubber tire paver ten days after the membrane system had been completed. At first, one edge of the paver screed cut into the membrane. This was quickly remedied by adjusting the screed and no further damage occurred to the membrane. Removal of the pavement for spot checks did not disclose any harmful effects caused by the 260^{o}F bituminous mix.

Periodic inspections of the pavement were made prior to the application of the one inch top course. No cracks or other detrimental conditions were detected although soundings taken with a steel rod indicated that little bond existed between the membrane and the pavement.

Electrical resistance readings taken on the completed pavement and membrane averaged 650,000 ohms per square foot. Although such readings are satisfactory, they may indicate that the membrane was damaged during the pavement application since earlier readings on the membrane alone had averaged 480,000 ohms per square foot.

A gradual decrease in electrical resistance readings have been noted on copper foil strips placed beneath the membrane. Such a decrease indicates the passage of moisture through the pavement and membrane at the test location.

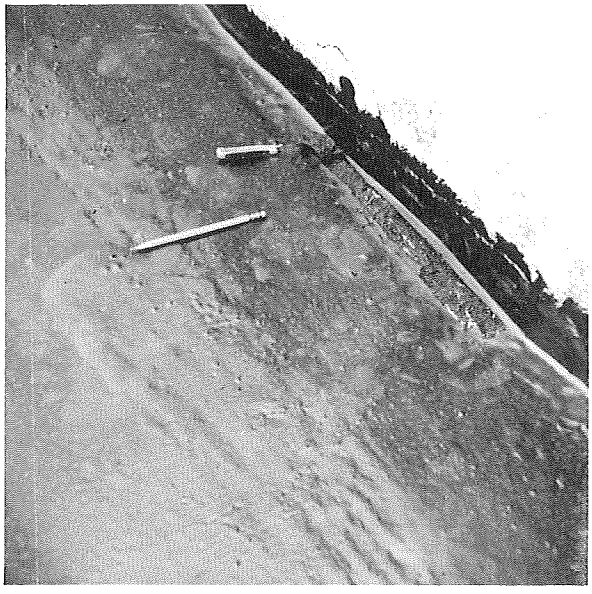
BON-LASTIC MEMBRANE

I 91 SB over State Aid No. 2

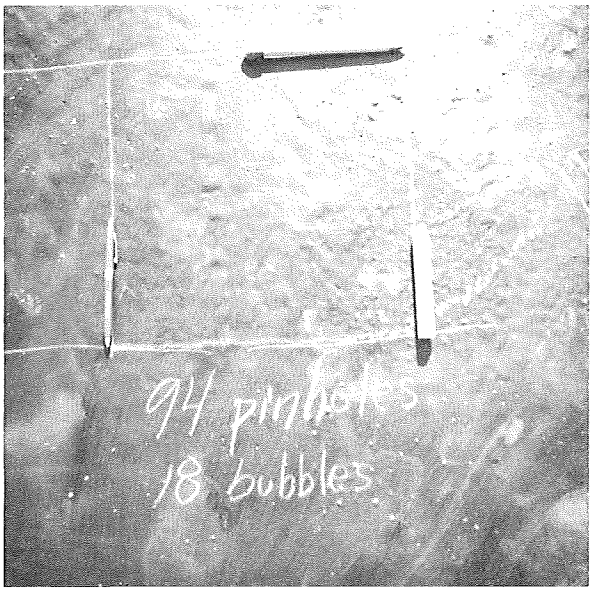
July 1972

Applying the polyurethane with a squeegee. Note asphalt droppings and prime coat on concrete.

Leveling the polyurethane with a paint roller.



Excesses of material, particularly along the curb, caused foaming which resulted in air cells in the membrane.



Inspection of cured membrane revealed an average of 49 pinholes and 10 bubbles per square foot, none of which were completely open to the concrete.

WORK PLAN #4 - CONTROL SECTION

TAR EMULSION AND GLASS FABRIC

PROJECT

Barton EMP I 91-3 (19)

CONTROL SECTION

I 91 northbound bridge over State Aid #2 at station 2171+43 - 2172+47, 0.4 miles north of the Vt Rte 16 interchange at Barton.

BRIDGE CONSTRUCTION DATA

Type of Structure - Simple span

Span Length - 100'

Overall Length - 102'

Curb to Curb Width - 39.33'

Skew - 7^{o}

Horizontal Curvature - 2^{o} - 45' Rt.

Grade - + 2.8303%

Superelevation - 13/16"/ft

DECK CONSTRUCTION DATA

Date Poured - August 27, 1971

Weather Conditions - Cloudy 35% humidity light rain during P.M.

Temperature - $70^{o}F$

Deck Thickness - 8"

Concrete Cover Over Reinforcing Steel - 2"

Concrete - Class AA

Cement - Type I 6½ bags per c.y.

Aggregate Size - 3/4" maximum

Air Entraining Admixture - Darex 7 to 8 oz per c.y.

Retarding Admixture - None

Pour Sequence - South to north

Finishing Method - Capitol finishing machine on outside beams, skewed 7^{o}

DECK CONSTRUCTION DATA - cont'd

Surface Texture - Broomed finish

Curing - Plastic cover plus sprinkler hose on high side of deck

Concrete Test Results:

Percent air - Low 5½% High 7% 6.4% average on 16 tests

Slump - Low 2 3/4" High 4" 3.3" average on 17 tests

Modulus of Rupture - 781 psi average @ 28 days

DECK CONDITION

Surface Texture - Light broom finish

Cracks - None detected

Steel Corrosion Readings - Initial readings taken on the deck averaged 0.07 volts, indicating no active corrosion.

PROTECTIVE TREATMENT

Product - Tar emulsion and woven glass fabric.
The brand of tar emulsion used was PR55-CTP manufactured by the Triram Corporation, 721 Waverly Street, Framingham, Massachusetts.
The glass fabric was manufactured by Burlington Glass Fabrics Co.

Test Results - Water content of the Tar Emulsion averaged 52% by weight.

APPLICATION PROCEDURE

(1) Prime coat of tar emulsion applied on moist concrete and allowed to dry.

(2) Coat of tar emulsion followed with the placement of a layer of glass fabric.

(3) Coat of tar emulsion with a layer of glass fabric placed perpendicular to the first layer of fabric.

(4) Coat of tar emulsion which is allowed to dry.

(5) Finish coat of tar emulsion.
The total coverage for the five coats of tar emulsion should be approximately ½ gallon per square yard.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	Cloud Cover	
	7/13/72		Air temperatures recorded in shade.
2:30	86°	20%	Finished cleaning deck with air blower and water. Began prime coat application.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION - cont'd

Time	Temp	Cloud Cover	
	7/13/72 cont'd		
3:30	85°	70%	50 gallons of tar emulsion applied with Huber applicator. Squeegees used along curbs and over copper foil strips.
	7/14/72		
11:00	80°	100%	Began applying second coat of tar emulsion and glass fabric along the curbs.
12:45	78°	100%	Began placing transverse strips of glass fabric.
2:00	78°	100%	Began placing longitudinal strips of glass fabrics.
4:30	80°	100%	Second layer of glass fabric complete.
5:00	79°		Began applying final coat with applicator. Total of 208 gallons was applied on 472 s.y. of concrete for an application rate of 0.44 gallons per s.y.
	7/17/72		
3:30	84°	20%	A sixth coat consisting of 40 gallons of tar emulsion was applied by squeegee. This was done voluntarily by the sub-contractor because some of the glass fabric was visible
4:15	82°	20%	through the fifth coat of tar emulsion.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 472 sy @ $4.00/s.y. = $1,888.00

Bituminous Concrete - Two - 1 inch thick courses
78 tons @ $7.00/ton = $ 546.00

DISCUSSION

Inspection of the membrane system upon completion revealed a number of areas where the glass fabric did not appear to be adequately covered with tar emulsion. For this reason, a sixth coat of tar emulsion was applied. This resulted in an overall application rate of 0.52 gallons per square yard.

Inspection of the system on July 18, just prior to paving, disclosed that a number of areas along the curb were not adequately sealed. The membrane also appeared to be somewhat softer than normal although it was not tacky to the touch.

Electrical resistance readings taken on the membrane ranged between 1,000 and 7,000 ohms with an average of 3,750 ohms per square foot. One set of moisture sensing copper foil strips also was placed beneath the membrane to monitor any future penetration of moisture through pavement and membrane system.

The first one inch course of bituminous pavement was placed with a rubber tired paver approximately 26 hours after the sixth coat of tar emulsion had been applied. Tar emulsion was pulled from the glass fabric at three locations when trucks braked quickly on the membrane system.

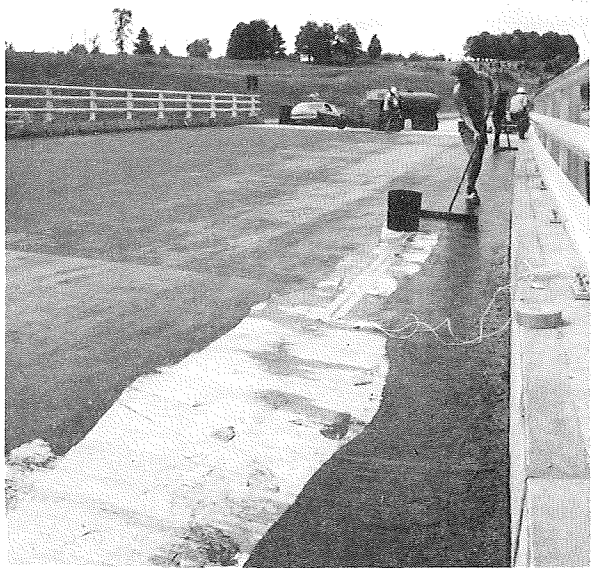
An 18 inch square concrete test slab with 2 inch shoulders was treated with five coats of tar emulsion and two layers of glass fabric at the same time the bridge was treated. The sample was left on the bridge curb to cure on Friday, July 14, 1972. When the sample was checked the following Monday, blisters were observed on the surface of the membrane. The blisters were believed to have been caused by rain water which had ponded on the test slab over the weekend. Similar blisters were not observed on the free draining bridge deck membrane prior to placement of the bituminous concrete wearing surface.

Although the electrical resistance readings taken on the tar emulsion and glass fabric system were very low, final resistance readings taken on the completed pavement and membrane were over three million ohms. This indicates that the bituminous pavement is highly impermeable and can initially be expected to protect the concrete from moisture and deicing chemicals.

TAR EMULSION & GLASS FABRIC

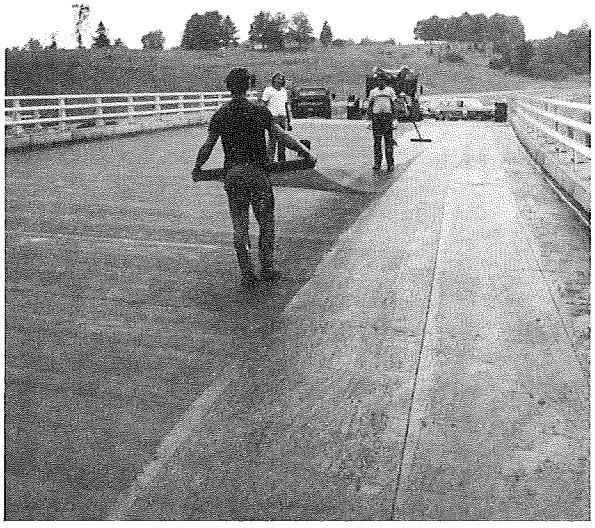
I 91 NB over State Aid No. 2

July 1972



Applying prime coat along curb areas. Note plastic-cloth covered copper foil strips.

Placing glass fabric in second coat and covering with third coat of tar emulsion.



Placing longitudinal strips of glass fabric.

Curb area not properly sealed.

WORK PLAN #5 - INITIAL REPORT

DURALKOTE 304 EPOXY

PROJECT

Barton EMP I 91-3 (19)

PROJECT LOCATION

In the County of Orleans, Vermont, beginning at the point of intersection with Vt Rte 16 southerly of Barton Village and extending northerly approximately 5.417 miles.

WORK LOCATION

I 91 Southbound bridge over Town Highway #40 at station 2211+61 - 2213+97, 4.5 miles south of the US Rte 5 Interchange at Orleans.

CONTROL SECTION

I 91 Northbound bridge over Town Highway #40, see data on pages 24 to 27.

BRIDGE CONSTRUCTION DATA

Type of Structure - 3 span continuous WF

Span Lengths - 65' - 100' - 60'

Overall Length - 233.64'

Curb to Curb Width - 39.33'

Skew - 30^{o}

Horizontal Curvature - 1^{o} 30' Lt.

Grade - + 2.7586%

Superelevation - ½"/ft

DECK CONSTRUCTION DATA

Date Poured - August 25, 1971

Weather Conditions - Fair

Temperature - 68^{o}F

Deck Thickness - 8"

Concrete Cover over Reinforcing Steel - 2" - 2¼" 2 5/32" average

Concrete - Class AA

DECK CONSTRUCTION DATA - cont'd

Cement - Type I 6½ bags per c.y.

Aggregate Size - 3/4" maximum

Air Entraining Admixture - Darex 7 oz/cy

Retarding Admixture - Plastimate

Pour Sequence - From both ends to the middle

Finishing Method - Capital finishing machine on beams, skewed 40°

Surface Texture - Broomed finish

Curing - Plastic cover - sprinkler hose along high side plus cross lines

Concrete Test Results:

Percent Air - Low 6% High 7½% 6.8% average on 26 tests

Slump - Low 2.5" High 4" 3.2" average on 28 tests

Modulus of Rupture - 605 psi average at 15 days

DECK CONDITION

Surface Texture - Light brooming visible on about 20% of the deck. Approach slabs have a moderate to heavy broomed surface.

Cracks - Twenty-three transverse cracks ranging from 2.6' to 14.5' in length were noted in the deck. All cracks observed on the surface could also be detected on the bottom of the deck. The severity of the transverse cracks decreased noticeably as they approached the curb section. See crack layout on Figure I, Page 20.

Spalling - Numerous small cracks or popouts were noted on the surface of the concrete. Removal of the cracked concrete revealed soft pieces of aggregate which could easily be dug out with a jacknife.

Miscellaneous - Many small bits of wood were observed in the concrete surface on the southerly end of the deck. Most appeared to be roots of ¼" diameter or less which could be found at the rate of nearly one piece per square foot.

Steel Corrosion Readings - Initial readings taken on the deck averaged 0.15 volts, indicating no active corrosion.

PROTECTIVE TREATMENT

Product - Duralkote 304 - Epoxy Coating
A solvent cut, two component, epoxy coating manufactured by Dural International Corporation, 95 Brook Avenue, Deer Park, New York 11729.

Test Results - The material was certified to meet the Vermont Department of

PROTECTIVE TREATMENT - cont'd

Highways specification for Item 372-A, Epoxy Coating Compound Laboratory tests conducted by the Materials Division showed compliance with viscosity standards required by the Department. However, the material did not pass the required flexibility test and did not meet color requirements.

RECOMMENDED APPLICATION PROCEDURE

Concrete surfaces should be sand blasted and/or acid etched. Combine one part by volume of Base with one part by volume of Hardener and mix thoroughly. Allow 30 to 45 minutes aging prior to application. Pot life is 8 hours at 75°F and a 3 to 5 mil application will dry in 3 to 4 hours at 75°F. The material may be applied by brush, roller or spray.

DECK PREPARATION PRIOR TO MEMBRANE APPLICATION

Hammers and chisels were used to remove concrete and epoxy grout droppings on the deck. Oil spots were scrubbed down with liquid detergent. The deck was then washed down with several hundred gallons of water from a tanker truck. After the concrete had dried, a 12% muriatic acid solution was applied on the concrete surface with water sprinkler cans. The deck was treated in three sections to insure that all areas could be properly flushed before any of the acid salts could dry on the concrete. After completion of the final section, an additional 2000 gallons of water was applied with a high pressure hose. A check of the wet concrete with litmus paper disclosed that all acids had been removed.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humidity	% Cloud Cover	
		7/10/72		Air temperatures recorded in shade.
9:15	60°	72	100	Began mixing 20 gal batch of Duralkote 304.
10:00	63°	75	100	Applying epoxy with long handled paint rollers on northerly approach slab.
10:20	63°	80	100	Application stopped due to rain - 10 gals applied.
		7/11/72		
7:15	62°	68	50	Concrete surface still wet from showers previous day.
8:20	66°	67	PC	Began mixing 20 gal batch of epoxy.
9:30	68°	57	70	Concrete dry except for areas along curb. Two sets of copper foil strips placed opposite westerly curb.
10:15	72°	60	50	Began application on northerly end of deck. Skipped area along curbs and expansion dam. Four men applying material.
11:00	75°	59	40	9 gals applied on 1180 s.f. for rate of 131 sf/gal. Many small pinholes noted in the first coat.
12:00	75°	56	30	12 gals applied on 1760 s.f. for rate of 147 sf/gal.
1:00	76°	51	30	Area first treated with material from second 20 gal.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION - cont'd

Time	Temp	% Humidity	% Cloud Cover	
		7/11/72 cont'd		batch has cracks throughout the coating. The epoxy had been remixed for an additional two minutes when lumps were initially observed in the material. Cracks may be due to not allowing induction time after remixing.
2:00	78°	48	20	13 gals applied on 1960 s.f. for rate of 151 sf/gal.
3:30	80°	42	20	Pinholes detected in some areas at a rate of up to 120 per sq. in. (1700 per s.f.).
4:45	78°	46	20	First coat complete except for an average of 1' along curbs. 70 gallons applied on approximately 8970 s.f. for an overall application rate of 128 sf/gal.
		7/12/72		
8:30	70°	67	20	Began mixing first 20 gal batch.
9:20	74°	59	25	Began applying second coat on southerly end of deck and first complete coat along westerly curb. Material applied previous day is completely cured.
10:30	78°	50	25	12 gals applied on 1480 s.f. for rate of 123 sf/gal.
11:30	82°	46	30	14 gals applied on 2330 s.f. for rate of 166 sf/gal.
1:45	87°	42	0	Coated 18" x 18" concrete test slab.
3:00	94°	31	5	112° in sun - light breeze.
3:30				Applied 2 gals of Duralbond 102 along expansion dam in an attempt to seal crack between concrete and bottom of steel plate. Water had been detected beneath the plate when an air blower unit was used to help clean the deck.
4:00	92°	34	25	Applying second coat along curb areas.
5:00	88°	35	30	70 gallons applied on approximately 9990 s.f. for an application rate of 142.7 sf/gal. Overall application rate for the 9427 s.f. treatment area was 134.7 sf/gal/coat.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 150 gallons @ $40.00/gal = $6,000.00
Cost per s.y. = $ 5.73

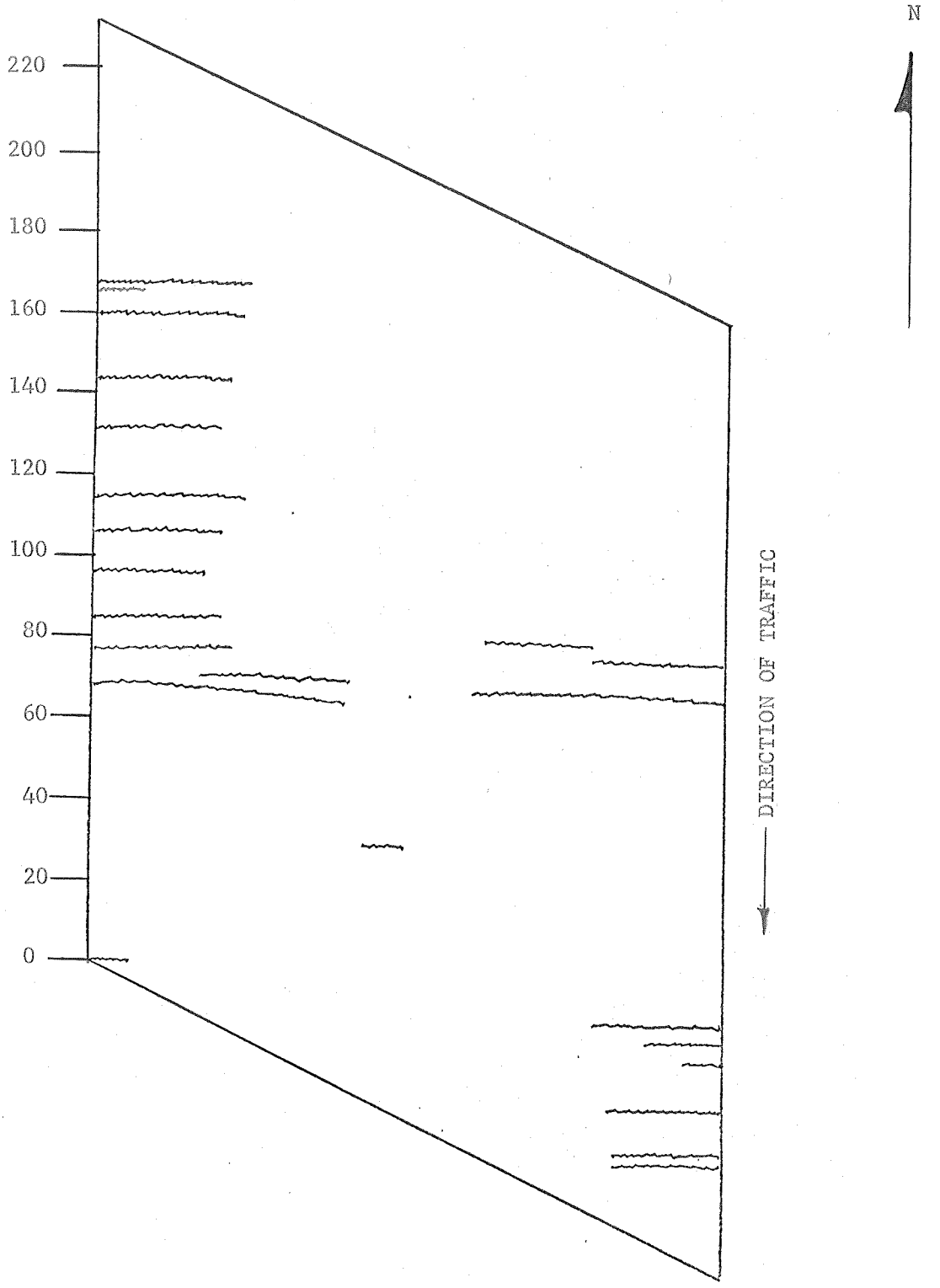
Bituminous Concrete - Two - 1 inch thick courses
151 tons @ $7.00/ton = $1,057.00

Figure 1

I 91 Southbound over Town Highway #40

Cracks in Concrete Deck

All cracks were noted on both the surface and bottom of the deck. Length of cracks and their locations are to scale. Vertical scale 40'/in Horizontal scale 10'/in



DISCUSSION

The preparation of the deck required more labor than other non-epoxy membrane systems. The work included acid etching the concrete surface to remove laitance in accordance with the product manufacturer's specifications.

The only difficulty encountered during the application of the first coat of epoxy was when lumps were detected in a 20 gallon batch of material as it was poured from the mixing drum into 5 gallon buckets. The material was then poured back into the drum and remixed for two additional minutes. The epoxy was applied on about 575 square feet of deck shortly before lunch. Inspection of the area after lunch revealed that the coating was lighter in color and it contained many small star like cracks and micro-fractures. When the application was continued, the coating appeared satisfactory. This gave the impression that the earlier problem was due to not allowing the epoxy to age for the required 30 to 45 minutes after it had been remixed.

Many small pinholes were noted in the first coat of epoxy soon after application and also after curing was complete. The pinholes ranged from very few in number to as many as 120 per square inch (1700 per square foot). Their size varied from an average maximum size of 1/64 inch down to much smaller sizes. Although concrete appeared to be visible at the bottom of many of the larger holes, testing with hydrocloric acid did not produce effervescence. This may have been due to the surface tension of the liquid not allowing it to pass through the relatively small holes. Although a few air bubbles were initially visible in the first coat, none were found prior to the application of the second coat.

Pinholes in the second coat numbered as many as 50 per square inch. Their size was somewhat smaller than the holes in the first coat. Air bubbles were also noted in the second coat on a few areas where the application was heavy. The bubbles, which ranged up to 5/8" diameter in size, all revealed one or more small pinholes in the first coat when broken open for examination. The bubbles remained in the coating after the epoxy had completed curing.

The overall application rate for the two coats was 67.4 square feet per gallon or an average of 134.7 square feet per gallon per coat. This amounted to a dry film

thickness of 14.7 mils.

Electrical resistance readings were taken on the epoxy membrane shortly before the deck was paved. With one exception, the readings ranged between 3,200 and 160,000 ohms with an average of 40,100 ohms per square foot. The exception was a reading of 500 ohms taken on a small area which had received only one coat of epoxy. The low reading shows the value of a two coat system over a single coat of epoxy. Resistance readings taken on the untreated concrete averages 350 ohms per square foot which was nearly as high as the reading taken on the single coat of epoxy.

Moisture sensing copper foil strips placed beneath the epoxy membrane systems were dislodged from the concrete surface during the paving operation and can not be used to evaluate the sealing property of the epoxy system.

The first one inch course of bituminous mix was applied with a rubber tired paver. No difficulties were encountered during the paving operation and no known damage occurred to the membrane except where the copper foil strips were located. Soundings taken on the first course of pavement with a steel rod indicated that there were no hollow areas between the membrane and the bituminous pavement.

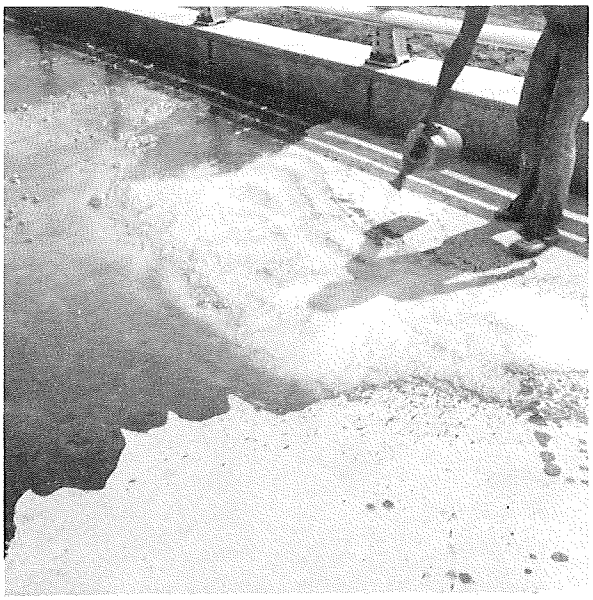
A strip approximately one foot wide was left unpaved along the westerly curb on the low side of the deck. Inspection of this area on November 7, 1972 revealed a number of areas where the epoxy coating had begun to peel from the concrete. However, the coating was still effectively sealing the fine transverse cracks in the deck adjacent to the curb. Electrical resistance readings taken the same day on the membrane and completed pavement ranged between a low of 49,000 and a high of 700,000 with an average of 223,600 ohms per square foot. The readings were basically the resistance value of the bituminous pavement since the average resistance of the epoxy system was only 40,100 ohms per square foot.

DURALKOTE 304 EPOXY

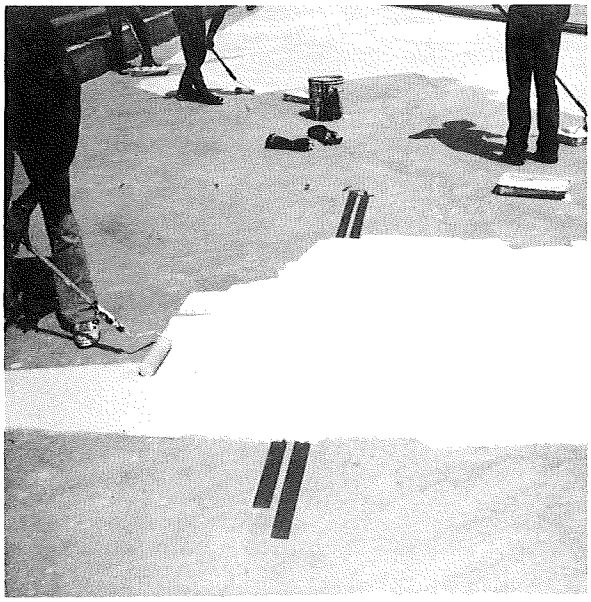
I 91 SB over Town Highway No. 40

July 1972

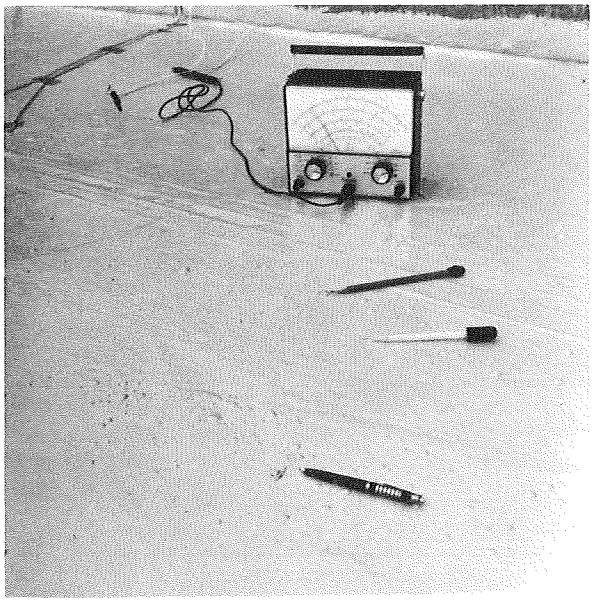
Twenty-two cracks were noted in the deck. The cracks ranged from 2.5 feet to 13 feet in length and extended through the full depth of the deck.



Surface laitance was removed by acid etching.



Applying the first coat over the moisture sensing copper foil strips.



One of several areas which had air bubbles in the second coat. Very small pinholes numbering up to 70 per square inch were also detected in many areas.

WORK PLAN #5 - CONTROL SECTION

TAR EMULSION AND GLASS FABRIC

PROJECT

Barton EMP I 91-3 (19)

CONTROL SECTION

Northbound bridge over Town Highway #40 at station 2210+41 - 2212+76, 1.1 miles north of the Vt Rte 16 Interchange at Barton.

BRIDGE CONSTRUCTION DATA

Type of Structure - 3 span continuous WF.

Span Lengths - 80' - 85' - 65'

Overall Length - 237.49'

Curb to Curb Width - 43.34'

Skew - 35°

Horizontal Curvature - 1° 30' Lt.

Grade - + 2.76%

Superelevation - ½"/ft

DECK CONSTRUCTION DATA

Date Poured - August 10, 1971

Weather Conditions - Overcast, 35% humidity

Temperature - Low 70°F High 85°F

Deck Thickness - 8"

Concrete Cover Over Reinforcing Steel - 2" - 2 3/8" 2¼" average

Concrete - Class AA

Cement - Type I 6½ bags per c.y.

Aggregate Size - 3/4" maximum

Air Entraining Admixture - Darex 6½ - 7 oz per c.y.

Retarding Admixture - Daratard HC

Pour Sequence - Placement from both ends to the middle with full depth at the southerly end and the final 2" of concrete placed on the northerly end last.

Finishing Method - Bidwell finishing machine, skewed 50°

DECK CONSTRUCTION DATA - cont'd

Surface Texture - Broomed finish

Curing - Plastic cover, sprinkler hose along high side plus cross lines

Concrete Test Results:

Percent Air - Low 5½% High 7½% 6.0% average on 27 tests
Slump - Low 2½" High 4" 3.3" average on 26 tests
Modulus of Rupture - Average 816 psi at 28 days

DECK CONDITION

Surface Texture - 25% of the deck had moderate brooming with the remainder lightly broomed. The surface was rougher than normal along the westerly curb and there were numerous holes in the concrete caused by movement of coarse aggregate during the finishing operation.

Cracks - Six transverse cracks ranging from 2.2' to 6.2' in length were noted adjacent to the westerly curb on the low side of the deck. There were also many short independent and connected cracks scattered throughout the deck. Most of the cracks which average 18" in length were at a 45° angle to centerline and ran towards the low southwesterly end of the deck.

Miscellaneous - The epoxy mortar beneath the granite curb did not appear to be sealing out moisture. The material absorbed water and was very slow in drying out.

Steel Corrosion Readings - Initial readings taken on the deck averaged 0.10 volts, indicating no active corrosion.

PROTECTIVE TREATMENT

Product - Tar emulsion and woven galss fabric
The brand of tar emulsion used was PR55-CTP manufactured by the Triram Corporation, 721 Waverly Street, Framingham, Massachusetts. The glass fabric was manufactured by Burlington Glass Fabrics Co.

Test Results - Water content of the Tar Emulsion averaged 52% by weight.

APPLICATION PROCEDURE

(1) Prime coat of tar emulsion applied on moist concrete and allowed to dry.

(2) Coat of tar emulsion followed with the placement of a layer of glass fabric.

(3) Coat of tar emulsion with a layer of glass fabric placed perpendicular to the first layer of fabric.

(4) Coat of tar emulsion which is allowed to dry.

(5) Finish coat of tar emulsion.
The total coverage for the five coats of tar emulsion should be approximately ½ gallon per square yard.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Cloud Cover	
	7/27/72		Light breeze. Humidity 40-65%. Air temperatures recorded in shade.
8:30	66°	80	Cleaning deck with brooms, air blower and water.
10:00	71°	80	Deck washed clean for the second time.
10:15	71°	80	Prime coat applied with a Huber applicator on a wet concrete surface. 91 gallons on 1000 s.y. for an application rate of 0.09 gallons per s. y. 10' long copper foil strips were placed on the concrete 3' from the westerly curb at a point approximately 160' south of the finger plate expansion dam and 5' strips were placed 12' from the westerly curb at a point approximately 220' south of the expansion dam.
11:30	71°	100	Began raining lightly.
11:45	70°	100	Heavy rains are beginning to wash off the tar emulsion.
12:00	68°	100	Rain stopped. Approximately 30% of the deck has no tar emulsion while the value of the remaining material is negligible due to the thin coating.
	7/28/72		Humidity 39-65%.
9:30	68°	100	Began reapplying first coat.
9:45	69°	100	96 gallons applied with applicator.
1:30	75°	65	Began applying tar emulsion and glass cloth along curbs.
3:30	72°	60	First layer of glass cloth complete on 1/3 of the deck.
5:45	68°	30	First layer of cloth complete.
	7/29/72		Humidity 30-50%.
8:30	63°	40	Began applying longitudinal strips of glass cloth.
12:00	76°	40	Second coat of glass cloth complete. 421 gallons of tar emulsion applied in the first 4 coats.
1:30	78°	40	Finish coat of 52 gallons applied with Huber applicator. A total of 473 gallons was applied on 1055 s.y. of concrete for an application rate of 0.45 gal per s.y.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 1055 s.y. @ $4.00/s.y. = $4,220.00

Bituminous Concrete - Two - 1 inch thick courses
148 tons @ $7.00/ton = $1,036.00

DISCUSSION

Inspection of the tar emulsion and glass fabric system upon completion revealed a number of areas along the curbs which did not appear to be completely waterproof. The condition was due to the rough configuration of the epoxy mortar and the granite curb combined with the difficulty in getting the right amount of tar emulsion on the vertical face. The field observations gave the impression that it would be unrealistic to expect the system to protect the concrete deck adjacent to the face of the curb. The horizontal surface area of the deck appeared to be satisfactory with the finish coat of tar emulsion completely covering the second layer of glass fabric even though the total application rate for the five coats was 0.45 rather than the recommended half gallon per square yard.

Electrical resistance readings taken on the membrane ranged between 2,900 and 4,200 ohms with an average of 3,600 ohms per square foot. Moisture sensing copper foil strips were also successfully placed beneath the membrane to monitor any future penetration of moisture through the pavement and membrane system.

The first one inch course of bituminous pavement was applied without difficulty using a rubber tired paver. Soundings taken with a steel rod did not indicate any hollow or unbonded areas between the pavement and membrane.

Electrical resistance readings taken on the completed pavement and membrane system ranged between 250,000 and 11 million ohms with an average of 3.36 million ohms. Such readings indicate that the pavement-membrane system can initially be expected to protect the concrete from moisture and deicing chemicals.

WORK PLAN #6 - INITIAL REPORT

UNIROYAL MEMBRANE

PROJECT

Barton-Derby EMP I 91-3 (20)

PROJECT LOCATION

In the County of Orleans, Vermont, beginning at a point approximately 0.462 miles southerly of the Barton-Irasburg Town Line and extending northerly 8.539 miles.

WORK LOCATION

I 91 southbound bridge over US Rte 5 at station 2449+38.50 - 2451+38.50 in Orleans.

CONTROL SECTION

I 91 northbound bridge over US Rte 5 See data on pages 39 to 42.

BRIDGE CONSTRUCTION DATA

Type of Structure - Three span continuous (welded plate girder) with cantilevered end spans.

Span Lengths - 34' - 132' - 34'

Overall Length - 200'

Curb to Curb Width - 42.6'

Skew - None

Horizontal Curvature - 0^{o}- 45'

Grade - - 4.4233%

Superelevation - 3/8" /ft

DECK CONSTRUCTION DATA

Deck Thickness - 8"

Concrete - Class AA

Cement - Type I 6½ bags per c.y.

Aggregate Size - 3/4" maximum

Pour Sequence

Sections 3 and 4 were poured on April 20, 1971.
Section 5 was poured on April 26, 1971.
Sections 6 and 7 were poured on April 28, 1971.

DECK CONSTRUCTION DATA - cont'd

Finishing Method - Bidwell finishing machine on fascia panel

Surface Texture - Broomed finish

Curing - Polyethelene sheeting and hay for 10 days

Date Poured - April 20, 1971 (Sections 3 and 4)

Weather Conditions - Clear 30% humidity 5 - 10 mph breeze

Temperature - Low 50°F High 60°F

Concrete Cover over Reinforcing Steel - 1 3/4-2½" 2" average

Air Entraining Admixture - Darex 8½ oz per c.y.

Retarding Admixture - None

Concrete Test Results:

Percent Air - Low 5½% High 7% 6¼% average on 8 tests

Slump - Low 2½" High 3½" 3 1/8" average on 8 tests

Modulus of Rupture - 786 psi average at 28 days

Date Poured - April 26, 1971 (Section 5)

Weather Conditions - Cloudy 30% humidity

Temperature - Low 38°F High 45°F no breeze

Concrete Cover over Reinforcing Steel - 1 3/4" - 2¼" 2" average

Air Entraining Admixture - Darex 8½ oz per c.y.

Retarding Admixture - None

Concrete Test Results:

Percent Air - Low 5½% High 7% 6¼% average on 4 tests

Slump - Low 2" High 4" 3" average on 4 tests

Modulus of Rupture - 891 psi average at 28 days

Date Poured - April 28, 1971 (Sections 6 and 7)

Weather Conditions - Clear 30% humidity 10-15 mph breeze

Temperature - Low 40°F High 60°F

Concrete Cover over Reinforcing Steel - 1 3/4 - 3½" 2" average on 3 tests

Air Entraining Admixture - Darex 8½ oz per c.y.

Retarding Admixture - 3 oz per bag maximum

DECK CONSTRUCTION DATA - cont'd

Concrete Test Results:

Percent Air - Low 6¼% High 7% 7% average on 11 tests

Slump - Low 1 3/4" High 3½" 2½" average on 3 tests

Modulus of Rupture - 776 psi average at 28 days

DECK CONDITION

Surface Texture - Sections 3 and 4 - smooth

Sections 5, 6 and 7 - moderate to rough broom finish

Cracks - Eight transverse cracks were noted in the end sections. Seven of the cracks ranged from 0.8' to 5' in length and one was 36' long. Four of the shorter cracks observed on the surface could also be detected on the bottom of the deck. No cracks were observed in the easterly curb while nine were detected in the westerly curb section.

Miscellaneous - Construction of the deck in five sections resulted in a rough riding surface.

Steel Corrosion Readings - Initial readings taken on the deck averaged 0.11 volts, indicating no active corrosion.

PROTECTIVE TREATMENT

Product - Uniroyal Liquid Membrane Waterproofing System.
A hot-applied rubberized asphalt compound (Liquid Membrane 6125), a surface conditioner and rubber sheets (Elastosheet T.M.) used to reinforce the flexible membrane along the curbs and at all joints.

Test Results - None. The material and its application were as recommended by the manufacturer.

RECOMMENDED APPLICATION PROCEDURE

A surface conditioner is applied on the concrete at a rate of 300 to 600 square feet/gal. Fifty pound cakes of the waterproofing membrane are melted in a double walled kettle until the material can be drawn free flowing at a temperature not exceeding 425°F. The material is applied evenly with a squeegee at the rate of one pound per square foot for an average thickness of 3/16". Rubber sheets (Elastosheet T.M.) are rolled down into the hot membrane along the curbs and over roadway joints. A second coat of the membrane is then applied over the rubber sheet. After cooling, the membrane is dusted with Portland cement at a rate of approximately 1,000 square feet per sack to prevent tracking.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humidity	Liquid Membrane Temp	
		6/5/72		Air temperatures recorded in shade. Clear 3-8 mph wind.
10:45				Deck washed and blown clean for a second time.
1:15	72°	32	395°	Uniroyal representative gave OK to begin applying primer along the easterly curb with a hand sprayer. Primer consisted of Uniroyal RC 70 cut back with gasoline and applied at the rate of 2900 s.f. per gallon (3 gallons used) as recommended by the Uniroyal representative.
2:00	70°	30	405°	Began applying liquid membrane and Elastosheet along easterly curb. The Elastosheet used was made of nytrile and neoprene rubber which had a lower durometer and greater flexibility than material used in the past.
3:30	74°	30	430°	Elastosheet was removed from the westerly curb when a lack of adhesion was detected. Actual bond to the liquid membrane did not exceed 5 to 10% with most occurring at the joint where extra pressure was applied with a rolling tool.
4:00	74°	30	445°	1832 s.f. treated with 1640 lbs for an application rate of 0.895 lbs per s.f. Air bubbles can be seen in the liquid membrane at the rate of approximately ten per square foot. When bubbles were broken open, visible areas of concrete were noted in all cases.
5:00	73°	33	400°	2620 s.f. treated application rate light averaging 0.65 lbs per s.f.
6:00	72°	34	400°	Oil bath 630° Two areas given a heavy primer application did not appear to have a reduction in the number of air bubbles in the liquid membrane.
7:00	71°	34	400°	4800 s.f. treated. Sundown at 7:50.
8:00	63°	48	405°	Fewer air bubbles appearing in the liquid membrane.
9:00	63°	54	390°	7875 s.f. treated with 900 s.f. remaining to be done.
9:45	54°	61	395°	Application complete.
		6/6/72		
9:00	64°	65	230°	Began reheating liquid membrane in kettle.
11:45	68°	59	495°	Applying second coat along westerly curb where Elastosheet had been removed.
1:00	72°	55	430°	Touching up holidays in the membrane and where the first coat appears thin. Dusting membrane with cement as it was made acceptable.
3:00	72°	50	450°	Application complete. 7316 pounds of Uniroyal Liquid Membrane applied on 8793 square feet of deck for an application rate of 0.83 lbs per s.f.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 977 s.y. at $8.00/s.y. = $7,816.00

Bituminous Concrete - Two - 1 inch thick courses

153 tons at $7.00 per ton = $1,071.00
Removal of first 1 inch thick course = $230.00
Replacement of first 1 inch thick course
53 tons at $7.00 per ton = $371.00

DISCUSSION

The primer application began approximately three hours after the deck had been washed clean. It consisted of an RC 70 asphalt cutback with gasoline so that it could be applied with a portable hand sprayer. The overall application rate was 2900 square feet per gallon. This satisfied the Uniroyal representative on the project who had recommended the light application rate rather than the formerly prescribed 300 to 600 square feet per gallon.

The squeegee application of hot rubberized asphalt began along the easterly curb. Strips of Elastosheet approximately eight inches wide were placed in the membrane so that they extended up onto the curb approximately two inches. Extra care was taken to insure that the rubber sheeting was firmly pressed into the hot membrane since past experience had shown that water which had entered the system had been able to flow freely under the Elastosheet along the joint between the curb and deck.

Soon after the Elastosheet had been placed along the westerly curb it was found that very little bond existed between the sheeting and the rubberized asphalt. Removal of the sheets disclosed that the total bonded area did not exceed five to ten percent. The lack of bond was believed due to a talcum like powder which had been placed on the Elastosheet to prevent the smooth surfaced, 37 mil thick, nytrile-neoprene rubber sheet from sticking together when packaged in 100 lineal foot rolls. The talcum dusted Elastosheet placed along the easterly curb exhibited satisfactory bond to the rubberized asphalt and consequently was not removed. The only notable difference between the applications made along the two curbs was that the easterly curb had been exposed to sunlight before and during the application while the westerly curb had not. The Elastosheet placed over the construction and deflection joints in the deck consisted of a different grade of material which had been left over from a project completed the previous year. The 50 mil thick textured sheeting bonded satisfactorily at all locations.

Air bubbles were noted in the liquid membrane shortly after application. They averaged about ten per square foot during the afternoon's application and decreased slightly in number during the application made in the evening. All bubbles revealed visible areas

of concrete when broken open. The bubbles were believed to be caused by the expansion of air in the concrete brought about by the 400°to 450°F temperature of the liquid rubberized asphalt. Two areas given a heavy primer application did not appear to have any reduction in the number of air bubbles.

Approximately 7000 pounds of rubberized asphalt was applied initially on 8793 square feet of concrete. The following day a second application was made along the westerly curb where the Elastosheet had been removed. Additional material was also applied over areas where the coating appeared light and over numerous holidays in the membrane. A total of 7316 pounds of rubberized asphalt was applied on 8793 square feet of concrete for an overall application rate of 0.832 pounds per square foot.

The first one inch course of bituminous pavement was placed on June 16, 1972, ten days after the membrane system had been completed. A prior inspection revealed three areas where water had gotten behind the Elastosheet along the easterly curb. The areas affected were from two to twelve inches in length. All three unbonded areas were cut open to release the trapped water and prevent further damage.

The rubber tired paver was able to move over the cement dusted membrane without causing any damage. The only disruption occurred when a truck loaded with bituminous mix slid while parked on the joint between the approach slab and the southerly end of the deck causing the Elastosheet to be displaced. The use of an eight to ten ton breakdown roller for initial compaction was not feasible due to the fluid condition of the membrane caused by the 260°F to 274°F bituminous mix. A one ton sidewalk roller was used to obtain the initial compaction and the heavy roller was used several hours later when the mix temperature was below 100°F. It may be assumed that less than the desired percent compaction was obtained.

Inspection of the bridge several weeks later disclosed that the pavement had begun to creep down the 4.4 percent grade of the deck. The movement, caused by a heavy volume of construction traffic, was detected by observing the sawed bituminous joints between the approach slabs and the deck. As periodic inspections were made, the conditions became worse. The down hill movement of the pavement approached 18 inches in the heavily traveled areas before the sawed joints became indistinguishable. Additional distress over the

joints included rutting, bleeding of the rubberized asphalt and exposure of sections of the Elastosheet.

The problems over the joints and a slight washboard effect in the pavement at several other locations resulted in a decision to remove the pavement. The work was accomplished with a grader on September 1, 1972. The removal did not include a strip approximately two feet wide along the westerly curb on the low side of the deck. Damage to the membrane occurred over five to ten percent of the deck at locations where the rubberized asphalt stuck to the bituminous pavement rather than the concrete deck. The bond between the remaining membrane and the deck varied at different locations. In some areas it was possible to hand strip the material from the concrete while at other locations the bond was too great to remove in that manner.

Air bubbles were also observed in the rubberized asphalt at several locations after the pavement had been removed. This disproved the theory that the bubbles in the liquid membrane will be eliminated when the bituminous pavement is placed.

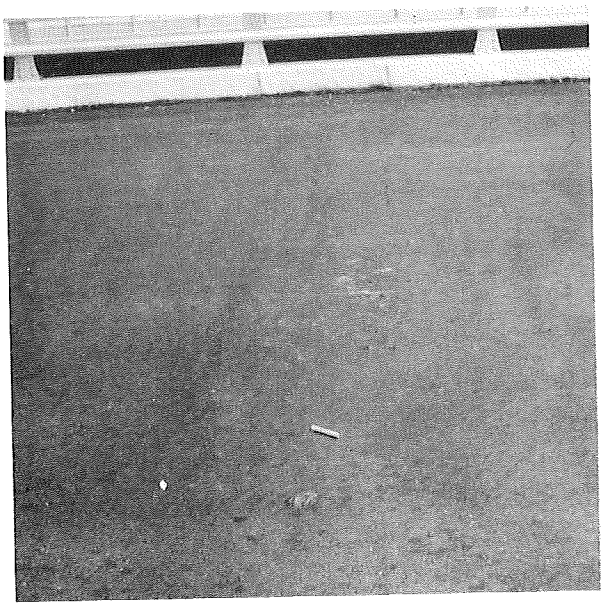
Electrical resistance readings taken on the Uniroyal membrane averaged 51,600 ohms per square foot. Readings taken on the completed pavement and membrane ranged between five million and infinity even though the membrane had been damaged at many locations and was not repaired before the first course of pavement was replaced. The high readings could probably be attributed to the sealing property of the pavement rather than the protective membrane.

UNIROYAL LIQUID MEMBRANE SYSTEM

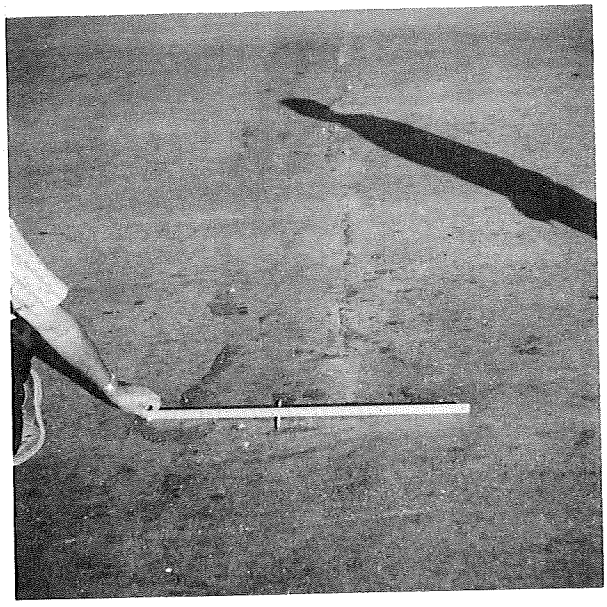
I 91 SB over US Rte. 5

June 1972

Distress adjacent to northerly approach slab includes movement of pavement and membrane which caused a bump and bleeding of the liquid membrane up through the pavement.



Distress over construction joint where Elastosheet had been placed.



Movement of pavement over joint at southerly approach slab.

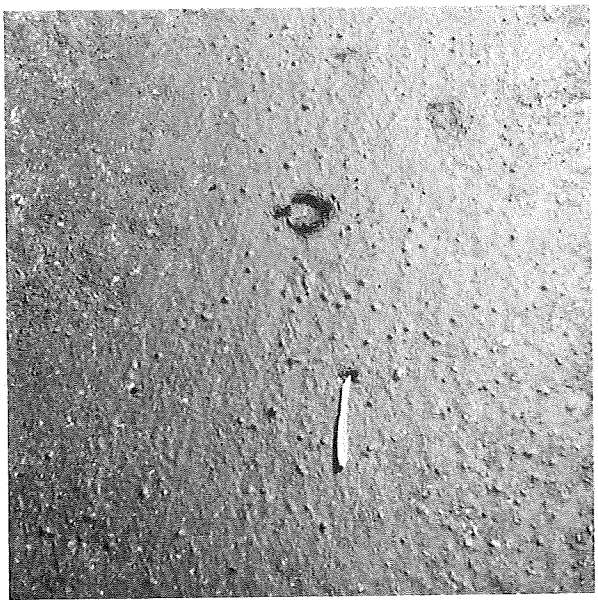
Removal of the distorted pavement with a grader resulted in exposed areas of concrete where the Uniroyal stuck to the bituminous mix rather than the concrete deck.

UNIROYAL LIQUID MEMBRANE SYSTEM

I 91 SB over US Rte. 5

June 1972

The bond between the remaining Uniroyal and the concrete allowed the membrane to be hand stripped from the deck at some locations.



One of several areas where air bubbles could still be found in the membrane after the pavement had been removed.

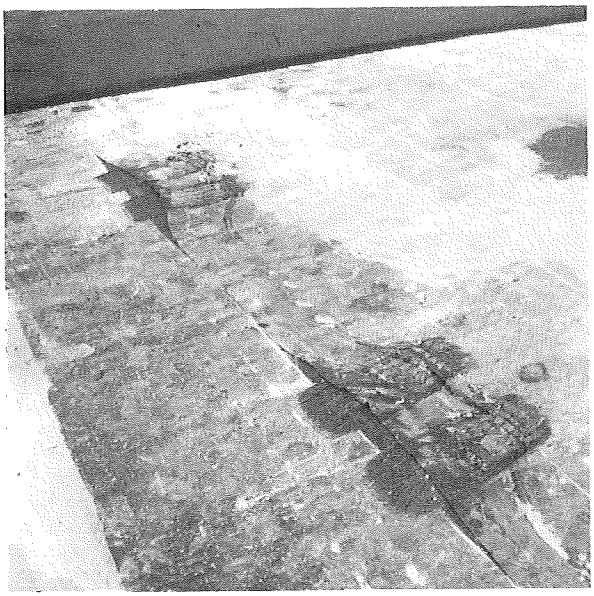
UNIROYAL LIQUID MEMBRANE SYSTEM

I 91 SB over US Rte. 5

June 1972

Applying second coat of liquid membrane along the curbs and over areas with holidays in the coating. Note cement dust application.

Largest of 3 areas along the westerly curb where water was able to get behind the Elastosheet before the pavement was placed.



Movement of Elastosheet over southerly deflection joint caused by a truck transporting the bituminous mix.

Movement of 1" thick pavement and membrane several weeks after application as indicated by keil mark on sawed pavement joint.

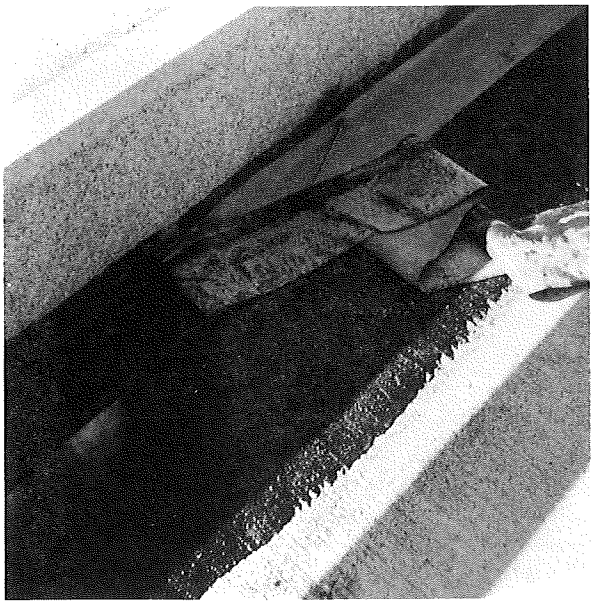
UNIROYAL LIQUID MEMBRANE SYSTEM

I 91 SB over US Rte. 5

June 1972

Applying liquid membrane and Elastosheet over deflection joint. Note primer application.

Forcing the Elastosheet into the liquid membrane at the joint between deck and curb.



Very little bond detected between the talcum dusted Elastosheet and liquid membrane along westerly curb. Sheeting was removed.

Bubbles noted in liquid membrane shortly after application. All revealed concrete when broken open.

WORK PLAN #6 - CONTROL SECTION

TAR EMULSION AND GLASS FABRIC

PROJECT

Barton-Derby EMP I 91-3 (20)

CONTROL SECTION

I 91 northbound bridge over US Rte 5 at station 2447+81 - 2449+81 in Orleans

BRIDGE CONSTRUCTION DATA

Type of Structure - Three span continuous (welded plate girder) with cantilevered end spans.

Span Lengths - 34' - 132' - 34'

Overall Length - 200'

Curb to Curb Width - 42.6'

Skew - None

Horizontal Curvature - Tangent

Grade - -3.99453%

Superelevation - ¼"/ft

DECK CONSTRUCTION DATA

Date Poured - June 9, 1971

Weather Conditions - Sunny and clear

Temperature - Unknown

Deck Thickness - 8"

Concrete Cover Over Reinforcing Steel - 2"

Concrete - Class AA

Cement - Type I 6½ bags per c.y.

Aggregate Size - 3/4" maximum

Air Entraining Admixture - Darex 1 - 7 oz per c.y.

Retarding Admixture - Daratard 6 - 18 oz per c.y.

Pour Sequence - Simultaneously from both ends with the north end poured to finish grade. South end poured only to the top mat of reinforcing steel and then finished when north end completed.

DECK CONSTRUCTION DATA - cont'd

Finishing Method - Bidwell on fascia panel

Surface Texture - Broomed finish

Curing - Polyethelene sheeting

Concrete Test Results:

Percent Air - Low 4% High 8% 6% average on 33 tests

Slump - Low 1½" High 5½" 2½" average on 33 tests

Modulus of Rupture - 797 psi average at 28 days

DECK CONDITION

Surface Texture - The broom finished concrete varied from smooth to very rough over different sections of the deck.

Cracks - Relatively few cracks were detected.

Miscellaneous - An area of concrete damaged when a rubber tire was burned on the deck was patched with an epoxy mortar compound. The epoxy mortar beneath the granite curb did not appear to be sealing out moisture. The material absorbed water and was very slow in drying out.

Steel Corrosion Readings - Initial readings taken on the deck averaged 0.11 volts, indicating no active corrosion.

PROTECTIVE TREATMENT

Product - Tar emulsion and woven glass fabric
The brand of tar emulsion used was PR55-CTP manufactured by the Triram Corporation, 721 Waverly Street, Framingham, Massachusetts. The glass fabric was manufactured by Burlington Glass Fabrics Co.

Test Results - Water content of the Tar Emulsion averaged 52% by weight.

APPLICATION PROCEDURE

(1) Prime coat of tar emulsion applied on moist concrete and allowed to dry.

(2) Coat of tar emulsion followed with the placement of a layer of glass fabric.

(3) Coat of tar emulsion with a layer of glass fabric placed perpendicular to the first layer of fabric.

(4) Coat of tar emulsion which is allowed to dry.

(5) Finish coat of tar emulsion
The total coverage for the five coats of tar emulsion should be approximately ½ gallon per square yard.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Cloud Cover	
	5/25/72		Air temperatures recorded in shade 3-10 mph breeze. Deck cleaned using air blower, brooms, and water.
6:30 p.m.	62°	0	Prime coat of tar emulsion applied with mechanical applicator on moist concrete surface.
	5/26/72		3-5 mph breeze
1:00	74°	0	Began applying glass fabric along curb areas.
3:00	72°	0	Applying glass fabric perpendicular to centerline.
5:00	72°	0	Operation stopped with 2360 s.f. covered.
	6/1/72		10-15 mph breeze
9:15	70°	15	Continuing application of transverse strips of glass fabric.
12:30	80°	10	First layer of glass fabric complete. Coat of tar emulsion placed over it did not completely cover the fabric in many areas. May be due to roughness of the concrete surface since application rate is OK.
1:30	81°	95	
4:30	79°	100	Finished application of longitudinal strips.
5:30	75°	100	Final coat of tar emulsion applied with mechanical applicator. the overall application rate for the deck was 0.546 gallons per square yard.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment	-	984 s.y. @ $4.00/s.y.	=	$3,936.00
Bituminous Concrete	-	Two 1 inch thick courses 72 tons @ $7.00/ton	=	$ 924.00

DISCUSSION

Inspection of the completed membrane system revealed a number of areas where the glass fabric did not appear to have a sufficient coating of tar emulsion over it. These areas were due to a rough or uneven concrete surface that required a heavier application of tar emulsion than the one-half gallon per square yard normally required. The overall application rate for the deck was 0.54 gallons per square yard. Areas along the curbs appeared to be adequately sealed at most locations.

The first one inch course of bituminous pavement was applied with a rubber tired paver the day after the system was completed. No difficulties were encountered.

On August 15, 1972 approximately two and one-half months after the first course of pavement had been placed, inspection of the deck revealed air bubbles beneath the pavement. It was assumed that the air was trapped between the pavement and the membrane rather than between the membrane and the concrete. The bubbles ranged up to two feet in diameter and succeeded in lifting the pavement up to one-half inch off the bridge deck. The application of weight to the bubbles resulted in lateral movement of the trapped air. Removal of the larger air bubbles was accomplished by puncturing the pavement with a knife. The remaining trapped air apparently escaped via the holes since subsequent inspections showed no bubbles or lifting of the pavement. Soundings taken with a steel rod indicated that 10 to 15 percent of the pavement was not bonded to the membrane and/or deck. The lack of bond may have been due to the fact that the tar emulsion system was wet from a rain shower which had occurred just before the first course of bituminous pavement was placed.

Electrical resistance readings of from 1,000 to 8,000 ohms were obtained on the membrane system the day it was completed. Readings taken on the completed pavement and membrane were in the order of a billion ohms. Such readings could probably be attributed to the sealing property of the bituminous pavement rather than the tar emulsion and glass fabric system.

WORK PLAN #7 - INITIAL REPORT

POLYTOK MEMBRANE 165

PROJECT

Barton-Derby EMP I 91-3 (20)

PROJECT LOCATION

In the County of Orleans, Vermont, beginning at a point approximately 0.462 miles southerly of the Barton-Irasburg Town Line and extending northerly approximately 8.539 miles.

WORK LOCATION

I 91 southbound bridge over State Aid Highway #3, Canadian Pacific Railroad and Barton River at station 2171+53 - 2172+53, 1.6 miles north of the US Rte 5 interchange at Orleans.

CONTROL SECTION

I 91 northbound bridge over State Aid Highway #3, Canadian Pacific Railroad and Barton River, see data on pages 55 to 61.

BRIDGE CONSTRUCTION DATA

Type of Structure - 1 simple span (composite) and 3 span continuous (welded plate girder - composite)

Span Lengths - 75' - 113' - 141' - 113'

Overall Length - 442'

Curb to Curb Width - 39.33'

Skew - 47° 30' lt

Horizontal Curvature - None

Grade - -2.64%

Superelevation - ¼"/ft.

DECK CONSTRUCTION DATA

Deck Thickness - 8"

Concrete - Class AA

Cement - Type I 6½ bags per c.y.

Aggregate Size - 3/4" maximum

Finishing Method - Capital finishing machine on outside beams skewed 47° 30' left

Curing - Polyethelene sheeting with water spray on curb sections

DECK CONSTRUCTION DATA - cont'd

Surface Texture - Broomed finish

SECTION I (simple span)

Date Poured - May 24, 1971

Weather Conditions - Summy 20% humidity

Temperature - Low 45°F High 70°F

Concrete Cover Over Reinforcing Steel - 1 3/4" - 2 3/4", 2" average on 11 tests

Air Entraining Admixture - Darex 6½ oz/c.y.

Retarding Admixture - None

Pour Sequence - North to south

Concrete Test Results:

Percent Air - Low 6½% High 7½% 7¼% average on 13 tests

Slump - Low 3½" High 4" 4" average on 13 tests

Modulus of Rupture - 678 psi average at 28 days

SECTION II (3 span continuous)

Date Poured - June 1, 1971

Weather Conditions - Sunny 20% humidity

Temperature - Low 45°F High 80°F

Concrete Cover Over Reinforcing Steel - 1 3/4" - 2¼", 2" average on 29 tests

Air Entraining Admixture - Darex 6-7oz/c.y.

Retarding Admixture - Daratard H. C.

Pour Sequence - Placement from both ends to the middle with full depth at the north end and the final 2" placed and finished on the southerly end last.

Concrete Test Results:

Percent Air - Low 5½% High 7½% 6 3/4% average on 54 tests

Slump - Low 2½" High 4" 3 3/4" average on 54 tests

Modulus of Rupture - 821 psi average at 28 days

DECK CONDITION

Surface Texture - The broom finished concrete varied from moderate to rough over different areas of the deck.

DECK CONDITION - cont'd

Cracks - Approximately 30 transverse cracks were noted with all visible on both the top and bottom of the deck. They varied in length from two feet to the full width of the deck. See crack layout sheet on Figure 2 Page 48.

Laitance - Areas of laitance were removed by sand blasting.

Miscellaneous - The epoxy mortar beneath the granite curb had sagged for almost the entire length of the westerly curb and at many locations along the easterly curb. The amount of sag made it possible to insert a four inch wide spatula beneath the granite curb at many locations.

Steel Corrosion Readings - Initial readings taken on the deck averaged 0.09 volts indicating no active corrosion.

PROTECTIVE TREATMENT

Product - Polytok Membrane 165. A two part modified polyurethane elastomer manufactured by the Carboline Company, 328 Hanley Industrial Court, St. Louis, Missouri 63144.

Test Results - The polyurethane elastomer displayed excellent bond when placed on concrete samples in the laboratory. The material remained flexible at sub zero temperatures and did not appear to be damaged when bituminous mixes were applied at temperatures up to 300°F. The material did not leak or show other signs of failure when placed on a two foot square concrete slab constructed with a three inch high curbing. The test period included freeze thaw cycles and over 30 days of sub freezing temperatures which ranged down to -15°F. The only bad feature noted was that pinholes often developed in the membrane coating shortly after application.

RECOMMENDED APPLICATION PROCEDURE

Remove all dirt and other contaminants from the concrete surface. Mix 3 parts by volume of component A with 1 part by volume of component B. Apply sufficient material to obtain a 40 mil dry film thickness using airless spray or squeegee. After 20 minutes drying time at 70°F, roll 50 pound asphalt impregnated roofing sheet over the Polytok Membrane 165 film. Asphalt sheets should be butted at the ends and laid parallel to one another with no more than ¼ inch distance between sheets. Allow 5 hours cure at 70°F before placing the bituminous concrete wearing surface with standard spreading equipment.

DECK PREPARATION PRIOR TO MEMBRANE APPLICATION

Surface materials were washed off the deck with high pressure water. Rough areas along the curb plus oil spots and other contaminants were removed by sand blasting. The two man operation took eight hours and consumed 1000 pounds of sand blast sand with much of it gathered and re-used a second time.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humidity	
	6/12/72		Temperature recorded in shade. 10% cloud cover. 3-6 mph breeze.
8:45			Began sandblasting rough areas on the deck - mainly along both curbs.
11:45	65°	44	Finished sandblasting at 6:30 P.M. 1000 lbs of sand used with some of the sand re-used.
5:30	64°	40	Cloudy. Began mixing the two component polyurethane with xylol solvent (50%-50%) prior to applying the material as a prime coat.
5:45	64°	41	Began applying primer on southerly simple span. Coverage complete at 6:20.
6:30	63°	43	Five man operation applying primer north of finger plate expansion dam.
7:30	62°	48	Primed areas dry to the touch in one hour. Smooth areas of concrete had an average of two or three air bubbles per square foot in the primer while rough areas contained up to 100 air bubbles per square foot.
8:30	60°	52	Prime coat complete. 74 gallons of Polytok Membrane 165 applied on 1981 s.y. for a dry film thickness of 6 mils.
	6/13/72		
9:00	62°	63	Light breeze. 25% cloud cover. Began mixing 20 gal batch.
10:00	66°	48	18 gallons squeeged on 642 s.f. for an application rate of 35.7 s.f./gal. Air bubbles and pinholes appeared in the membrane immediately after application. The high viscosity of the polyurethane made it difficult to pour from the mixing barrel and to spread on the deck.
10:45	69°	45	2 gallons of xylol added to the second 20 gallon batch in an attempt to reduce air bubbles and pinholes and to speed up the squeegee operation.
11:15	70°	43	42 gallons applied on 2732 s.f. for an application rate of 65 s.f./gal. Roofing sheet will be placed on a second coat which will be required to maintain proper membrane thickness.
12:00	71°	42	Area treated at 9:30 (no solvent) is dry to the touch. Membrane has an equal number of air bubbles and pinholes at the rate of 75 to 150 per s.f. Area treated at 10:45 (with solvent) is still very tacky.
12:40	71°	39	80 gallons applied on 3852 s.f. for an application rate of 48.2 s.f./gal. Placing 65 pound roofing sheet over liquid membrane.
1:45	75°	33	Reduced xylol to 1 gallon per 20 gallons of mixed polyurethane.
2:15	78°	32	100°F on primed deck in sun. Some difficulty in maintaining proper alignment of roofing sheet. Bond to liquid membrane makes it difficult to realign. Edges of sheets are curling away from the liquid membrane at various points along the roll creating "fish mouths".
3:30	79°	32	Pinholes in the cured membrane on the southerly span did not produce any reaction when tested with hydrocloric acid. Air bubbles broken open and tested in the same manner were also apparently sealed at the bottom.
4:00	81°	30	Approximately 75% of the continuous span covered. Fewer air bubbles are appearing in the membrane. Average area has 10 to 20 air bubbles ranging from 1/16" to 1/8" in diameter. Reduction in number may be due to a peak in the air temperature.
5:30	79°	31	Application complete. Final 25% of the deck covered with 50 pound roofing sheet. Began second coat along the curbs (18" width).

OBSERVATIONS MADE DURING MEMBRANE APPLICATION - cont'd

Time	Temp	% Humidity	
6/13/72 cont'd			
6:30	77°	33	Began applying second coat on southerly span. Area covered with 50 pound roofing sheet.
7:00	77°	35	Application complete. 470 gallons of Polytok Membrane 165 applied on 1981 s.y. for a dry film thickness of 38 mils. Total coverage for prime and finish coat averaged 44 mils.
7/28/72			
6:30	63°	44	Began applying 4 gal batch along westerly curb.
7:00			Mixing 20 gal batch. 2½ pints xylol added.
8:00			Finished application. Material applied on 790 s.f. of damaged membrane along the westerly curb. Concrete along the westerly curb now has satisfactory coating for a minimum 3 foot width.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

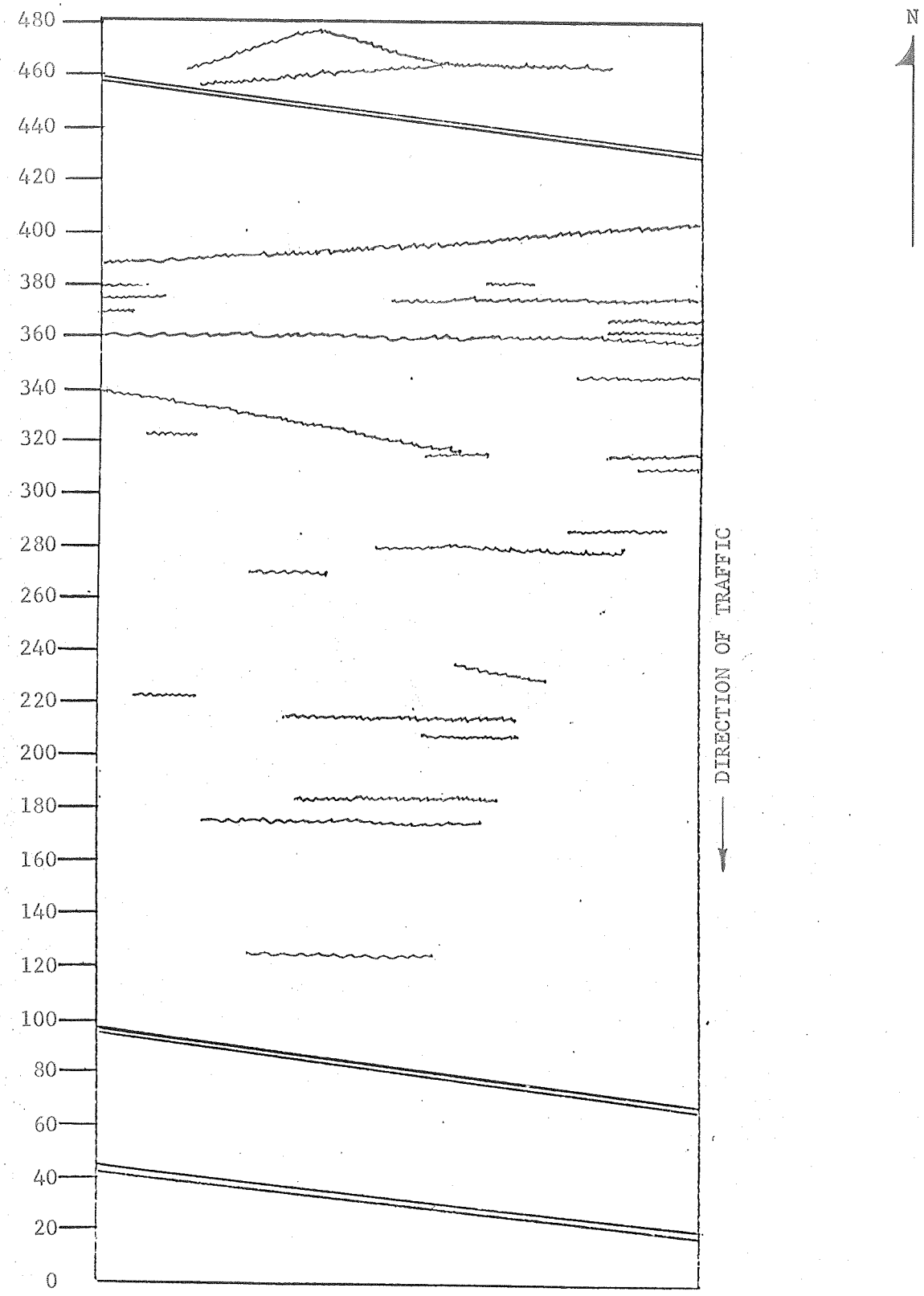
Membrane Treatment -	Prime coat	=	$1,055.00	
	1981 s.y. @ $4.00/s.y.	=	$7,924.00	
	Membrane Repair	=	$ 395.00	
Bituminous Concrete -	Two-1 inch thick courses			
	230 tons @ $7.00/ton	=		$1,610.00
	Removal of first course of pavement	=		$ 785.00
	Replacement of first course of pavement			
	134 tons @ $7.00/ton	=		$ 938.00

Figure 2

I 91 SB over S.A. #3, C.P.R.R., & Barton River

Cracks in Concrete Deck

Length of cracks and their locations are to scale. Vertical Scale 60'/in. Horizontal Scale 10'/in.



DISCUSSION

A prime coat consisting of a 50-50 mixture of Polytok Membrane and xylol solvent was applied on the concrete with squeegees. The manufacturer recommended the use of the prime coat (not originally specified) to reduce pinholing in the membrane such as had occurred during laboratory evaluations when the polyurethane had been used alone. A total of 148 gallons of the material was used for an average application rate of 134 square feet per gallon. This amounted to a dry film thickness of 6 mils. Treated areas were dry to the touch in approximately one hour. Air bubbles were noted in the prime coat at the rate of two or three per square foot on areas of smooth concrete while areas with a rough surface texture had up to 100 air bubbles per square foot.

The membrane application began on the southerly simple span the following day. Although the solvent cut prime coat had been easy to apply, the high viscosity of the uncut two component polyurethane made it difficult to remove from the mixing drum and also difficult to spread with squeegees. Close control resulted in an application rate of 35.7 s.f./gal (36.4 s.f./gal ideal) for the first 20 gallon batch, although the thickness of the membrane varied considerably within the treated area (the manufacturer recommends an airless spray application for greater uniformity of coverage).

In an attempt to obtain a more even coverage and to speed up the application procedure, two gallons of xylol solvent were added to each 20 gallon batch of Polytok Membrane. Application data furnished by the manufacturer stated that a solvent could be added to the polyurethane at the rate of one pint per gallon for spray applications. The lower viscosity made the application easier but the speed up resulted in an application rate of 65 square feet per gallon on the remainder of the simple span. Because of the light application, roofing sheet was not placed on the membrane until a second coat of the polyurethane was placed on the area later in the day.

As the membrane application progressed, 65 pound asphalt saturated roofing sheet was rolled into the liquid membrane. The time lapse between applying the polyurethane and placing the roofing sheet varied between 30 minutes and one hour. In all cases, good initial bond was established between the sheets and membrane making it impossible to realign any rolls which were placed with poor alignment. When the supply of 65 pound

roofing sheet was exhausted, 50 pound sheets were used on the northerly quarter of the deck and over the simple span after the second coat of polyurethane was applied.

A large number of air bubbles and pinholes appeared in the liquid membrane shortly after application. In the first area treated with the polyurethane without solvent, equal amounts of air bubbles and pinholes were noted at the rate of from 75 to 150 per square foot. When the solvent was added to the polyurethane, somewhat fewer air bubbles and pinholes were detected. During the late afternoon application, the number of air bubbles and pinholes decreased to an average of from 10 to 20 per square foot. The decrease coincided with the peak in the normal daily air temperature cycle. This further substantiates the belief that most air bubbles and pinholes are caused by the escape of air from the concrete (out-gassing) brought about by increased air pressure which is the result of a rise in temperature.

Pinholes and air bubbles in the cured membrane on the southerly span did not reveal any open areas of concrete when visually inspected and tested with hydrochloric acid. The testing included breaking open the air bubbles in the membrane. It should be noted however, that visual observations and the use of acid would probably not disclose the presence of minute holes in the membrane.

When the entire deck had been covered with one coat of polyurethane, a second application was made over the simple span to increase the membrane thickness. This area was covered immediately with the 50 pound roofing sheet. The final step was the application of a second coat of polyurethane over a three foot width adjacent to the curbs and the placement of roofing sheet over it.

The overall application rate for the deck was 37.9 square feet per gallon which amounted to a 38 mil coating. Combined with the six mil prime coat, the total coverage amounted to a 44 mil dry film thickness.

Application of the first 1" course of pavement began on the southerly simple span on June 16, 1972, three days after the membrane had been applied. The first problem occurred when the tires on one side of the paver began spinning as the paver lapped the first pass of bituminous pavement. The spinning was believed due to a combination of the 2.5% grade and the fact that the roofing sheet has softened beneath the 260° bituminous

mix. The dislocated roofing sheet was removed and the remainder of the simple span was paved without further difficulty.

The first pass down the continuous span resulted in approximately 350 square foot of improperly placed pavement. The problem was caused by a lack of bond between the roofing sheet and the Polytok Membrane. This resulted in pieces of the roofing sheet periodically blocking sections of the pavers screed. The blockage prevented the bituminous mix from being placed as the paver moved ahead. The second pass with the paver resulted in about the same number of problem areas. In addition to the open areas in the pavement mat, a number of cracks developed in the pavement during compaction. Some of the cracks appeared to be over the ends of the roofing sheets while others were at locations where the roofing sheet had become wrinkled or dislocated.

Before the third pass was made with the paver, most of the unbonded roofing sheet was removed. This included all of the 65 pound roofing and about half of the 50 pound roofing, since some of the latter was bonded to the polyurethane. The complete lack of bond experienced with the heavier roofing sheet may have been partially due to its grittier surface coating. The pavement application was stopped after the third pass leaving a 12 foot width of deck unpaved.

The lack of bond between the roofing sheet and the polyurethane may have been caused by a combination of factors. According to Carboline field technicians, who inspected the bridge deck at a later date, the lack of bond was caused by too long a delay in placing the roofing sheet on the polyurethane. They described the initial bond that had been experienced between the roofing sheet and membrane as a false bond. This explanation made sense in that the roofing sheet did not create similar problem on the simple span, where it was placed shortly after the second polyurethane application was made.

The lack of bond did not appear to be related to the fact that the polyurethane had not completely cured at some locations. Areas where the roofing sheet had not bonded were completely cured whereas areas where the roofing sheet was partially bonded were often surrounded by areas of uncured polyurethane. The uncured polyurethane appeared and felt similar to a firm, moist sponge. The suspected reason for the lack of cure was that the solvent was not able to escape after the roofing sheets were applied and consequently prevented the polyurethane from curing. This tends to contradict the reasoning that the

roofing sheet did not bond because the polyurethane had cured too much before the sheets were placed. Another possible reason for lack of cure was improper or insufficient mixing of the polyurethane components.

Due to numerous cracks and the lack of bond between the pavement and membrane system, the pavement was removed on July 24, 1972. When the use of a gradall resulted in damage to the membrane on the northerly end of the deck, a grader was used to remove the remaining pavement with very little damage resulting. The pavement was not removed from the southerly simple span.

Although scattered spots of uncured polyurethane were found over approximately 40 percent of the area where the pavement was removed, an inspection seven days later disclosed that all of the polyurethane had completely cured. This included approximately 800 square feet of damaged membrane which had been given a second coat three days before the inspection.

No difficulties were reported during the reapplication of the pavement. However, an inspection made several days later revealed a number of cracks and porous areas in the pavement. Soundings taken with a steel rod indicated hollow areas over at least 10 percent of the area checked. At many locations, tapping with the steel rod caused water to bubble out of the cracks and porous areas in the pavement.

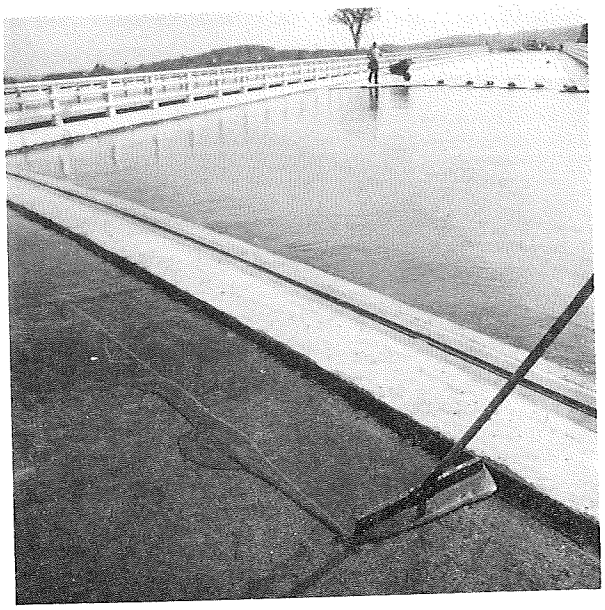
Electrical resistance readings taken on the polyurethane without roofing sheet ranged between 5,800 and 180,000 ohms with an average of 60,000 ohms per square foot. Such readings indicate that moisture is able to pass through the membrane. Readings taken on the membrane with roofing sheet averaged 1.3 million ohms while readings taken on the first inch of pavement and membrane without roofing sheet averaged 1.8 million ohms. When the second course of pavement was placed, electrical resistance readings taken on the southerly simple span ranged between 140,000 and 8 million ohms.

Follow-up evaluations will be confined to areas not damaged by the removal of the first course of pavement.

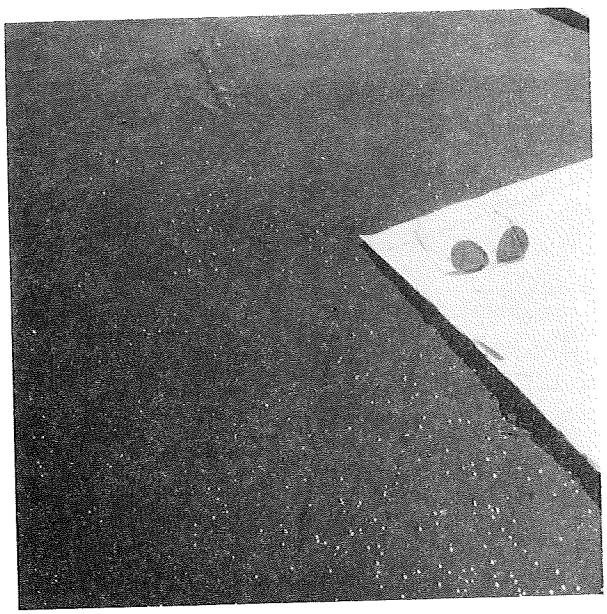
POLYTOK MEMBRANE 165

I 91 SB over Barton River

June 1972

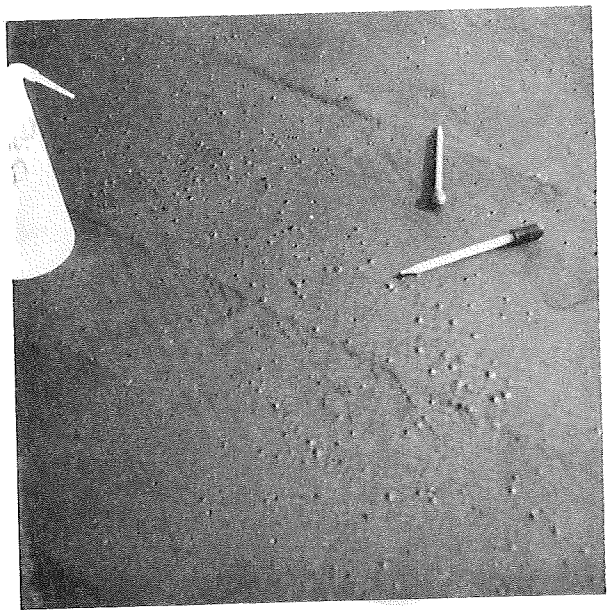


Applying 40 mil finish coat over a prime coat of Polytok Membrane cutback 50% with xylol.



Bubbles and pinholes which appeared in the liquid membrane shortly after application.

Covering the liquid polyurethane with asphalt roofing sheets.



Inspection of the bubbles and pinholes visually and with the use of hydrochloric acid revealed no open areas of concrete.

POLYTOK MEMBRANE 165

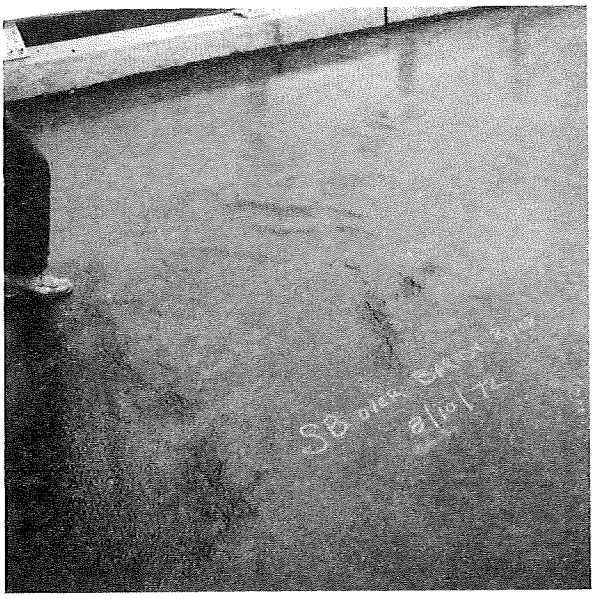
I 91 SB over Barton River

June 1972

Movement of the unbonded roofing sheet caused blockage of the paver screed.

Removal of unbonded roofing sheet revealed partially cured polyurethane in some areas.

Removal of the pavement with a grader was accomplished with very little damage to the membrane.



The reapplication of pavement on the polyurethane without roofing sheet resulted in numerous cracks and porous areas.

WORK PLAN #7 - CONTROL SECTION

TAR EMULSION AND GLASS FABRIC

PROJECT

Barton-Derby EMP I 91-3 (20)

CONTROL SECTION

I 91 northbound bridge over State Aid Highway #3, Canadian Pacific Railroad and Barton River at station 2537+15.45 - 2541+62.88, 1.7 miles north of the US Rte 5 Interchange at Orleans.

BRIDGE CONSTRUCTION DATA

Type of Structure - 1 simple span (composite) and 3 span continuous (welded plate girder - composite).

Span Lengths - 75' - 113' - 141' - 113'

Overall Length - 442'

Curb to Curb Width - 39.33'

Skew - 47° 30' lt.

Horizontal Curvature - None

Grade - -2.500%

Superelevation - ¼"/ft

DECK CONSTRUCTION DATA

Deck Thickness - 8"

Concrete - Class AA

Cement - Type 1 6½ bags per c.y.

Aggregate Size - 3/4" maximum

Finishing Method - Capital finishing machine on outside beams skewed 47° 30' left.

Curing - Polyethelene sheeting with water spray on curb sections

Surface Texture - Broomed finish

SECTION 1 - (simple span)

Date Poured - May 11, 1971

Weather Conditions - Sunny 30% humidity

Temperature - Low 45°F High 70°F

DECK CONSTRUCTION DATA - cont'd

Concrete Cover Over Reinforcing Steel - 1 7/8"- 2 1/8" 2" average on 10 tests

Air Entraining Admixture - Darex 9 oz per c.y.

Retarding Admixture - None

Pour Sequence - From north to south

Concrete Test Results:

Percent Air - Low 6% High 7¼% 6½% average on 10 tests

Slump - Low 3½" High 4" 3½" average on 4 tests

Modulus of Rupture - 724 psi average at 28 days

SECTION II - (3 span continuous)

Date Poured - May 18, 1971

Weather Conditions - Sunny 30% humidity

Temperature - Low 45°F High 90°F

Concrete Cover Over Reinforcing Steel - 2" assumed

Air Entraining Admixture - Darex 7 to 9 oz per c.y.

Retarding Admixture - Daratard H.C.

Pour Sequence - Placement from both ends to the middle with full depth at the north end and the final 2" placed on the southerly end last.

Concrete Test Results:

Percent Air - Low 5½% High 9% 7¼% average on 54 tests

Slump - Low 2" High 4" 3½" average on 45 tests

Modulus of Rupture - 709 psi average at 28 days

DECK CONDITION

Surface Texture - The broomed concrete surface varied from smooth to quite rough.

Cracks - Transverse cracks were visible on the continuous spans.

Steel Corrosion Readings - None taken prior to placement of membrane and pavement.

PROTECTIVE TREATMENT

Product - Tar emulsion and woven glass fabric
The brand of tar emulsion used was PR55-CTP manufactured by the Triram Corporation, 721 Waverly Street, Framingham, Massachusetts. The glass fabric was manufactured by Burlington Glass Fabrics Co.

Test Results - Water content of the tar emulsion averaged 52% by weight.

APPLICATION PROCEDURE

(1) Prime coat of tar emulsion applied on moist concrete and allowed to dry.

(2) Coat of tar emulsion followed with the placement of a layer of glass fabric

(3) Coat of tar emulsion with a layer of glass fabric placed perpendicular to the first layer of fabric.

(4) Coat of tar emulsion which is allowed to dry.

(5) Finish coat of tar emulsion.
The total coverage for the five coats of tar emulsion should be approximately ½ gallon per square yard.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	
5/24/72		Clear 5 - 15 mph breeze Air temperatures recorded in shade.
9:00	65°	Deck cleaned using air blower, brooms and water.
10:00	67°	Prime coat of tar emulsion applied with a mechanical applicator.
11:15	69°	Began applying glass fabric along the curb. Prime coat although dry to the touch, is sticking to workmens' feet and consequently is being pulled from the concrete in many areas.
4:30	71°	Began placing transverse strips of glass fabric along the skew of the bridge.
7:15	66°	Application stopped. 700 s.y. covered with 3 coats of tar emulsion and 1 layer of glass fabric. 470 gallons applied on 4066 s.y. for an application rate of 0.115 gal/s.y./application.
5/25/72		Clear 3 - 10 mph breeze.
6:00	42°	Application started.
9:15	55°	First layer of glass fabric complete on continuous spans.
10:30	60°	First layer of glass fabric complete on simple span.
11:45	63°	Began placing longitudinal strips of glass fabric.
5:30	65°	Application complete on continuous spans. Starting on simple span.
5/26/72		Clear 3 - 5 mph breeze.
8:00	49°	Began applying the final coat with a mechanical applicator.
10:00	60°	Finished applying final coat along curbs with brushes. 951 gallons of tar emulsion applied for an average application rate 0.48 gallons per square yard.

COST OF PROTECTIVE MEMBRANE AND CONCRETE WEARING SURFACE

Membrane Treatment -	1988 s.y. @ $4.00/s.y. =	$7,952.00
Bituminous Concrete -	Two - 1 inch thick courses 273 tons @ $7.00/ton =	$1,911.00

DISCUSSION

The prime coat of tar emulsion did not display good adhesion to the concrete surface in many areas. This was revealed when the material stuck to the workmens' shoes leaving exposed concrete when they began applying the second coat. The problem was believed due to a lack of sufficient moisture on the surface of the concrete during the application of the prime coat although the mechanical applicator was designed to apply a light misting of water on the concrete proceeding the tar emulsion.

Many wrinkles occurred during the initial application of the transverse strips of glass fabric. This was due to windy conditions and an inexperienced crew. Therefore the usual method of placing the glass fabric into a fresh coat of tar emulsion was modified to allow placing the glass fabric on the deck and working the emulsion into it. This change was approved by the company representative on the project. After the workmen became experienced in handling the glass fabric, the normal procedure was used.

Difficulties were also encountered in applying the system along the curbs. A wallpaper brush proved beneficial in smoothing and removing excess tar emulsion from the treated area of the curb and also in pressing the fabric into voids and rough areas. However, inspection of the completed system revealed many areas along the curbs which did not appear to be adequately sealed. The membrane system also disclosed areas which did not appear to have a satisfactory buildup of tar emulsion over the glass fabric. These areas were the result of rough concrete surface conditions which required more tar emulsion than the specified one-half gallon per square yard. The overall application rate for the deck averaged 0.48 gallons per square yard.

An 18 inch square concrete test slab with two inch shoulders was treated with tar emulsion and glass fabric when the membrane system was applied on the bridge. After curing, the sample was exposed to freeze-thaw cycles in the laboratory. Blisters and bubbles were observed in the sample after five cycles. The results were similar to those that occurred on other samples tested in the same manner in the laboratory several months earlier.

Electrical resistance readings were taken on the membrane system alone, and with one inch of pavement. Because water was allowed to flow from the test area in some cases, the results were later considered invalid. Field experience has indicated that if water is allowed to flow from the one square foot test area, resistance readings will decrease. This is particularly true if the water flows along the curb where it may contact drain gutters or areas not properly sealed. Electrical resistance readings taken on the completed pavement and membrane system were also incomplete in that insufficient testing time was allowed at each test location.

TAR EMULSION & GLASS FABRIC

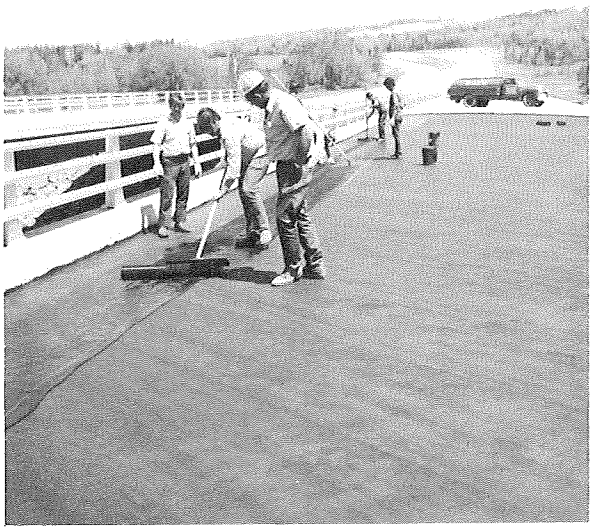
I 91 NB over S.A. No. 3, C.P.R.R. & Barton River

May 1972

Placing the second coat of glass fabric along the curb.

Working tar emulsion into the glass fabric extending up the curb.

Placing transverse strips of glass fabric along the skew of the deck.

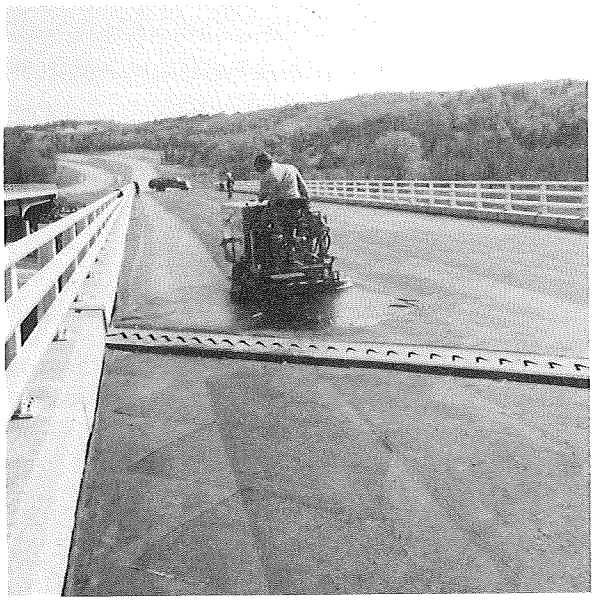


Placing longitudinal strips of glass fabric.

TAR EMULSION & GLASS FABRIC

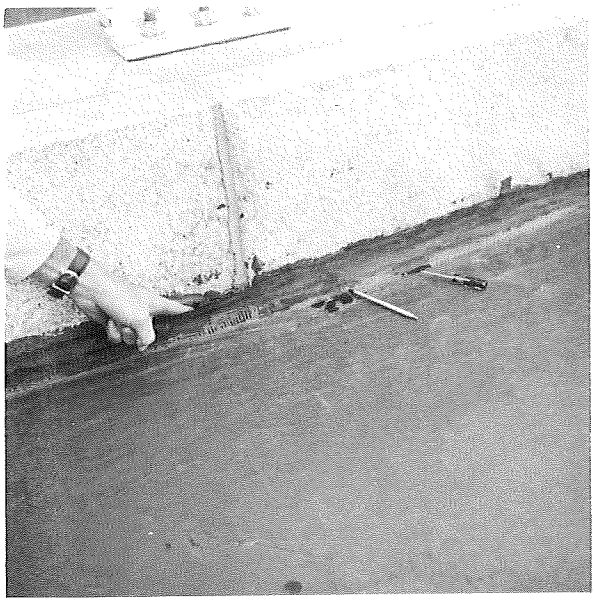
I 91 NB over S.A. No. 3, C.P.R.R. & Barton River

May 1972

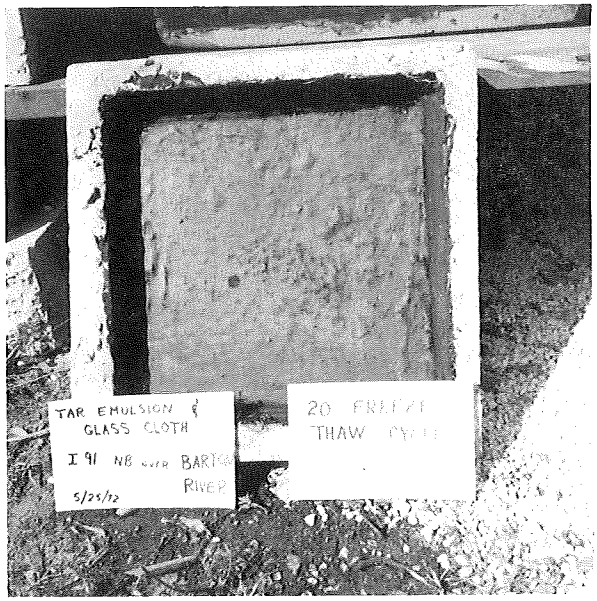


Placing final coat of tar emulsion with mechanical applicator.

Areas with a rough or uneven concrete surface did not appear to have a sufficient buildup of tar emulsion when the final coat had dried.



The system's sealing value did not appear satisfactory at many locations along the curbs.



A concrete sample treated at the project site developed blisters when it was covered with water and exposed to five freeze-thaw cycles.

WORK PLAN #8 - INITIAL REPORT

DURALKOTE 306 EPOXY

PROJECT

Barton EMP I 91-3 (19)

PROJECT LOCATION

In the County of Orleans, Vermont, beginning at the point of intersection with Vt Rte 16, southerly of Barton Village and extending northerly approximately 5.417 miles.

WORK LOCATION

I 91 northbound bridge over Town Highway #29 at station 2358+21 - 2359+10, 3.8 miles north of the Vt Rte 16 interchange at Barton.

CONTROL SECTION

I 91 northbound bridge over State Aid #2. See data on pages 11 to 15.

BRIDGE CONSTRUCTION DATA

Type of Structure - Simple span

Span Length - 79.06'

Overall Length - 89'

Curb to Curb Width - 39.33'

Skew - 17^{o} - 07' - 20"

Horizontal Curvature - Tangent

Grade - + 0.2500%

Superelevation - ¼"/ft

DECK CONSTRUCTION DATA

Date Poured - June 23, 1971

Weather Conditions - Clear 25% humidity 5 mph breeze

Temperature - 74^{o}F

Deck Thickness - 8"

Concrete Cover Over Reinforcing Steel - 2" - 2¼" 2 1/8" average

Concrete - Class AA

DECK CONSTRUCTION DATA - cont'd

Cement - Type I 6½ bags per c.y.

Aggregate Size - 3/4" maximum

Air-Entraining Admixture - Darex 9 oz per c.y.

Retarding Admixture - None

Pour Sequence - North to south

Finishing Method - Capitol finishing machine on outside beams, skewed 17°

Surface Texture - Broomed finish

Curing - Sprinkler hoses along curb lines plus plastic cover

Concrete Test Results:

Percent Air - Low 5½% High 7½% 6.55% average on 15 tests

Slump - Low 2½" High 4" 3.4" average on 14 tests

Modulus of Rupture - 830 psi average @ 28 days

DECK CONDITION

Surface Texture - Light broom finish

Cracks - None detected

Laitance - Less than the normal amount of laitance on the surface of the concrete

Miscellaneous - The deck had asphalt droppings on the concrete

Steel Corrosion Readings - Initial readings taken on the deck averaged 0.12 volts, indicating no active corrosion.

PROTECTIVE TREATMENT

Product - Duralkote 306 - Coal Tar Epoxy Sealer
A 100% solids, two component, rapid setting, bituminized epoxy manufactured by Dural International Corporation, 95 Brook Avenue, Deer Park, New York 11729

Test Results - The material was certified to meet the Vermont Department of Highways specification for Item 372-B, Epoxy Membrane Sealer.

RECOMMENDED APPLICATION PROCEDURE

All contaminants must be removed by sandblasting or other mechanical means. Acid etching may be used in lieu of sandblasting on new or relatively clean

RECOMMENDED APPLICATION PROCEDURE - cont'd

concrete. Combine one part by volume of Base with one part by volume of Hardner and mix thoroughly. A one gallon quantity has a pot life of approximately 10 minutes at 75°F. The material can be applied with a brush, spray, roller or squeegee. Sand should be broadcast into the resin within 5 minutes of application.

DECK PREPARATION PRIOR TO MEMBRANE APPLICATION

Most of the asphalt droppings on the deck were removed by sandblasting. Five hundred pounds of sand was used in a 2 hour period for that purpose. The deck was then washed clean with water. After the concrete had dried, a 12% muriatic acid solution was applied on the concrete surface with water sprinkler cans. The deck was treated in two sections to insure that the concrete could be properly flushed before any of the acid salts could dry on the surface. After completion of the final section, an additional 1000 gallons of water was applied with a high pressure hose. The surface of the concrete was checked with litmus paper to insure that all of the acids had been removed.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humidity	
	7/29/72		Air temperatures recorded in shade. Partly cloudy.
11:00	75°	33	Began mixing first 4 gallon batch. Epoxy applied at the rate of 87 sf/gal on northerly end of deck and 3' onto approach slab. A 20-30 mesh silica sand was cast on the liquid epoxy.
11:20			4 gallons applied at the rate of 46 sf/gal. Air bubbles noted immediately in thicker coating.
11:35			1 quart solvent (xylol) added to 4 gal batch to improve penetration into the concrete. Lower viscosity resulted in an application rate of 117 sf/gal.
12:10	74°	45	16 gallons on 1260 sf for an average application of 89 sf/gal. Area hit by a 10 minute shower. The rain cut some of the oil in the epoxy. Four gallons of epoxy wasted.
1:30			The epoxy is slightly tacky in all areas.
2:30			Most of the epoxy is flexible but no longer tacky. Appears to be curing out.
	7/31/72		Clear until mid-afternoon.
8:00	63°	49	Sweeping and blowing dust and dirt off the deck. The epoxy which had been rained on before curing has a dull surface finish but appears to be satisfactory otherwise.
8:30	66°	47	Began mixing. One quart xylol added to each 4 gal batch
9:00	69°	37	16 gallons applied. Some air bubbles and bubble clusters can be seen in the fresh epoxy.
9:40	71°	42	First coat complete. 25 gallons applied on 2460 sf for an average application rate of 98 sf/gal. Overall coverage for the first coat was 90.7 sf/gal.
2:30	86°	25	Began applying second coat. No solvent used. Trying for an application rate of 35 sf/gal as recommended by manufacturer.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION - cont'd

Time	Temp	% Humidity	
	7/31/72 cont'd		
5:00	86°	32	68 gallons applied on 2480 sf for an average application rate of 36.5 sf/gal.
5:45	78°	39	Application complete. 113 gallons applied on second coat for an overall application rate of 32.9 sf/gal.
			154 gals. applied on 3720 s.f. for a total coverage of 24.2 s.f./gal or an average of 48.4 s.f./gal/coat.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 158 gallons @ $40.00/gal = $6,320.00
Cost per s.y. = $ 15.30

Bituminous Concrete - Two - 1 inch thick courses
76 tons @ $7.00/ton = $ 532.00

DISCUSSION

The surface preparation of the deck, which included acid etching and selected sand-blasting, resulted in an excellent gritty surface texture that was free of laitance or other surface protrusions.

The application of Duralkote 306 Coal Tar Modified Epoxy was efficiently handled as a three man operation. Two gallons of each component were drawn from 55 gallon drums and mixed for a three minute period with a jiffy mixing blade. The material was then poured in a windrow across the deck and spread out with a squeegee. The first pass always left many holidays but when the material was reworked in the opposite direction, the concrete appeared to be completely coated. Ottawa silica sand (20-30 mesh) was then immediately broadcast onto the liquid epoxy. Although the ten minute pot life had been expected to cause some problems, it turned out that the material could easily be applied in eight or nine minutes including the three minute mixing time.

The application rate for the first four gallon batch was 87 square feet per gallon. The second unit was applied at a much lower rate for a comparison. When more air bubbles were noted in the thicker coating, a decision was made to apply a light initial coat and a heavier second coat. The manufacturer had not specified a two coat system but did acknowledge that two coats might reduce or eliminate pinholes in the membrane. The manufacturer had recommended that a solvent be added to the epoxy used in the first coat to lower the viscosity of the material and thereby increase the extent of its penetration into the concrete. This was done at the rate of one quart of xylol per four gallons of epoxy.

After 16 gallons of epoxy had been applied, a sudden rain shower hit the work area. The downpour cut some of the oil or bituminous components in the epoxy causing it to flow off the deck with the runoff water. The area involved consisted of 29 lineal feet along the northerly end of the deck and three feet on the approach slab with a total area of 1260 square feet. Inspection of the area about two hours after the shower disclosed that the epoxy had cured although it had a dull surface finish rather than the normal glossy finish. It was also noted that a small amount of water could be drawn out of the epoxy in some areas by rubbing the oily feeling surface. The remainder of the

first coat was applied two days later without incident. The application rate for the first coat ranged between 46 and 130 square feet per gallon with an overall rate of 90.7 square feet per gallon. This amounted to an average thickness of 17 mils.

Bubbles, bubble clusters and pinholes occurred at varying rates in the initial coat. The bubble clusters consisted of approximately a dozen small air bubbles grouped together. They were believed to be caused by the solvent in the epoxy. Many of the bubbles disappeared as the epoxy hardened while some remained in the form of pinholes in the membrane.

The application of the second coat began as soon as the first coat was tack free. An application rate of 35 square feet per gallon was aimed for as verbally recommended by the manufacturer while the actual rate varied between 25 and 55 square feet per gallon. The overall application rate for the second coat was 32.9 square feet per gallon for a mil thickness of 52. The total coverage for both coats was 24.2 square feet per gallon for a thickness of 69 mils.

Inspection of the second coat during and shortly after application revealed air bubbles up to 5/8 inch in diameter on the northerly end of the deck. This was on the area where the first coat had been rained on. Relatively few bubbles were noted on the remainder of the deck. Observations made the following day disclosed that almost all of the air bubbles in the membrane had changed to pinholes or small depressions. Areas checked on the northerly end of the deck averaged 75 pinholes per square foot. The pinholes were apparently not open to the concrete however, since electrical resistance readings were very high and testing with hydrocloric acid did not produce any effervescence. Many areas on the southerly half of the deck were free of pinholes or depressions while scattered areas had an average of eight or ten pinholes per square foot. The general appearance of the membrane, particularly along the critical curb areas gave the visual impression that the concrete was well sealed. It was also noted that the membrane was quite flexible to the touch.

An attempt to check the bond between the two coats of epoxy was made by striking the membrane with a hammer. This revealed that the top coat on the northerly approach slab could easily be pealed from the bottom layer after the membrane had been cracked

open. This was undoubtedly due to the affect of the rain on the first coat since when the same procedure was tried on an area where the first coat had not been exposed to rain, the material could not be separated into two individual layers.

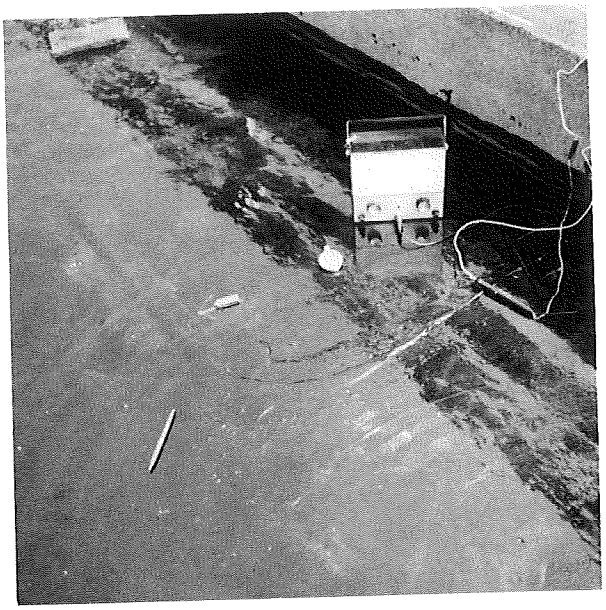
Electrical resistance readings were taken on the epoxy membrane shortly before the bituminous pavement was placed. The readings ranged from a low of 1.2 million ohms to a high of 700 million ohms with an average of 30 million ohms per square foot. One set of moisture sensing copper foil strips was also placed beneath the membrane to monitor any future penetration of moisture through the pavement and membrane system.

The first one inch course of bituminous pavement was placed with a rubber tired paver approximately 19 hours after the final coat of epoxy had been applied. No difficulties were encountered during the paving operation nor was any damage to the membrane observed when the hot mix was removed from several areas for inspection.

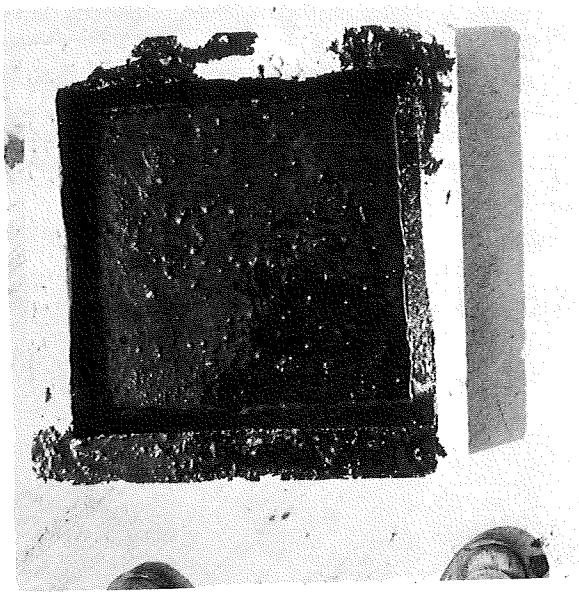
Soundings taken with a steel rod on the first course of pavement did not indicate any hollow areas between the pavement and the epoxy membrane. However, a lack of bond between the two materials was exhibited in one area when the bituminous mix stuck to the tire of a vehicle which had been parked leaving a hole in the pavement.

Electrical resistance readings taken on the completed pavement and membrane were in excess of 50 million ohms indicating that the pavement-membrane system is highly impermeable.

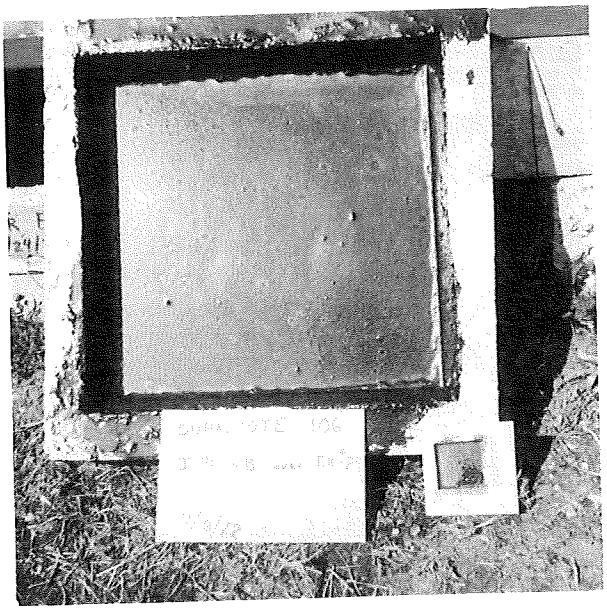
DURALKOTE 306 EPOXY
I 91 NB over Town Highway No. 29
July 1972



Taking initial readings on copper foil strips. Note bubbles where extra epoxy was placed over lead wires.



Bubbles and pinholes in first coat of epoxy placed on concrete test slab.



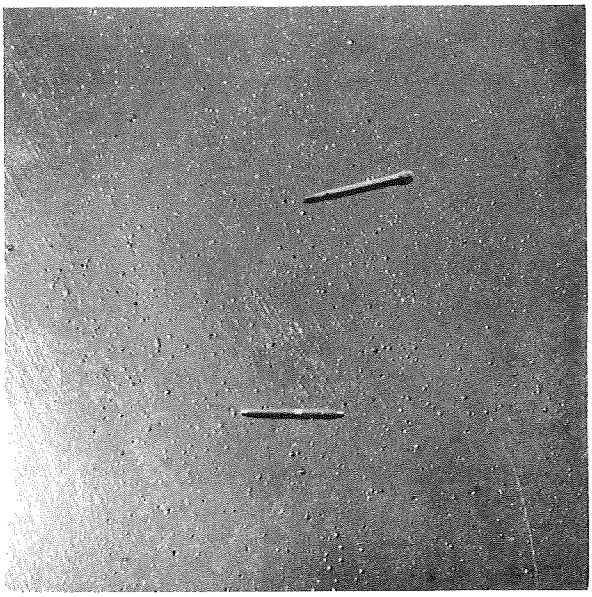
Concrete test slab after second coat of epoxy had cured.

The lack of bond between pavement and epoxy is revealed by area where the hot mix stuck to the tire of a parked vehicle.

DURALKOTE 306 EPOXY

I 91 NB over Town Highway No. 29

July 1972



First coat applied at the rate of 46 sf/gal. without solvent resulted in many air bubbles and pinholes.

First coat thinned with solvent and applied at the rate of 125 sf/gal. resulted in bubble clusters numbering about 5 per sf.

Applying second coat at an average rate of 33 sf/gal.

Air bubbles up to 5/8" diameter appeared in the second coat placed over the section of prime coat which had been rained on. Many areas on the southerly end of the deck had no pinholes.

WORK PLAN #9 - INITIAL REPORT

HEAVY DUTY BITUTHENE

PROJECT

Barton EMP I 91-3 (19)

PROJECT LOCATION

In the County of Orleans, Vermont, beginning at the point of intersection with Vt Rte 16, southerly of Barton Village and extending northerly approximately 5.417 miles.

WORK LOCATION

I 91 southbound bridge over Town Highway #29 at station 2359+40 - 2360+29, 1.7 miles south of the US Rte 5 Interchange at Orleans.

CONTROL SECTION

I 91 northbound bridge over State Aid Highway #2. See data on pages 11 to 15.

BRIDGE CONSTRUCTION DATA

Type of Structure - Simple span

Span Length - 78.37'

Overall Length - 89'

Curb to Curb Width - 39.33'

Skew - 18° 33' 30"

Horizontal Curvature - Tangent

Grade - + 0.09818%

Superelevation - ¼"/ft

DECK CONSTRUCTION DATA

Date Poured - July 15, 1971

Weather Condition - Clear 25% humidity 5 mph breeze

Temperature - 72°F

Deck Thickness - 8"

Concrete Cover Over Reinforcing Steel - 2" - 2½" 2¼" average

Concrete - Class AA

Cement - Type I 6½ bags per c.y.

Aggregate Size - 3/4" maximum

Air Entrainment Admixture - Darex 7 to 8 oz per c.y.

DECK CONSTRUCTION DATA - cont'd

Retarder Admixture - None

Pour Sequence - Continuous placement from south to north

Finishing Method - Capitol finishing machine on outside beams

Surface Texture - Broomed finish

Curing - Sprinkler hoses along curbs and centerline plus plastic cover

Concrete Test Results:

Percent Air - Low 5½% High 7% 6.2% average on 11 tests

Slump - Low 2½" High 4" 3.2" average on 11 tests

Modulus of Rupture - Average 742 psi at 28 days

DECK CONDITION

Surface Texture - Light broom finish

Cracks - None detected

Laitance - Less than the normal amount on the surface of the concrete

Miscellaneous - The deck had a large amount of asphalt droppings scattered over the entire area with heavy concentrations in the main wheel paths at either end of the bridge.

Steel Corrosion Readings - Initial readings taken on the deck averaged 0.13 volts, indicating no active corrosion.

PROTECTIVE TREATMENT

Product - Bituthene Heavy Duty Membrane manufactured by W. R. Grace & Company.
Heavy Duty Bituthene consists of a woven polyproplene mesh coated on one side with a factory applied layer of adhesive-consistency, rubberized asphalt. The total thickness of the membrane is approximately 80 mils. The material is supplied in 3 ft wide by 45 ft long rolls interwound with a special release paper which protects the adhesive surface until it is ready to apply.

Test Results - The material was applied on a 24" square concrete slab which was constructed with 3" high curbing on all sides. The sample did not leak or show other signs of failure after six months of testing. The test period included freeze-thaw cycles and 30 days of sub-freezing temperatures down to a low of -15°F. Application of bituminous mixes up to 300°F in temperature were made on samples without apparent damage to the material.

RECOMMENDED APPLICATION PROCEDURE

Bituthene primer is applied on the concrete surface by brush, roller or spray at the rate of 200 to 400 square feet per gallon. When the primer has dried for one hour or until tack free, the sheet membrane application may begin. A bead of Bituthene Mastic is placed at the base of the curbing with a caulking gun. Short strips of Bituthene approximately 8 inches wide are cut from a roll and placed along the base of the curbing so that the material extends up the curb the desired height. A second complete roll of the material is then placed over the strips placed along the curb. Successive rolls are placed with 4 inch edge overlaps and 6 inch end overlaps. The sheets are placed from the low point to the high point of the deck with the sheets overlapping in shingle fashion. In the case of a bridge with a normal crown application should be made from both sides to the middle with the center strip overlapping the adjacent strips. After the membrane has been rolled to insure complete contact with the concrete, a bead of Bituthene Mastic should be applied to all exposed edges. A protective wearing course of pavement should be applied within 30 days.

DECK PREPARATION PRIOR TO MEMBRANE APPLICATION

Sand and other material was washed off the deck with high pressure water. Most of the thick lumps of asphalt were removed with chisels and grass edging tools. Removal of numerous small asphalt droppings was not required according to the product manufacturer's representative who was on the project.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humidity	% Cloud Cover	
		8/14/72		Temperatures recorded in shade.
7:00			100	Light rain shower.
10:00	68°	47	90	Concrete dry except along curbs.
10:30	69°	46	90	Began primer application along the westerly curb. Some moisture present along the curb line but W. R. Grace representative not concerned.
11:15	68°	36	40	Temperature 78° in sun. Prime coat complete on 3/5 of deck.
11:30	68°	36	40	Began applying 5/8" bead of mastic and 8" wide strips of membrane along the curb. Noticed that the primer did not bond to some of the areas of concrete which had moisture. The material could be rolled off the concrete with a finger. Copper foil strips placed 7' from the westerly curb at sta 45-50, 3' from the westerly curb at sta 81-86, and 3½' from the easterly curb at sta 86-91.
12:45	72°	39	90	Began placing first full roll of Bituthene along curb over 8" wide strips. Material cut in 6' to 10' strips in order to make the application up onto the curb easier. Material bonds very readily to the concrete.
1:30	69°	45	100	94 lineal feet of membrane applied in 45 minutes.
2:00	70°	44	100	Primer application completed along easterly curb. 15 gallons used on 3730 s.f. for an application rate of 249 sf/gal.
3:30	71°	40	80	5 gallons of Bituthene mastic was placed in ½" joint at southerly end of deck and 1½" wide cork filled joint at northerly end of deck.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION - cont'd

Time	Temp	% Humidity	% Cloud Cover	
	8/14/72 cont'd			
5:00	69°	42	100	Approximately ½ of the deck covered (200 sy), seven strips wide. Numerous small air bubbles trapped beneath the sheets.
	8/15/72			
8:15	55°	48	100	Began application along the easterly curb.
10:45	66°	40	100	Nine rolls applied. Application becoming easier with experience.
12:00	72°	35	100	Thirty rolls placed on the deck. Difficulty in attaining proper alignment resulted in considerable waste with overlaps. Five more rolls of material will be required to complete coverage.
	8/24/72			
1:30	85°	43	100	Began repriming area requiring membrane. Water detected behind membrane along both curbs.
3:00	86°	44	50	Temperature 94° in sun. High temperature appears to be causing slightly more entrapped air beneath the membrane sheets.
5:00	82°	44	60	Four rolls plus an additional 20 s.f. were used to complete the coverage. Mastic being applied along edges. A total of 4655 s.f. of Bituthene was placed on 3730 s.f. of concrete.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 414.4 sy @ $7.25/sy = $3,004.40

Bituminous Concrete - Two - 1 inch thick courses
72 tons @ $7.00/ton = $504.00

DISCUSSION

A light rain fell on the deck shortly before the Bituthene application was to have started. Approximately one-half hour after the concrete surface first appeared to be dry the W. R. Grace representative on the project gave the OK to begin the primer application. The primer consisting of 75% solvent and 25% rubberized asphalt, was applied with long handled paint rollers. The initial application at the northerly end of the deck and along the westerly curb consisted of clear resin and solvent due to the fact that the first five gallon pail of primer was not stirred prior to application. In-

spection of the quick drying primer disclosed very little bond to several areas along the westerly curb where some moisture had been present during application. Similar areas along the easterly curb were not primed until late in the afternoon when they were thoroughly dry. The overall application rate for the prime coat was 249 square feet per gallon.

When the prime coat was completely dry, a 5/8 inch bead of Bituthene mastic was applied at the base of the curb. Short strips of the membrane averaging eight inches in width were then placed along the base of the curb so that they extended up the curb approximately two inches. Six to ten foot long strips of the membrane sheet were then placed on the deck over the short strips, once again extending up the curb two inches, to form a double application at the curb line.

The application of the complete rolls on the deck progressed slowly at first. This was due mainly to the difficulty in attaining proper alignment of the rolls. Without correct alignment it was necessary to cut the material and restart the application in order to insure proper overlap and not waste material. The adhesive quality of the product did not allow readjustment of the material once it was firmly placed on the concrete. Use of chalk lines on the deck proved to be beneficial but during the first days application many short strips of membrane ranging from 5 to 10 feet in length were common. Some difficulties were also experienced with the release paper sticking to the edges and the bottom of the membrane.

The experience gained the first afternoon resulted in a speed up in the second day's application with four of the first six rolls placed full length without cutting. An experimental roll of Bituthene manufactured in the United States was also placed. The roll was 60 feet in length and had a heavier release paper adjacent to only the adhesive side of the membrane. The heavier release paper eliminated the problem of the paper tearing and also reduced by one-half the amount of waste paper which had to be disposed of. This would amount to a savings in labor since one man kept busy just picking up the waste paper.

The application terminated the second day when all of the available material had been placed. The lack of sufficient material was due to not allowing for overlaps

when the order for material was placed. When the additional material was received and applied, a total of 4655 square feet of membrane sheeting was placed on 3720 square feet of concrete. This amounted to approximately 20 percent more material used then concrete surface area covered. Most was due to the required overlaps and double application at the curb lines. However, 208 square feet or approximately 4.5 percent of the material was waste due mainly to the difficulty in maintaining the correct amount of overlap.

The amount of air trapped beneath the membrane varied at different locations. Slightly more and larger bubbles seemed to occur during the final application when the air temperatures were higher. Most of the air bubbles over 1½ inches in diameter were punctured and the air was squeezed out while the smaller bubbles were allowed to remain. The self sealing characteristics of the material was evidenced during removal of the entrapped air in that if care was not taken as the air was squeezed out, the hole would become sealed and a new hole would have to be made. The size of the air bubbles did not appear to change when the membrane was exposed to sunlight and high air temperatures prior to paving nor did they create any problems when the bituminous pavement was placed.

Inspection of the membrane system eleven days after the initial application had been made disclosed that water had gotten behind the membrane along both curbs. Twelve small openings where water may have entered were detected on the top edge of the membrane along the westerly curb. However, no open areas could be found along the easterly curb. This gives speculation to the possibility that the water behind the membrane was due to migration of moisture from the back face of the granite curb rather than through the membrane system. The fact that water was able to travel along the vertical face of the curb was due to the membrane not having adequate bond to the epoxy mortar at the base of the granite curb. The lack of bond may have been due to an incomplete primer application on the face of the curb.

Electrical resistance readings taken on the membrane system were all recorded as infinity. Three sets of moisture sensing copper foil strips were also placed beneath the membrane to monitor any future penetration of moisture.

The first one inch course of bituminous pavement was placed with a rubber tired paver on August 29, 1972, five days after the membrane system had been completed. The

application began at 6:45 in the evening with the air temperature at 72°F. The temperature of the bituminous mix ranged between 232°F and 265°F. A number of cracks developed in the pavement during application. They were apparently due to the membrane sheets stretching, since inspection of the membrane beneath cracked areas did not disclose any joints, tears, or other distress. Most of the original cracks in the pavement were sealed during the initial compaction with an 8 to 10 ton roller. However, other cracks developed at that time. They were, in nearly all cases, a reflection of the edges and end of the membrane sheets. When the initial compaction was delayed on one area until the temperature of the bituminous mix dropped to 150°F, very few cracks occurred in the pavement. A total of 21 transverse and longitudinal cracks averaging 1.9 feet in length remained in the pavement when the final compaction was completed.

The final one inch course of pavement was placed on September 1st, utilizing a large rubber tired paver capable of placing hot mix over a 28 foot width. When the paver first traveled onto the section of pavement with the membrane beneath, the pavers' tires caused rutting in the first course of pavement.

The problem was eliminated when the weight of the paver was reduced by not keeping the hopper completely filled with bituminous mix. The rutting which had occurred was removed with compaction and the cracks which had remained in the first course of pavement did not reflect through into the top course.

Soundings taken with a steel rod indicated satisfactory bond between the membrane and bituminous pavement. Electrical resistance readings taken on the membrane and completed pavement were also recorded as infinity.

BITUTHENE HEAVY DUTY MEMBRANE

191 SB over Town Highway No. 29

August 1972

Applying 8-inch wide strips of Bituthene over bead of mastic at the curb line. Note clear primer adjacent to the curb.

Placing 8 to 12 foot long strips on the deck so it extends up the face of the curb approximately 2 inches.

Applying the first continuous roll of Bituthene.

Note short strips due to difficulty in maintaining correct alignment and overlap.

BITUTHENE HEAVY DUTY MEMBRANE

191 SB over Town Highway No. 29

August 1972

Rolling the membrane. Note entrapped air.

Puncturing large air bubbles and sealing the holes and overlaps with mastic.

Water found behind the membrane system at the curb 11 days after installation.

The worst of 21 cracks which occurred in the first course of pavement during the initial compaction.

WORK PLAN #10 - INITIAL REPORT

POLYTOK MEMBRANE 165

PROJECT

Barton EMP I 91-3 (19)

PROJECT LOCATION

In the County of Orleans, Vermont, beginning at the point of intersection with Vt Rte 16 southerly of Barton Village and extending northerly approximately 5.417 miles.

WORK LOCATION

I 91 southbound bridge over Vt Rte 16 at station 2147+98.31 - 2149+78.60 in Barton

CONTROL SECTION

I 91 northbound bridge over Town Highway #40, see data on pages 24 to 27.

BRIDGE CONSTRUCTION DATA

Type of Structure - 3 span continuous WF

Span Lengths - 51' - 77' - 48'

Overall Length - 176'

Curb to Curb Width - 39.33'

Skew - 13° 34'

Horizontal Curvature - None

Grade - -2.000%

Superelevation - ¼"/ft.

DECK CONSTRUCTION DATA

Date Poured - September 24, 1971

Weather Conditions - Fair 25% humidity No breeze

Temperature - 65°F

Deck Thickness - 8"

Concrete Cover Over Reinforcing Steel - 2" - 2½" 2¼" average

Concrete - Class AA

Cement - Type I

Aggregate Size - 3/4" maximum

DECK CONSTRUCTION DATA - cont'd

Air Entraining Admixture - Darex 6 oz/c.y

Retarding Admixture - Plastiment 4-2 oz/sack

Pour Sequence - South to north continuous

Finishing Method - Capital finishing machine

Surface Texture - Broomed finish

Curing - Sprinkler hose and plastic cover

Concrete Test Results:

Air Entrainment - 6% - 6 3/4% 6.4% average on 12 tests

Slump - 2½" - 3½" 3.1% average on 13 tests

Modulus of Rupture - 825 psi average at 28 days

DECK CONDITION

Surface Texture - Slight to moderate broom finish. Northerly end of deck has a number of holes in surface caused by movement of coarse aggregate during brooming.

Cracks - Thirty-two transverse cracks ranging from 1.8' to 39.3' in length were noted in the deck. All cracks were observed on both the top and bottom of the deck. See crack layout on Figure 3, Page 84.

Steel Corrosion Reading - Initial readings taken on the deck averaged 0.13 volts, indicating no active corrosion.

PROTECTIVE TREATMENT

Product - Polytok Membrane 165. A two part modified polyurethane elastomer manufactured by the Carboline Company, 328 Hanley Industrial Court, St. Louis, Missouri 63144.

Test Results - The polyurethane elastomer displayed excellent bond when placed on concrete samples in the laboratory. The material remained flexible at sub zero temperatures and did not appear to be damaged when bituminous mixes were applied at temperatures up to 300°F. The material did not leak or show other signs of failure when placed on a two foot square concrete slab constructed with a three inch high curbing. The test period included freeze thaw cycles and over 30 days of sub freezing temperatures which ranged down to -15°F. The only bad feature noted was that pinholes often developed in the membrane coating shortly after application.

RECOMMENDED APPLICATION PROCEDURE

The initial suggested guide specifications for applying Polytok Membrane 165 were modified as follows, due in part to the problems experienced on Interstate 91 southbound over State Aid #3, the Canadian Pacific Railroad and Barton River.

RECOMMENDED APPLICATION PROCEDURE - cont'd

Remove all dirt and other contaminates from the concrete surface. Fill all holes or other irregularities in the concrete surface with a suitable grouting material. Apply a prime coat by spray or squeegee at the rate of 250-300 square feet per gallon using Polytok components A and B mixed with an equal volume of solvent. Allow the prime coat to become tack free before applying the finish coat. This normally takes 20 to 30 minutes at 75°F. Mix three parts by volume of component A with one part by volume of component B. Mixing time should not be less than five minutes or more than ten minutes per 20 gallon batch. Apply by spray or squeegee at a uniform rate of 30 square feet per gallon for a dry film thickness of 40 mils (previous specifications called for an application rate of 36.4 square feet per gallon to obtain a 40 mil dry film thickness). After 15 minutes and within 45 minutes of when the polyurethane is applied, place 30 pound asphalt saturated asbestos roofing felt over the membrane. Sheets should be laid parallel to each other with a minimum of 3/4 inch gap between edges and with ends butted. The felt sheets should be rolled to insure complete adhesion and to remove any air pockets or "fishmouths". Large "fishmouths" should be slit with a knife and adhered. Allow five hours cure at 70°F before applying wearing surface.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humidity	
8/23/72			Air temperatures recorded in shade. Clear. Carboline field service technician on project.
8:00	66°	69	Began mixing polyurethane with solvent (Xylol) at 50%-50% rate.
9:30	71°	53	8 gallons applied with squeegee on 900 s.f. Application made as light as possible as recommended by Carboline representative.
10:15	76°	57	32 gallons applied on 5800 s.f.
11:15	80°	58	A total of 50 gallons (25 polyurethane + 25 solvent) applied on 7200 s.f. for prime coat application rate of 144 s.f. per gallon.
2:00	80°	50	Hazy. Prime coat tack free. Electrical resistance readings on the prime coat averaged 2150 ohms.
3:00	79°	46	Began mixing 20 gallons of polyurethane with 1 gallon of xylol for finish coat application. Material mixed for seven minutes with jiffy mixing blade.
3:20	74°	66	20 gallons applied on 600 s.f. Copper foil strips placed 2.5' from westerly curb at 47'-52' from southerly expansion dam and 5' from curb at 123'-128' from expansion dam.
4:10			Operation stopped after 60 gallons had been applied on 1840 s.f. due to threatening weather. 30 pound asphalt saturated organic roofing sheet placed on the liquid polyurethane (Celotex/ Barrett(R) Type 2 shingle underlay). "Fishmouths" which developed along the edges of the roofing sheet could not be eliminated by rolling with a 150 pound steel roller.
5:15			Work area hit by moderate rain shower. Water flowing over the roofing sheet collected in the "fishmouths" along the edges of the butted sheets. Attempts to squeeze water out of the "fishmouths" and seal them by rolling were not successful.
8/25/72			100% cloud cover.
9:25	75°	74	Began mixing 20 gallon batch using one gallon of xylol as before.
10:25	77°	71	Roofing sheet is being overlapped in shingle fashion. "Fishmouths are occurring along the edges of the sheets at about the same rate as the previous day.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION - cont'd

Time	Temp	% Humidity	
	8/25/72 cont'd		
10:45	78°	70	Continuous rolling of the roofing sheets did not produce adhesion along the edges.
11:00	79°	68	Mixing time increased from 6 to 10 minutes to eliminate brown streaks which were visible in the polyurethane at times.
11:15	80°	67	Roofing sheet omitted on westerly side of deck from a point 145' north of the expansion dam to the approach slab. Bubbles appeared in the liquid polyurethane shortly after application and ripples also developed on the surface at many locations. In most cases the bubbles consisted of a large bubble followed by a chain of progressively smaller bubbles.
11:30	81°	64	Began application along the easterly side of the deck. Polyurethane is also being applied under sheet overlaps in an attempt to bond down the edges.
12:30	85°	58	Application stopped 89 feet north of expansion dam due to a shortage of material. Fewer bubbles accurred along the easterly side of the deck and ripples appeared over only half of the 89 foot long section.
	9/6/72		Clear. 80°F in the sun.
1:10	66°	31	Carboline representative back on project. Dirt and dust removed from primed concrete with blower unit. Copper foil strips placed 3.5' from easterly curb at 130'- 135' from the southerly expansion dam.
2:30	69°	26	Forty gallons applied on 1196 s.f. for application rate of 29.9 s.f./gal. Membrane covered with overlapped roofing sheet.
4:00	69°	27	Area 177' north of expansion dam to the approach slab treated with Bon-Lastic Membrane manufactured by the Robson Corporation. The Robson polyurethane was used to complete the deck because 5 gallons of Polytok hardner was lost in shipment.
5:30	68°	29	Application complete. 215 gallons of Polytok Membrane and 10 gallons of Bon-Lastic Membrane applied on 800 s.y. for a dry film thickness of 37.4 mils. Total coverage for prime and finish coat averaged 41.6 mils.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 800 s.y. @ $4.00/s.y. = $3,200.00
Cost of prime coat = $ 372.00

Bituminous Concrete - One-1 inch thick course
62 tons @ $7.00/ton = $ 434.00

Figure 3

I 91 Southbound over Vt Rte 16
Cracks in Concrete Deck

All cracks were noted on both the surface and bottom of the deck length of cracks and their locations are to scale. Vertical Scale 30'/in. Horizontal Scale 10'/in.

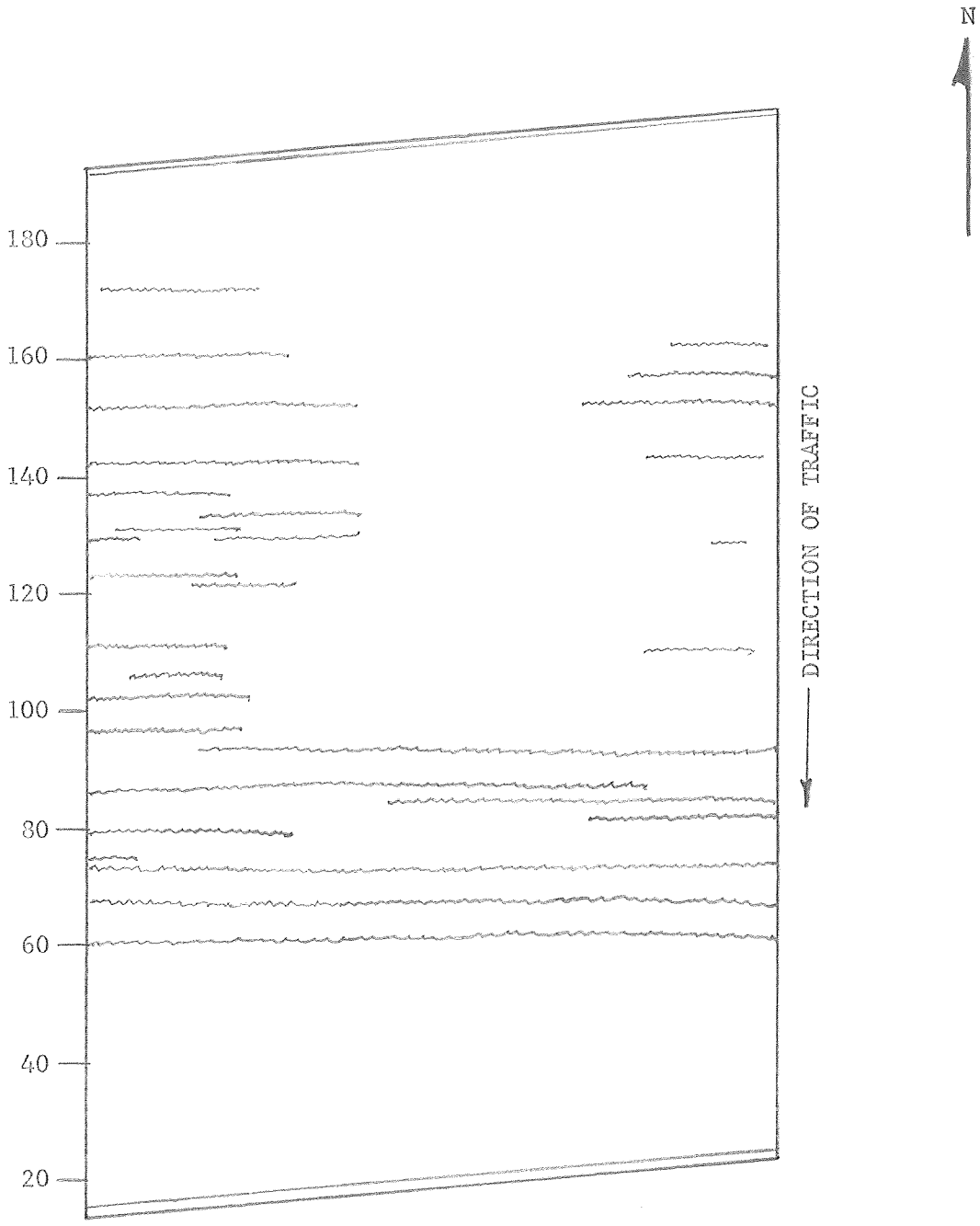
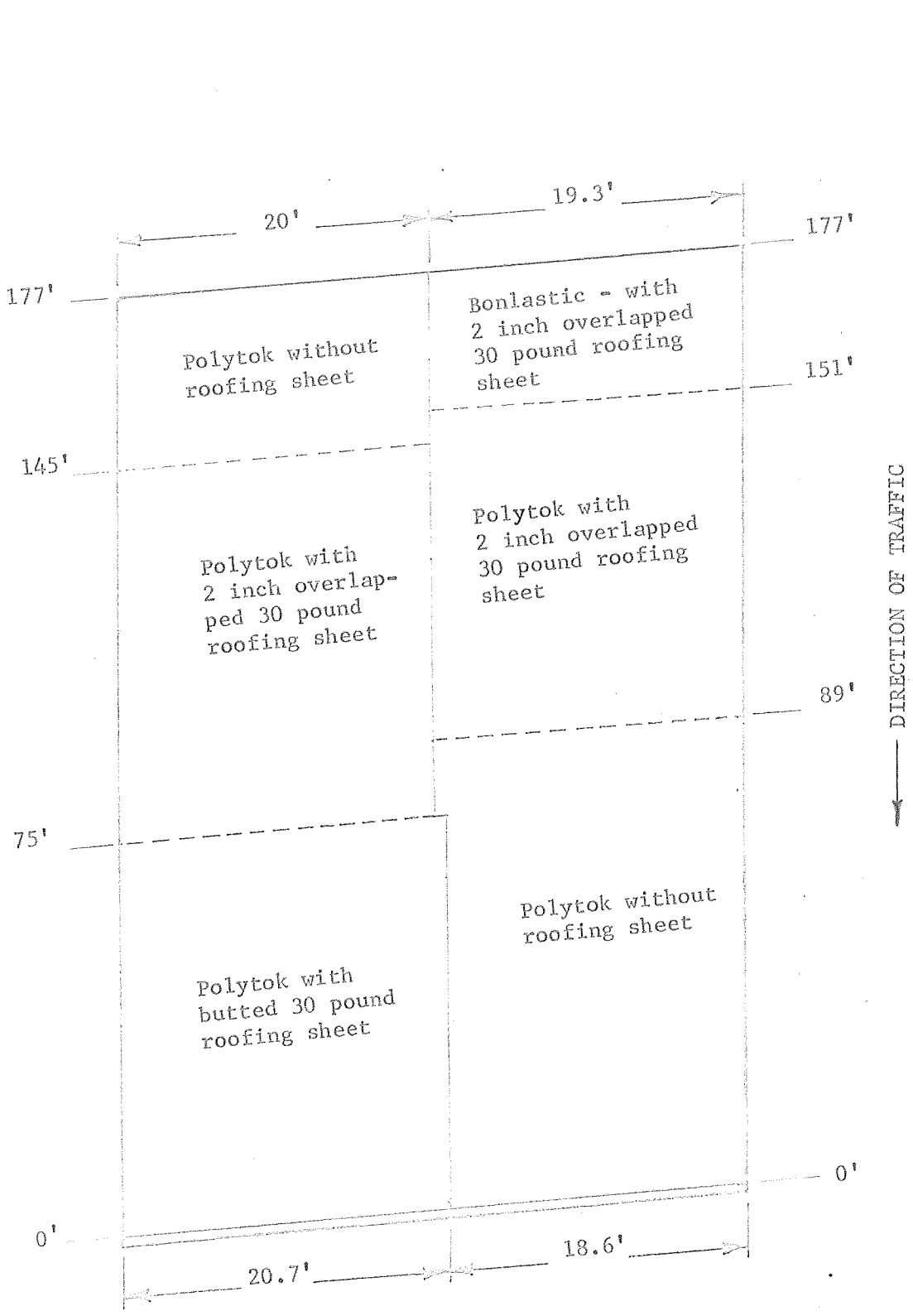


FIGURE 4

I 91 SOUTHBOUND OVER VERMONT ROUTE 16

POLYTOK MEMBRANE 165



DISCUSSION

The application of Polytok Membrane 165 on I 91 southbound over Vt Rte 16 was made under revised application specifications with a factory representative on the project.

A prime coat consisting of a 50-50 mixture of Polytok Membrane and xylol solvent was applied at the rate of 144 square feet per gallon for a 4 mil dry film thickness. Very few bubbles were noted in the prime coat which cured in approximately one hour.

One gallon of solvent was added to each 20 gallon batch of polyurethane used for the finish coat. Within the prescribed 15 to 45 minute time period, a 30 pound asphalt saturated organic roofing sheet was placed over the liquid polyurethane (inorganic roofing material recommended by the manufacturer was not commercially available in the area). Shortly after application, "fishmouths" developed at various intervals along the edges of the sheets. Although the sheets were periodically rolled with a 150 pound steel roller, the effort did not succeed in adhering the unbonded edges.

The application was stopped due to threatening weather after 60 gallons were applied on 1840 square feet of concrete. When showers did occur, the water flowed under areas of the roofing sheet which were not bonded to the polyurethane. When the application commenced again 2 days later, the Carboline service technician requested that the roofing sheets be placed with the edges overlapped in shingle fashion to prevent water from getting beneath any unbonded edges before the pavement could be placed. This procedure worked satisfactorily although "fishmouths" appeared once again along the edges and rolling did not alleviate the problem.

Approximately 2360 square feet of membrane was placed without an overlay of roofing sheet (see figure 4 , page 85). This was done with the concurrence of the Carboline representative when personnel involved with the paving operation expressed concern over the possibility that the "fishmouths" might result in problems with the first course of bituminous pavement. It was also felt that a comparison between the two methods would be of value in future evaluations.

A large number of air bubbles appeared in the liquid polyurethane that was not covered with roofing sheet. In most cases, the bubbles consisted of a large bubble,

often up to 3/4 inch in diameter, followed by a chain of from 3 to 15 progressively smaller bubbles. Although the bubble chains were suspected of being caused by air in the polyurethane being spread by the squeegees, it was noted that all of the bubble chains pointed in a direction that was at a 45^{o} angle with the direction of application. Ripples were also noted on the membrane surface. They were believed due to the wind which was gusting quite hard at times.

As the polyurethane cured, most of the large bubbles receeded, leaving a crater like shape on the membrane surface. When the bubbles were broken open for inspection, only the prime coat was noted on the concrete. However, it should be noted that testing with hydrocloric acid did not disclose the presence of any open concrete and electrical resistance readings were over two million ohms on the bubbled area. The inspection also disclosed that the membrane could be peeled from the prime coat at many locations.

The final 1760 square feet of concrete on the northeasterly end of the deck was treated on September 6, 1972 when additional material was received. Because five gallons of the Polytok hardner was lost in shipment, the final 560 square feet of deck and approach slab was treated with Bon-Lastic Membrane, a polyurethane manufactured by the Robson Corporation of Oxford, Maryland. Roofing sheet was placed on the membrane during the final days application. "Fishmouths" occurred along the edges of the overlapped sheets at about the same frequency as before. It should be noted that where "fishmouths" did occur, the actual thickness of the membrane was reduced since approximately half of the polyurethane remained on the unbonded roofing sheet.

The overall application rate for the deck was 32.1 square feet per gallon which amounted to a 37.4 mil coating. Combined with the 4.2 mil prime coat, the total coverage amounted to an average of 41.6 mil dry film thickness.

Application of the first 1" course of pavement began on September 21, 1972, three weeks after the membrane system had been completed. Although no problems occurred during the first pass with the paver, ripples and cracks appeared in the bituminous mix from several areas disclosed that the cracks had occurred over both the "fishmouths" and the ends of the roofing sheets. A total of 29 cracks averaging one foot in length were logged over a 900 square foot area along the northeasterly side of the deck.

As additional passes were made with the paver, the thickness of the bituminous mat was increased from 7/8" compacted to nearly 1 1/2" in an attempt to eliminate the cracks and ripples. Although the increased thickness may have helped, many small cracks still developed, particularly in the area with the butted roofing sheets. No cracks or ripples were detected in the pavement placed over the membrane without roofing sheet.

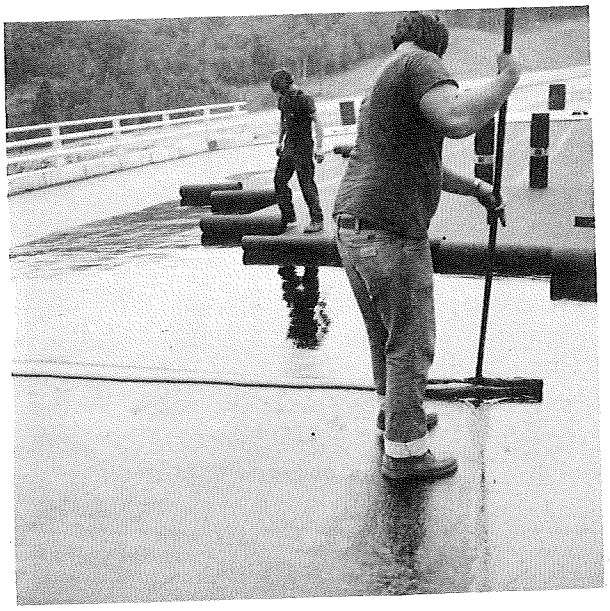
The final 1" course of pavement will be placed in 1973 under a future contract.

Electrical resistance readings taken on the polyurethane without roofing sheet or pavement ranged between 2.6 million and 17.3 million ohms. Readings on the membrane with roofing sheet averaged over 7 million ohms while readings on the membrane, roofing sheet, and first course of pavement were, with one exception, between 500 million and infinity. The exception was a half million ohm reading taken on an area with cracks in the pavement.

POLYTOK MEMBRANE 165
I 91 SB over Vt Rte 16
August 1972

Thirty cracks ranging in length from 2' to the full width of the deck were noted. All cracks extended through the full depth of the deck.

One of several areas where air bubbles were noted in the prime coat which consisted of 50% Polytok and 50% Xylol. Note concrete surface texture.



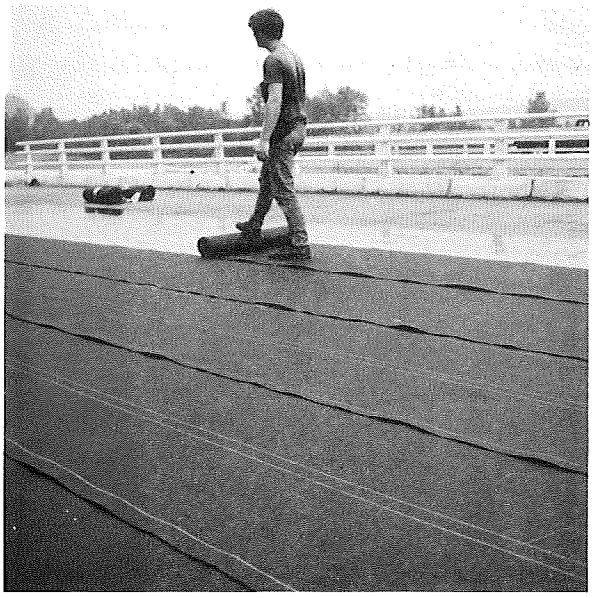
Rolling out butted 30 pound asphalt saturated roofing sheets on the freshly applied membrane.

Squeezing water out from under areas of the roofing sheet which did not bond to the membrane.

POLYTOK MEMBRANE 165

I 91 SB over Vt Rte 16

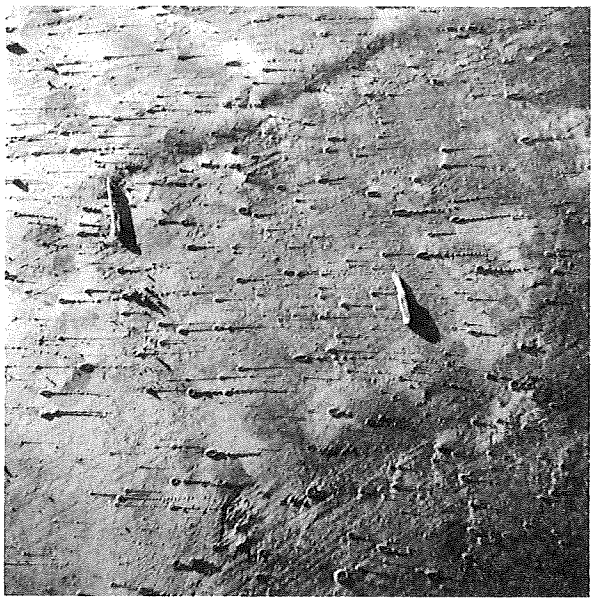
August 1972



Rolling out sheets lapped in shingle fashion. Note fish mouths beginning to develop along edges.

Rolling the roofing sheets in an attempt to bond the material down to the membrane.

Air bubbles and ripples in the membrane left uncovered shortly after application.

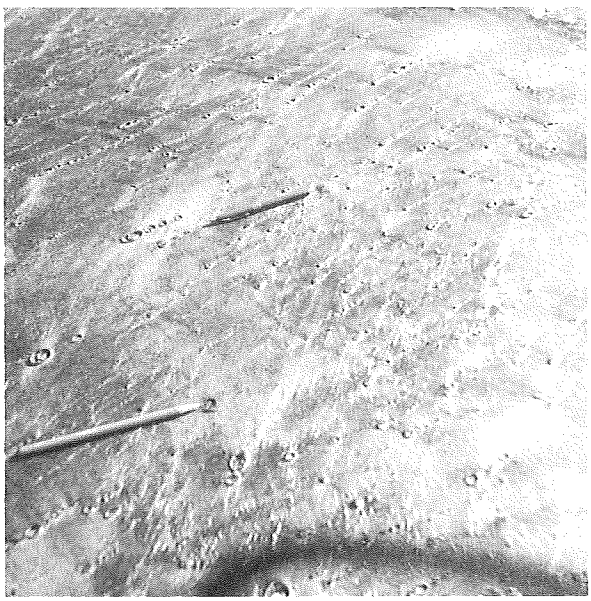


Air bubbles and craters in the cured membrane.

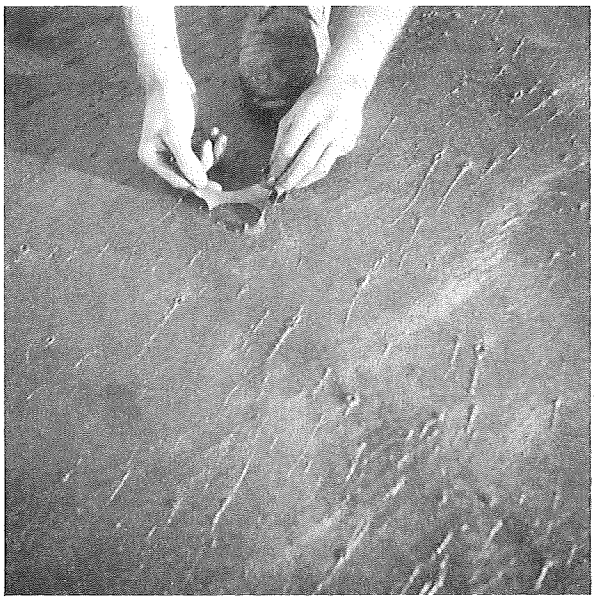
POLYTOK MEMBRANE 165

I 91 SB over Vt Rte 16

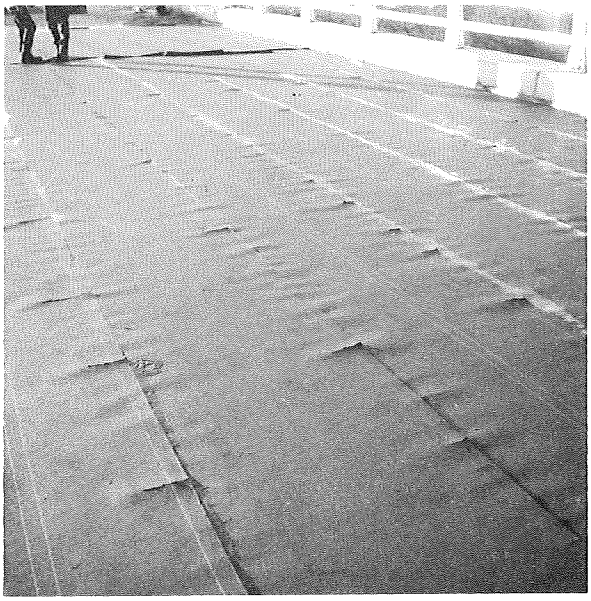
August 1972



When air bubbles were broken open, little more than primer was detected on the concrete in many cases.



After a bubble or crater was broken open, the membrane could be peeled from the primed concrete.



Fishmouths in the roofing sheet were cut open on the final area treated.

Ripples and cracks in the first 1" course of pavement were caused by the roofing sheet.

WORK PLAN #11 - INITIAL REPORT

DURALBOND 102 EPOXY

PROJECT

Barton EMP I 91-3 (19)

PROJECT LOCATION

In the County of Orleans, Vermont, beginning at the point of intersection with Vt Rte 16 southerly of Barton Village and extending northerly approximately 5.417 miles.

WORK LOCATION

I 91 northbound bridge over Vt Rte 16 at station 2148+16.17 - 2149+96.46 in Barton

CONTROL SECTION

I 91 northbound bridge over Town Highway #40. See data on pages 24 to 27.

BRIDGE CONSTRUCTION DATA

Type of Structure - 3 span continuous WF

Span Lengths - 51' - 77' - 48'

Overall Length - 176'

Curb to Curb Width - 39.33'

Skew - 13^{o} 34'

Horizontal Curvature - None

Grade - 2.000%

Superelevation - ¼"/ft

DECK CONSTRUCTION DATA

Date Poured - September 17, 1971

Weather Conditions - Cloudy 40% humidity

Temperature - 66^{o}F

Deck Thickness - 8"

Concrete Cover Over Reinforcing Steel - 2" - 2 3/4" 2¼" average

Concrete - Class AA

Cement - Type I

DECK CONSTRUCTION DATA - cont'd

Aggregate Size - 3/4" maximum

Air Entraining Admixture - Darex 6 to 7 oz per c.y.

Retarding Admixture - Plastiment 6 oz/sack - 2½ oz/sack

Pour Sequence - North to south continuous

Finishing Method - Capital finishing machine

Surface Texture - Broomed finish

Curing - Polyethelene sheeting plus sprinkler hoses at centerline and along curbs

Concrete Test Results:

Percent Air - Low 6% High 7½% 7.1% average on 14 tests

Slump - Low 3/12" High 4" 3.6" average on 13 tests

Modulus of Rupture - 916 psi average @ 28 days

DECK CONDITION

Surface Texture - The concrete had a light to moderate broom finish from the southerly end of the deck to a point 130' north. The remaining area had small craters or indentations which gave the impression that the concrete had been rained on before it had set up.

Cracks - One 15 foot long transverse crack was noted at a point 143.3' from the beginning of the westerly curb.

Steel Corrosion Readings - Initial readings taken on the deck averaged 0.137 volts, indicating no active corrosion.

PROTECTIVE TREATMENT

Product - Duralbond 102
A 100% non-volatile epoxy bonding compound manufactured by Dural International Corporation, 95 Brook Avenue, Deer Park, New York 11729.

Test Results - The material was certified to meet the Vermont Department of Highways specification for Item 372-C, Epoxy Bonding Compound.

RECOMMENDED APPLICATION PROCEDURE

All concrete surface contaminants must be removed by sandblasting or acid etching. Combine one part by volume of Base with one part by volume of Hardner. Mix thoroughly for at least three minutes with an electric drill and apply. A one gallon quantity has a pot life of approximately 40 minutes at 75°F. The material can be applied with a stiff bristled brush.

DECK PREPARATION PRIOR TO MEMBRANE APPLICATION

The deck was washed clean with water. After the concrete had dried, a 12% muriatic acid solution was applied with water sprinkler cans. The deck was treated in three sections to insure that each section could be properly flushed with water before any of the acid salts could dry on the concrete. After the final section was completed, the entire deck was washed with an additional 1500 gallons of water. Spot checks made on the concrete with litmus paper indicated that all of the acids had been removed.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humidity	
	7/19/72		Overcast. Air temperatures recorded in shade.
9:20	78°	74	Began mixing 10 gal batch. Material has very high viscosity. Difficult to remove from individual containers. Mixed for 15 minutes before material appeared thoroughly mixed. Trowel application left to thick a coating on the concrete, switched to hard rubber squeegees.
9:55			Started raining.
10:00			10 gallons applied on 287 s.f. along both sides of the finger plate expansion dam on the southerly end of the deck.
10:05			Heavy rains caused the epoxy to turn a milky color making it appear doubtful that the coating will perform satisfactorily.
	7/20/72		
8:15	66°		Fog. Began mixing ten gallon batch. All batches mixed for 5 minutes.
9:15	68°		Clear. 30 gal applied on 975 s.f. for an application rate of 32.5 s.f./gal. High viscosity is making it difficult to apply a thin coat of the epoxy.
9:45	72°		Received permission from the manufacturer to add ½ to 1 pint of solvent per gallon of mixed epoxy to reduce viscosity and increase coverage.
11:00	77°		30% cloud cover. 10 gallons of epoxy with 4 pints of xylol added applied at the rate of 56.5 s.f./gal.
11:50	80°	45	20 gallons applied on 1454 s.f. for an application rate of 72.7 s.f./gal ½ pint xylol added per gallon.
12:30	84°		30 gallons applied on 2279 s.f. for an application rate of 76 s.f./gal. Bubbles noted in coating.
1:00	85°	38	20 gallons applied on 1710 s.f. for an application rate of 85.5 s.f./gal. First coat complete. 120 gallons applied on 7207 s.f. for an overall application rate of 60 s.f./gal.
2:45	86°	35	Began mixing epoxy for second coat. 2 pints of xylol added per 10 gallon batch. First area treated is dry to the touch.
3:30	86°	37	20 gallons applied on 2160 s.f. for an application rate of 108 s.f./gal. Inspection of the first coat of epoxy at four locations disclosed pinholes, craters, air bubbles and bubble clusters at the rate of from 32 to 880 per square foot. Most of the holes did not appear to be open to the concrete.
4:30		38	20 gallons applied on 1927 s.f. for an application rate of 96.4 s.f./gal. Fewer pinholes and bubbles are appearing in the second coat.
5:00		42	100% cloud cover. 20 gallons applied on 1612 s.f. for an application rate of 80.6 s.f./gal.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION - cont'd

Time	Temp	% Humidity	
5:45		48	Application complete. Final five gallons of epoxy placed over area treated on 7/19/72. 20 gallons applied on 1565 s.f. for an application rate of 78.3 s.f./gal. A total of 80 gallons was applied on the second coat for an overall application rate of 90.1 s.f./gal. Flint shot aggregate was hand applied on the final coat of epoxy at the rate of 0.37 pounds per s.y.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment	-	200 gallons @ $40.00/gal	=	$8,000.00
		Cost per s.y.	=	$ 9.99
Bituminous Concrete	-	One-1 inch thick course 59 tons @ $7.00/ton	=	$ 413.00

DISCUSSION

Duralbond 102 Epoxy, although recommended for use by the manufacturer as a bonding compound was used as a deck membrane because of an error in the contract specifications.

The high viscosities of the epoxy components made it difficult to remove them from their containers. Ten gallon batches of the material were mixed for a minimum of five minutes utilizing an electric drill and Jiffy mixing blade.

The material was initially applied with steel trowels. Because this method resulted in too thick a coating; hard rubber squeegees were tried. This method of application was faster and increased the coverage per gallon.

Rain showers stopped the application after ten gallons of epoxy had been applied on 287 square feet of concrete adjacent to the finger plate expansion dam at the southerly end of the deck. The rain on the fresh epoxy caused it to turn a milky color when cured. The color and dull surface finish gave the impression that it might not perform satisfactorily.

An application rate of 32.5 square feet per gallon was obtained the following day with the first 30 gallons of material. After discussing coverage rates with the manufacturer, a decision was made to add one-half to one pint of xylol solvent per gallon

of mixed epoxy in an attempt to decrease the viscosity of the material and thereby obtain greater coverage from each gallon. Subsequent application rates ranged between 56 and 85 square feet per gallon with an overall average of 60 square feet per gallon on the first coat. This resulted in an average thickness of 29 mils.

Air bubbles and holes were noted in the first coat of epoxy shortly after application. Spot checks made on the partially cured coating at four locations revealed from 32 to 880 bubbles and holes per square foot. The air bubbles consisted of individual bubbles and clusters of a dozen or more air bubbles. The bubble clusters were probably caused by the addition of the solvent since they did not occur in the area treated with the 100 percent solids epoxy. The holes in the coating appeared in the shape of both craters and pinholes which for the most part did not appear to be open to the concrete.

The application of the second coat began as soon as the first coat was tack free. Solvent was added at the rate of two pints per ten gallon batch and an aggregate (Flint Shot, 20 - 40 mesh) was hand applied at the rate of 0.37 pounds per square yard. The application rate of the epoxy varied between 78 and 108 square feet per gallon with an average of 90.1 square feet per gallon for a 19 mil thickness. The total coverage for both coats was 36.8 square feet per gallon for a mil thickness of 48.

The final coat contained fewer air bubbles and holes than had been noted in the first coat and although a few of the holes appeared to be open to the concrete, testing with hydrocloric acid did not disclose that they were. Electrical resistance readings were generally satisfactory averaging 1.15 million ohms. They ranged from a low of 200,000 ohms on an area with a light coat of epoxy containing more than the average number of holes to a high of 4.8 million ohms.

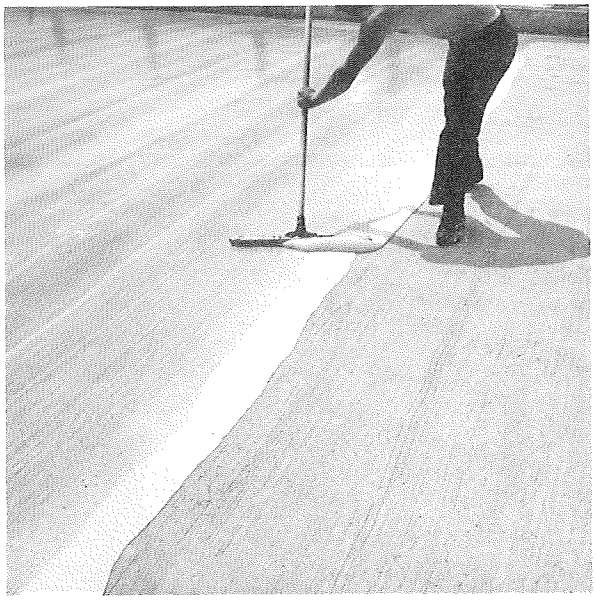
No difficulties were encountered during the application of the first one inch course of pavement. The final course of pavement will be placed in 1973 under a future contract.

Electrical resistance readings have not yet been taken on the pavement-membrane system.

DURALBOND 102 EPOXY

I 91 NB over Vt Rte 16

July 1972



Applying first coat of epoxy cut back with 5% solvent as per manufacturer's recommendation. Application rate averaged 60 sf/gal.

Applying second coat at an average rate of 90 sf/gal.

Air bubbles and pinholes were noted in both coats. Note air bubble clusters in the cured epoxy coating.

Testing with hydrochloric acid disclosed that the air bubbles and pinholes were not open to the concrete. Resistance readings were high, averaging 1.2 million.

of mixed epoxy in an attempt to decrease the viscosity of the material and thereby obtain greater coverage from each gallon. Subsequent application rates ranged between 56 and 85 square feet per gallon with an overall average of 60 square feet per gallon on the first coat. This resulted in an average thickness of 29 mils.

Air bubbles and holes were noted in the first coat of epoxy shortly after application. Spot checks made on the partially cured coating at four locations revealed from 32 to 880 bubbles and holes per square foot. The air bubbles consisted of individual bubbles and clusters of a dozen or more air bubbles. The bubble clusters were probably caused by the addition of the solvent since they did not occur in the area treated with the 100 percent solids epoxy. The holes in the coating appeared in the shape of both craters and pinholes which for the most part did not appear to be open to the concrete.

The application of the second coat began as soon as the first coat was tack free. Solvent was added at the rate of two pints per ten gallon batch and an aggregate (Flint Shot, 20 - 40 mesh) was hand applied at the rate of 0.37 pounds per square yard. The application rate of the epoxy varied between 78 and 108 square feet per gallon with an average of 90.1 square feet per gallon for a 19 mil thickness. The total coverage for both coats was 36.8 square feet per gallon for a mil thickness of 48.

The final coat contained fewer air bubbles and holes than had been noted in the first coat and although a few of the holes appeared to be open to the concrete, testing with hydrocloric acid did not disclose that they were. Electrical resistance readings were generally satisfactory averaging 1.15 million ohms. They ranged from a low of 200,000 ohms on an area with a light coat of epoxy containing more than the average number of holes to a high of 4.8 million ohms.

No difficulties were encountered during the application of the first one inch course of pavement. The final course of pavement will be placed in 1973 under a future contract.

Electrical resistance readings have not yet been taken on the pavement-membrane system.

SUMMARY OF FINDINGS & RECOMMENDATIONS

The following discussions will cover the good and bad characteristics of each product tried to date. It is emphasized that all recommendations in this report are very tentative since long term evaluations will be required to draw definite conclusions on the overall effectiveness of each product. However, recommendations on further use have been made at this time since it is believed that products with definite limitations should not be considered further while other products, which appear to have better potential, are available for evaluation.

Product recommendations are based upon the following desireable characteristics which would be expected in the ideal membrane system.

Minimum necessary surface preparation of the concrete.

An application suitable to most weather conditions. Not moisture sensitive.

Easy application.

Impervious to moisture penetration. 500,000 + ohms electrical resistance.

Not subject to bubbling or pinholing.

Adequate bond to the concrete.

Adequate seal along the curb lines.

Sufficient flexibility to resist cracking.

Not susceptible to heat damage.

Sufficient toughness to resist damage during paving application.

Sufficient stability to resist movement during paving and under continuous traffic.

The membrane should not affect the performance of the bituminous pavement.

Resistant to age deterioration.

High ratio of service life to in-place cost.

BON-LASTIC MEMBRANE

SUMMARY OF FINDINGS

Bon-Lastic Membrane does not require extensive surface preparation of the concrete but the polyurethane is very sensitive to moisture. Close control over the application rate was necessary since a slight increase over the recommended 40 mil thickness causes the material to foam. Extensive pinholing and bubbling occurred in the membrane although existing testing techniques did not prove that any of the holes were open to the concrete. The material exhibited good bond to both the concrete and the granite curb. It appeared to have sufficient flexibility to bridge small cracks in the deck. Electrical resistance readings on the membrane were satisfactory (480,000 ohms per square foot) but readings taken on the completed pavement and membrane averaged only slightly higher (650,000 ohms per square foot). Such readings suggest that the membrane may have been damaged during the pavement application. This might not have happened if roofing sheet had been placed over the membrane as specified, however, use of roofing sheet might have resulted in problems with the application of the first course of pavement. Low electrical resistance readings on copper foil strips placed beneath the membrane indicate the passage of moisture through the pavement and membrane at the test location. Soundings indicated that the pavement was not bonded to the membrane.

RECOMMENDATION

Further use of Bon-Lastic Membrane should be suspended until the results of long term evaluation can be obtained.

TAR EMULSION AND WOVEN GLASS FABRIC

SUMMARY OF FINDINGS

The material is not moisture sensitive and required little surface preparation of the concrete. The normal rough configuration of the curb sections made it impossible to obtain a complete seal along the curbs. Electrical resistance readings averaged approximately 3800 ohms per square foot indicating that the system allows moisture to pass through it. Concrete samples treated with the system developed blisters and delaminations of the individual layers when exposed to water or freeze-thaw cycles. Concrete samples treated with tar emulsion in the laboratory absorbed as much water as untreated samples.

RECOMMENDATION

Tar emulsion and woven glass fabric is not recommended for further use as a bridge deck membrane.

DURALKOTE 304 EPOXY

SUMMARY OF FINDINGS

Surface preparation requires that the concrete be sandblasted or acid etched and completely free of moisture. Extensive pinholing occurred in both the first and second coats of the epoxy coating although testing with hydrochloric acid did not prove that the holes were open to the concrete. Electrical resistance readings averaged 40,100 ohms per square foot. Such readings indicate that moisture can pass through the membrane. The material failed flexibility requirements and consequently may not have sufficient flexibility to bridge cracks in the deck. Field observations have already disclosed that the coating has peeled from the concrete at several locations adjacent to the curb. Blisters developed on concrete samples treated with the epoxy and moisture absorptions were as high as those found on untreated concrete samples.

RECOMMENDATION

Duralkote 304 is not recommended for further use as a bridge deck membrane.

UNIROYAL LIQUID MEMBRANE SYSTEM

SUMMARY OF FINDINGS

Uniroyal Liquid Membrane 6125 is not as sensitive to moisture as many of the other membrane products and it requires little surface preparation of the concrete. Generally, the material bonds well to the concrete although exceptions were noted. Water was able to enter the system and travel along the curbs beneath the Liquid Membrane and Elastosheet on two of the four decks treated. Air bubbles were noted in the Liquid Membrane on all applications. Electrical resistance readings on the membrane were low, averaging 51,600 ohms per square foot. Softening of the membrane caused by the heat of the bituminous mix made compaction of the first course of pavement difficult. Migration of the first course of pavement and membrane due to traffic resulted in the removal of the pavement from one deck. Cracks, depressions and lateral migration of the pavement have occurred on structures treated with Uniroyal in 1971. The $9.00 per square yard average cost was nearly double the cost of many of the membrane treatments.

RECOMMENDATION

Uniroyal Liquid Membrane should not be considered for use on bridges with excessive superelevation or grades over approximately 3%. A full depth wearing course should also be placed before traffic is allowed over the pavement-membrane system. Further use of Uniroyal Liquid Membrane is not recommended unless follow-up evaluations prove that the product's effectiveness out weighs the problem encountered with pavement stability.

POLYTOK MEMBRANE 165

SUMMARY OF FINDINGS

Polytok Membrane 165 does not require extensive surface preparation of the concrete. Pinholes and bubbles occurred at varying rates in both the prime and finish coats although testing did not prove that the holes were open to the concrete. The polyurethane appeared to effectively seal the concrete along the critical curb areas. It also appeared to have sufficient flexibility to bridge small cracks in the deck. Poor bond was noted between the prime and finish coats in one area. A delay in the roofing sheet application resulted in a lack of bond between the sheets and the polyurethane. This in turn led to the removal of the first course of pavement from one deck. Where "fishmouths" occurred along the edges of the roofing sheet, the actual thickness of the membrane was reduced since approximately half of the polyurethane remained on the roofing sheet. Cracks occurred in the first course of pavement over both the "fishmouths" and the ends of the roofing sheets. Electrical resistance readings on the polyurethane without roofing sheet varied from an average of 60,000 ohms on one deck to over 2 million ohms per square foot on the second deck. Readings on the membrane with roofing sheet were generally satisfactory on both decks with readings ranging between 1 million and 7 million ohms.

RECOMMENDATION

If follow-up evaluations indicate that Polytok Membrane 165 is effective without roofing sheet, continued use of the product would be recommended. Further use of the system with roofing sheet is not recommended.

DURALKOTE 306 EPOXY

SUMMARY OF FINDINGS

Surface preparation requires that the concrete be sandblasted or acid etched and completely free of moisture. The application was relatively easy although the ten minute pot life could conceivably cause problems. A large number of pinholes and bubbles occurred in the first coat while relatively few were noted in the finish coat. Electrical resistance readings on the membrane were high, averaging 30 million ohms per square foot. The membrane remained flexible to the touch upon curing. Concrete samples treated with Duralkote 306 have absorbed less water than samples treated with any other epoxies, polyurethanes, or tar emulsions tried to date. Although the in-place cost was high, new application rates specified for epoxy membrane sealers would lower the cost of this product. A single coat application on the exposed concrete surfaces of "Church Hill Bridge" in Bethel resulted in bond failure shortly after application. The surface preparation and application procedure were not observed.

RECOMMENDATION

Duralkote 306 is recommended for further use as a bridge deck membrane.

HEAVY DUTY BITUTHENE

SUMMARY OF FINDINGS

Bituthene did not require extensive surface preparation. Attaining proper alignment of the rolls to insure sufficient overlap without waste was somewhat difficult. The material displayed excellent bond and self-sealing characteristics. Air bubbles trapped beneath the membrane did not appear to cause any problems. Water detected between the membrane and the vertical surface of the curb was believed due to the collection of rain water through small openings along the top edge of the membrane sheets and from migration of moisture from the back face of the granite curb through the porous epoxy mortar. The free movement of the water along the base of the curbs was due to a lack of bond between the membrane and the epoxy mortar which may have been caused by an incomplete primer application on the face of the curb. All electrical resistance readings on the membrane were recorded at infinity. Some cracks occurred in the first course of pavement. They were, in nearly all cases, a reflection of the edges and ends of the membrane sheets. No cracks were noted in the completed pavement.

RECOMMENDATION

Heavy Duty Bituthene is recommended for further use with the following limitations. The product should be used with caution on bridges with steep grades or excessive banking due to the possibility of pavement and membrane migration under traffic. Consideration should be given to the practice of butting sheet membranes at the base of the curb. Such a procedure would eliminate the potential entrapment of water along the vertical face of the curb which might occur if the membrane did not remain bonded.

DURALBOND 102 EPOXY

SUMMARY OF FINDINGS

Surface preparation requires that the concrete be sandblasted or acid etched. The material is designed to bond to damp or moist concrete. The high viscosity of the epoxy made it difficult to apply. Air bubbles and pinholes occurred in both the first and second coats although testing with hydrocloric acid did not prove that the holes were open to the concrete. Electrical resistance readings were generally satisfactory averaging 1.15 million ohms per square foot. The low flexibility of the material may result in deflection cracks or loss of bond due to differences in thermal expansion and contraction of the epoxy and concrete.

RECOMMENDATION

Duralbond 102 was not designed for use as a bridge deck membrane due to its lack of flexibility and should not be considered for further use in this manner.

TAR EMULSION (TWO COAT SYSTEM)

BASIC INFORMATION

The application of tar emulsion was covered in an initial report, Work Plan #1, issued in May 1972.

SUMMARY OF FINDINGS

Tar emulsion is not moisture sensitive and requires little surface preparation of the concrete. Some difficulties were encountered in getting the proper amount of material on the concrete along the curbs. Shrinkage cracks were noted in areas where the application was too heavy. Concrete samples treated with tar emulsion in the laboratory absorbed as much water as untreated samples. Cured samples of tar emulsion gained weight when submerged in water but did not regain their initial flexibility. The cost of two coats of tar emulsion is very low, often averaging about $1.50 per square yard. Bridge decks treated in the past with tar emulsion have required maintenance due to damage caused by chloride intrusion. Chlorides have been detected in concrete cores taken from bridge decks treated with two coats of tar emulsion.

RECOMMENDATION

The two coat tar emulsion system is not recommended for further use as a bridge deck membrane.

RAMBOND 223 EPOXY

BASIC INFORMATION

The application of Rambond 223 Epoxy was covered in an initial report, Work Plan #3, issued in April 1972.

SUMMARY OF FINDINGS

Surface preparation requires that the concrete be sandblasted. The material is not moisture sensitive. The application was somewhat difficult due to the high viscosity of the epoxy. Extensive pinholing occurred in the single coat system. Testing with hydrocloric acid disclosed that an average of 20 holes per square foot were open to the concrete. Electrical resistance readings were unsatisfactory averaging 5,100 ohms per square foot. The application of a second coat of epoxy over limited areas eliminated most of the pinholes and increased the electrical resistance to an average of 45,000 ohms per square foot. Field observations made eleven months after the membrane application disclosed that a number of cracks had occurred in the coating adjacent to the curbs sections. Sodium chloride was detected in concrete cores taken from a bridge deck treated with a single coat of Rambond 223 Epoxy in 1967. The bridge deck had been exposed to chloride applications for three years prior to the core recovery.

RECOMMENDATION

Rambond 223 is not recommended for further use as a bridge deck membrane.

RAMCOAT EPOXY

BASIC INFORMATION

Ramcoat Epoxy was applied on Interstate 91 Southbound over Vermont Route 25 in Bradford under terms covered in Work Plan #3. The application will be covered in an interim report which will include follow-up information gathered on bridges treated under Work Plans #1-#3.

SUMMARY OF FINDINGS

Surface preparation requires that the concrete be sandblasted and completely free of moisture. The application of the two coat system was made without difficulty using paint rollers. Although some pinholes were noted in the first coat of epoxy, none were detected in the final coat. Electrical resistance readings averaged 1100 ohms per square foot. Such readings indicate that moisture can pass through the coating.

RECOMMENDATION

Further use of Ramcoat Epoxy should be suspended until the results of long term evaluations can be obtained.

TABLE 2

PRODUCT EVALUATION SUMMARY

FIELD OBSERVATIONS	Bon-Lastic Membrane Polyurethane	Tar Emulsion & Glass Fabric Control	Duralkote 304 Epoxy Paint	Uniroyal Liquid Membrane Rubberized Asphalt	Polytok Membrane 165 Polyurethane	Polytok Membrane 165 Polyurethane With Roofing Sheet	Duralkote 306 Cold Tar Epoxy	Heavy Duty Bituthene Sheet Membrane	Duralbond 102 Epoxy Bonding Compound	Tar Emulsion 2 coats	Rambond 223 Epoxy	Ramcoat Epoxy Paint
Surface Preparation	Wash & Sweep	Wash & Sweep	Sand Blast or Acid Etch	Wash & Sweep	Wash & Sweep	Wash & Sweep	Sand Blast or Acid Etch	Wash & Sweep	Sand Blast or Acid Etch	Wash & Sweep	Sand Blast or Acid Etch	Sand Blast or Acid Etch
Moisture Sensitive	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes
Ease of Application	Average	Average	Easy	Difficult	Average	Average	Easy	Difficult	Average	Easy	Difficult	Easy
Bond & Seal at Curb	Good	Good/Poor	Good	Fair	Good	Good	Good	Fair	Good	Poor	Fair	Fair
Bubbles and/or Pinholes	Many	None	Few/Many	Many/Few	Few	Unknown	Few	Many/None	Few/Many	None/Few	None/Many	None
Electrical Resistance *	480,000	3,940	41,000	51,600	60,000 to 2,600,000	1,300,000 to 8,000,000	30,000,000	Infinity	1,200,000	No Test	5,100	1,100
Difficulty with Pavement	No	No	No	Yes	No	Yes	No	Yes	No	No	No	No
Cost per s.y.	$4.50	$4.00	$5.73	$9.00	$4.50	$4.50	$15.26	$7.25	$9.99	$1.40	$22.15	$1.32

* All readings were taken on the membranes before the pavement was applied.

LAB OBSERVATIONS

Flexibility	Good	Fair	Poor	Good	Good	Good	Good	Good	Poor	Fair	Poor	Fair
Moisture Absorption	1.7%	2.55%	3.47%	--	1.91%	--	0.52%	--	1.04%	--	--	--
Elongation over Cracks	Good	Poor	Poor	Good	Good	Good	Fair	Good	Poor	Poor	Poor	Fair