EXPERIMENTAL BRIDGE DECK MEMBRANE

APPLICATIONS IN VERMONT

REPORT 74-4

National Experimental & Evaluation Program
Bridge Deck Protective Systems
Work Plans #12 - #19
Initial Report

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VERMONT DEPARTMENT OF HIGHWAYS

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ABSTRACT

This report covers the application of seven membrane systems on eight new bridge decks. Information includes background data on deck construction, concrete test results, condition of the decks, membrane product data, laboratory test results, observations made during the membrane applications, cost information, preliminary field test results and discussions on the applications. Summaries of each membrane system are concluded with recommendations on further use.

Initial observations and test results indicate that the preformed sheet systems show the greatest promise in protecting bridge decks from moisture and chloride intrusion. Liquid applied materials often prove to be unsatisfactory due to the formation of pinholes, air bubbles or blisters in the coating shortly after application. Such conditions are caused by the escape of air and moisture vapor from the concrete.

EXPERIMENTAL BRIDGE DECK MEMBRANE APPLICATIONS IN VERMONT

INTRODUCTION

Recent studies have shown that the deterioration of reinforced concrete bridge decks is one of the most serious problems facing Highway and Transportation Agencies throughout the United States and Europe.

Factors contributing to the premature deterioration include poor concrete quality, improper construction practices, corrosion of the reinforcing steel, freeze-thaw action, chemical attack, and to a lesser degree, studded tire wear, heavy wheel loads and increased traffic volumes.

Spalling or delamination of the concrete surface caused by corrosion of the reinforcing steel is considered to be the most serious form of deterioration. This problem has been directly related to large increases in the use of deicing chemicals by Highway Agencies (1, 2, 3). Examples include the recent repair or replacement of bridge decks with serious corrosion problems which had been free of such conditions when inspected in a cooperative study by the PCA and ten participating States in 1962. (3, 4, 5).

Improvements in mix design and construction practices have been implemented to retard the rate of chloride intrusion and thus extend the time to corrosion of the steel. These include a reduction in the water-cement ratio and an increase in the concrete cover over the top mat of reinforcing steel. However, such procedures are not believed to be sufficient to protect structures located in areas given heavy applications of deicing chemicals as a recent study (2) has shown that chlorides are capable of migrating through one inch of typical bridge deck concrete in as few as seven days.

Other methods currently being tried in an attempt to prevent deck deterio-

ration include the use of membrane waterproofing (6, 7, 8, 9) mastic asphaltic concrete overlays (Gussasphalt) (10, 11), low slump thin Portland Cement and latex modified concrete overlays (12), epoxy coated or galvanized reinforcing steel, and the use of Cathodic protection to inhibit ongoing corrosion of the reinforcing steel (13). Removal of chlorides from contaminated concrete is being attempted by flushing the deck with distilled water from the bottom up and by electrochemical means. Research is also in progress on neutralization of chlorides and the use of polymer, polymer modified, and polymer impregnated concrete.

Membrane waterproofing is presently the most widely used method of attempting to protect bridge decks from deterioration. During the 1971-1973 construction seasons the Vermont Department of Highways placed 16 different membrane systems on 28 new bridge decks under the terms of the National Experimental and Evaluation Program #12, Bridge Deck Protective Systems (14). The information in this report covers the application of seven membrane systems on eight bridges in 1973. Similar reports were written on applications made in 1971 and 1972 (15).

Surveillance of the bridge decks will continue until valid conclusions can be obtained on the effectiveness of the protective treatments. Follow-up reports shall include information on climatic conditions, deicing chemical applications, traffic data, results of follow-up electrical resistance tests, copper foil strip readings, steel potential readings and chloride analysis of concrete core samples.

WORK PLAN #12 - INITIAL REPORT
HOT MOPPED ASPHALT AND GLASS FABRIC

PROJECT

Lyndon-Barton I 91-3(18) Stage II

PROJECT LOCATION

In the Counties of Orleans and Caledonia, Vermont, beginning approximately 5.415 miles southeast of the Lyndon-Barton town line and extending northwesterly 18.741 miles.

WORK LOCATION

I-91 northbound bridge over State Aid Highway #9 at station 1225+58.36 to 1227+08.60, 1.5 miles north of the Rte 5 interchange at Lyndon.

BRIDGE CONSTRUCTION DATA

Type of Structure - Non-composite continuous rigid frame

Span Lengths - 43'- 70'- 35' Overall Length - 155.24'

Curb to Curb Width - 39'- 4" Skew - 26°- 15'- 10"

Horizontal Curvature - 1°- 30' Lt.

Grade - -1.0000% Superelevation - 1/2" per foot

DECK CONSTRUCTION DATA

Date Poured - June 12, 1972

Weather Conditions - Cloudy 1-5 mph breeze

Temperature - 60°F Deck Thickness - 8"

Concrete Cover Over Reinforcing Steel - 1-7/8"- 2-3/4" 2-1/4" average on 42 tests

Concrete - Class AA Cement - Type I 6-1/2 bags per c.y.

Aggregate Size - 3/4" maximum

Air Entraining Admixture - Darex 8 oz/c.y.

Retarding Admixture - Plastiment. First 57 c.y. - 5 oz/sack
Second 57 c.y. - 4 oz/sack
Third 57 c.y. - 3 oz/sack

Pour Sequence - North to south

DECK CONSTRUCTION DATA - cont'd

Finishing Method - Gomaco rotating cylinder screed

Surface Tecture - Burlap drag

Curing - Fogging and polyethylene cover

Concrete Test Results:

Percent Air - 5-1/2% - 7% 6-1/4% average on 18 tests

Slump - 2-1/2" - 3" 2-3/4" average on 18 tests

Modulus of Rupture - 611 psi average at 28 days

DECK CONDITION

Surface Texture - Gritty open textured surface. Very little laitance. Typically rough along the curbs.

Cracks - Fifteen transverse cracks averaging 3.5' in length were noted in the deck. Most were found at a point 1' to 3' out from the curb in the negative moment areas on the low side of the banked deck. See crack layout on Figure 1, Page 10.

Steel Potential Readings - Initial readings taken on the deck averaged 0.06 volts indicating no active corrosion.

Average Initial Chloride Level - 21 parts per million.

PROTECTIVE TREATMENT

Product - Hot mopped asphalt and woven glass fabric.

Test Results - None. Samples not available. System specified due to positive recommendations from other Highway Departments.

RECOMMENDED APPLICATION PROCEDURE

(1) Apply a prime coat of cutback asphalt at the rate of approximately 100 square feet per gallon.
(2) Apply asphalt flashing cement along the base of the curb after the prime coat has dried.
(3) Apply a mopping of asphalt over an area approximately 20 inches wide on the low side of the deck and place a half width of glass fabric in it.
(4) Apply a mopping of asphalt over the half width of fabric and an equal width of the primed concrete. Place a full width strip of fabric in this mopping so that half of the area has 2 layers of fabric.
(5) Continue the "shingling" process until the entire surface to be treated is covered.
(6) Apply a final mopping of hot asphalt over the entire area. Each coat of asphalt shall be applied at the rate of 0.33 gallons per square

RECOMMENDED APPLICATION PROCEDURE - cont'd

yard for a total coverage of 1 gallon per square yard.

(7) Apply a coat of asphalt flashing cement at the top edge of the membrane along the vertical curb face.

DECK PREPARATION PRIOR TO MEMBRANE APPLICATION

Deck washed clean, protrusions removed with chisels and grass edging tools. Surface blown clean just prior to prime coat application.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humid.	Asphalt Temp	
	5/16/73			Air temperatures recorded in shade. Clear.
3:30	64°	18		Began applying Flintkote Asphalt Primer 910-01 with squeegees. The cutback asphalt has a very low viscosity, appears to be penetrating into the concrete.
4:15	64°	18		Air bubbles up to 1/2 inch in diameter and clusters of very small air bubbles noted in prime coat shortly after application.
4:30				15 gals applied on 1770 s.f. for application rate of 118 s.f./gal.
5:00				Copper foil strips placed 3 feet from the westerly curb at a point 114 to 119 ft. from the southerly end of the deck.
5:30	64°	19		35 gals applied on 4320 s.f. for application rate of 123 s.f./gal.
5:50	64°	20		70° in sunlight. Bubbles no longer visible in first area treated and are not occurring in material now being placed.
6:15	63°	21		Application complete. 49 gals applied on 6150 s.f. for an average application rate of 125.5 s.f./gal.
	5/18/73			100% overcast. 5-15 mph breeze.
7:30	54°	43		Breaking 100 lb. cakes of asphalt and placing same in roofing kettle. Asphalt identified as Type 3 Built-Up Roofing Asphalt. Meets C.S.A. Specification A123-7, made in Canada.
8:30	53°	45		Areas given heavy coat of primer contain up to 75 air bubbles/s.f., none in some area. Primer soft and sticky where ponded in small holes in deck surface.
9:25	54°	42	430°	Began applying asphalt along southwesterly end of deck. Wooden shingles used to smooth 18" wide strip of glass fabric and remove wrinkles. Fabric placed 1" up the curb face.
10:00	56°	44	350°	Asphalt cooling rapidly on the deck. Wrinkles in glass fabric will not bond to the asphalt unless

OBSERVATIONS MADE DURING MEMBRANE APPLICATION - cont'd

Time	Temp	% Humid.	Asphalt Temp	
	5/18/73 cont'd			they are smoothed out within 5 seconds. Coating is only slightly tacky to the touch one minute after placement.
10:45	52	50		Application stopped due to showers.
	5/23/73			Inspected area treated on 5/18/73 and took electrical resistance readings.
	5/25/73			100% overcast.
7:15	52°	54		Removing dust from prime coat with brooms and blower unit. Copper Foil strips placed 2.75' from westerly curb at a point 31' to 36' from the northerly end of the curb.
8:00	54°	55	350°	Placing asphalt cement along edge of membrane at base of curb. Material used - Barrett Plastigum Roof Cement, consisting of an asphalt base, petroleum solvent and asbestos fibers.
8:45	56°	54	385°	Placing second full width strip of fabric. Having some difficulty sealing the glass fabric into the asphalt. The roofer claims the difficulty is due to the asphalt not being hot enough.
9:30	56°	54	385°	Using "pony" (spreader box) to place asphalt in place of the mops.
10:10	58°	53	405°	Placed asphalt and glass fabric on concrete test slab. Application is improving with fewer wrinkles occurring in glass fabric.
11:15	62°	48		Necessary to heat "pony" with torch after each pass since holes plug with asphalt.
12:20	68°	37	375°	8-1/2 strips of glass fabric in place.
1:10	68°	38	355°	Wrinkles in the first layer of glass fabric are nearly always leveled out when the second coat of asphalt is placed by a chain like grid hooked on the back of the spreader box.
2:00	68°	38	395°	Placing final strip of fabric plus half strip along the curb.
2:50	67°	37	410°	Began applying final coat with "pony" and then leveling and smoothing with mop.
3:30	68°	35	465°	Final coat complete on 2400 s.f.
4:25	65°	24	420°	Approximately 5% of the fabric is not sealed against the easterly curb. Asphalt cement used to seal top of membrane system.
5:15	66°	21		Application complete. Asphalt application rate unknown due to the temporary removal of the kettle and a portion of the asphalt after the application had begun.

BITUMINOUS CONCRETE WEARING SURFACE

Placement - Two 1 inch thick courses with the first course placed with a rubber tired paver.

Aggregate Size - 3/8" maximum.

BITUMINOUS CONCRETE WEARING SURFACE - cont'd

Asphalt - AC-5 viscosity grade.
First course designed with 8% asphalt content and 1-1/2% asbestos fibers.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment -	688.5 s.y.	@	$3.75/s.y.	=	$2,582.00
Bituminous Concrete -	111 tons	@	$10.00/ton	=	$1,110.00

DISCUSSION

The deck was primed with a cutback asphalt applied at an average rate of 125 square feet per gallon. Air bubbles up to 1/2 inch in diameter were noted in the prime coat with a reduction in number noted as the application proceeded. Although the prime coat was allowed to dry over a 40 hour period, a few soft puddles of primer were noted in surface depressions before the hot asphalt treatment began.

The mopped application of hot asphalt began along the curb on the southeasterly end of the banked deck. Pieces of wooden shingle were used to smooth the glass fabric into the hot asphalt and prevent wrinkles. If the fabric was not leveled within a period of approximately five seconds it often did not bond down due to rapid cooling of the asphalt.

Rain showers stopped the application after two coats were applied on a 360 square foot area. The application did not continue the following day due to a forecast of showers. Electrical resistance readings were taken on a number of treated areas. The readings ranged from 600 to 2000 ohms per square foot on the prime coat, 10,000 to 80,000 on one coat of asphalt and glass fabric, and 450,000 to 790,000 on areas with two coats of asphalt and two layers of glass fabric. Inspection of areas with one coat of asphalt disclosed from 120 to 150 air bubbles and 20 to 50 pinholes per square foot. The bubbles averaged 1/8 inch in diameter with a few up to 1/2 inch. Small pinholes were noted in the top of some of the air bubbles. Fewer bubbles were noted in areas given two coats of asphalt. Excel-

lent bond was noted between the asphalt and the prime coat. The curb area was not sealed with asphalt and glass fabric at all locations.

When the application started again, an asphalt roofing cement was placed along the joint between the deck and curb prior to the application of the asphalt and fabric. When the membrane was completed along the curb a spreader box (pony) was used to apply the asphalt in place of the mops. This reduced the application time significantly resulting in placement of a 3 foot by 156 foot strip in about 8 minutes. A chain grid or mesh hooked to the back of the box was effective in leveling out and covering wrinkles in the previous layer of glass fabric.

The temperature of the asphalt often exceeded the 350°F maximum specified. This was due to local overheating in the kettle and also because the roofing applicators were accustomed to heating the asphalt in excess of 450°F. The higher temperature did help insure penetration of the glass fabric into the asphalt while the fabric did not always bond to the asphalt in the 350°F range if placement was delayed by a few extra seconds.

The third coat of asphalt was placed with the spreader box and reworked with mops to insure that all of the glass fabric was covered. The overall application rate could not be determined due to the temporary removal of the kettle and a portion of the asphalt after the application had begun.

Inspection of the system upon completion disclosed an average of 81 pinholes per square foot. Almost all of the holes were 1/16 inch or less in diameter. Electrical resistance readings on the completed membrane ranged from 20,000 to 80,000 ohms per square foot with an average of 46,000 ohms.

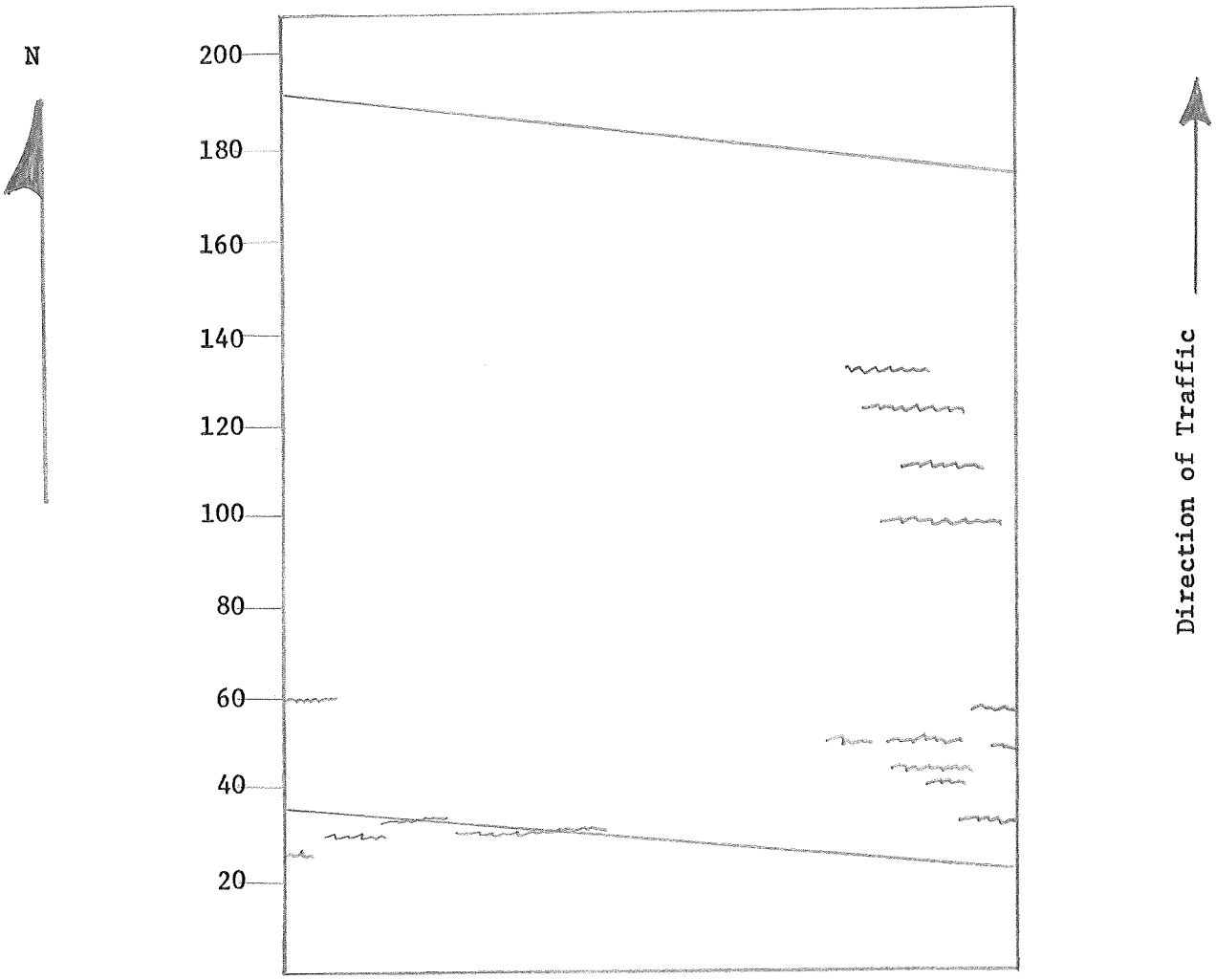
The first 1 inch course of asbestos modified pavement was placed without any visible damage to the membrane system. Electrical resistance readings taken on the membrane and completed pavement were recorded at infinity indicating that the combined system was initially impervious.

FIGURE I

I-91 Northbound over State Aid #9

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.



HOT MOPPED ASPHALT & GLASS FABRIC

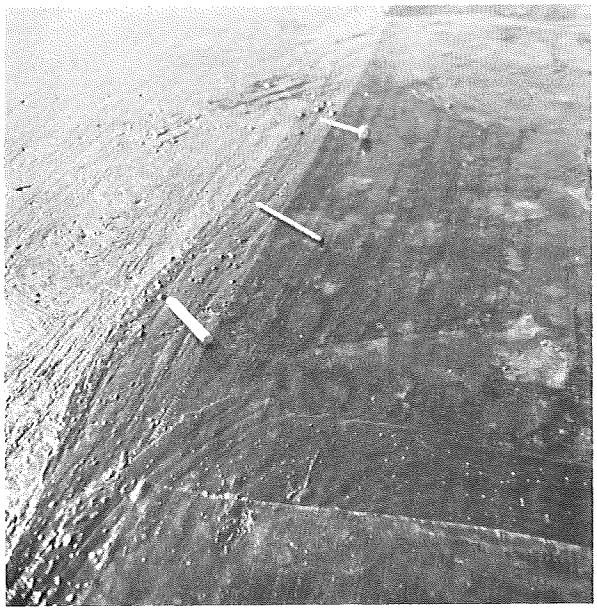
I-91 NB Over State Aid No. 9

May 1973

Bubbles up to ¾ inch in diameter appeared in the cut-back asphalt prime coat shortly after application.

Placing glass fabric in the first coat of asphalt along the curb. Note moisture sensing copper foil strips placed beneath the membrane to detect the passage of moisture.

Placing glass fabric in first coat of hot asphalt.



Bubbles and pinholes in the first coat of asphalt.

WORK PLAN #13 - INITIAL REPORT
RAMBOND 620-S EPOXY

PROJECT

Lyndon-Barton I 91-3(18) Stage II

PROJECT LOCATION

In the counties of Orleans and Caledonia, Vermont, beginning approximately 5.416 miles southeast of the Lyndon-Wheelock town line and extending northwesterly 18.741 miles.

WORK LOCATION

I-91 southbound bridge over State Aid Highway #9 at station 1226+30.23 - 1227+80.41, 1.2 miles south of the Vt Rte 122 interchange at Lyndonville.

BRIDGE CONSTRUCTION DATA

Type of Structure - Non-composite continuous rigid frame

Span Lengths - 43'- 70'- 35' Overall Length - 150.09'

Curb to Curb Width - 39'- 4" Skew - 22°- 31'- 42"

Horizontal Curvature - 1°- 30'- 00" lt

Grade - -1.1100% Superelevation - 1/2" per foot

DECK CONSTRUCTION DATA

Date Poured - June 22, 1972

Weather Conditions - Cloudy 1-5 mph breeze

Temperature - 70°F Deck Thickness - 8"

Concrete Cover over Reinforcing Steel - 1-7/8" - 2-3/8" 2-1/8" average on 42 tests

Concrete - Class AA Cement - Type I 6-1/2 bags per c.y.

Aggregate Size - 3/4" maximum Air Entraining Admixture - Darex 8 oz/cy

Retarding Admixture - Plastiment first 53 c.y. - 5 oz/sack
second 43 c.y. - 4 oz/sack
third 61 c.y. - 3 oz/sack

Pour Sequence - North to south

Finishing Method - Gomaco rotating cylinder screed

DECK CONSTRUCTION DATA - cont'd

Surface Texture - Burlap drag

Curing - Fogging and polyethylene cover

Concrete Test Results:

Percent Air - 5-1/2 - 7-1/2 6-1/2 average on 20 tests

Slump - 2"- 3-1/2" 2-3/4" average on 20 tests

Modulus of Rupture - 607 psi average at 28 days

DECK CONDITION

Surface Texture - Open textured moderately rough surface.

Cracks - Seventeen transverse cracks averaging 9.7 feet in length were noted in the deck with 53% of the cracks also visible on the bottom of the deck due to heavy staining. Many short transverse and pattern type cracks were also noted in the deck surface. See crack layout on Figure 2, Page 15.

Average Initial Chloride Level - 25 parts per million.

PROTECTIVE TREATMENT

Product - Rambond 620-S Elastomeric Epoxy. A two component 100% solids epoxy coating manufactured by the Ramchem Company, Box 746, Montpelier, Vermont 05602.

Test Results - Samples of the epoxy displayed excellent flexibility at all temperature ranges. Initial laboratory tests indicated the material possessed average resistance to moisture absorption, however, extended testing has since disclosed that the epoxy will soften under continuous immersion.

RECOMMENDED APPLICATION PROCEDURE

Sandblast or acid etch concrete surfaces. Mix the A and B components thoroughly and apply the epoxy by brush, roller, notched trowel or squeegee at the rate of 40 to 80 square feet per gallon.

DECK PREPARATION PRIOR TO MEMBRANE APPLICATION

The bridge deck was sandblasted clean.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humidity	
	4/20/73		Clear. Air temperatures recorded in shade.
12:00	63°	18	Completed sandblasting operation which had begun previous day.
12:30	63°	14	Began applying first coat of epoxy by squeegee along the easterly curb.
1:05	64°	14	A light application of Ottawa sand was cast in the epoxy coating to break the small air bubbles which formed shortly after application. The application rate for the first 1248 s.f. averaged 34.6 s.f./gal.
1:45	67°	13	Application rate increased to 39 s.f./gal. by applying more pressure on squeegees. Reworking epoxy with squeegees in an attempt to break air bubbles.
3:00	73°	12	96 gallons on deck.
5:15	73°	17	First coat complete. 120 gallons applied on 6150 s.f. for an average application rate of 51.3 s.f./gal.
	4/21/73		65% cloud cover A.M. Clear to 30% cloud cover in P.M.
10:30	58°	35	Epoxy placed previous day is still quite tacky. Heavy application along westerly curb is nearly free of pinholes.
11:30	62°	33	Applying second coat of epoxy as light as possible.
12:10	64°	28	28 gallons applied. Most of the pinholes in the first coat are not reappearing in the second coat.
1:45	71°	24	52 gallons applied on 4435 s.f. for application rate of 85.3 s.f./gal.
3:00	75°	35	Second coat complete. 80 gallons applied on 6150 s.f. for an average application rate of 76.9 s.f./gal.
	4/25/73		Clear. 5-15 mph wind. The epoxy is tack free but is still giving off an odor which indicates curing is not yet complete.
2:30	60°	28	Began epoxy application at centerline with intent to place third coat along low side of banked deck.
3:20	60°	29	20 gallons applied. Bubbles are forming in the liquid epoxy but at a reduced rate as compared to earlier coats.
4:15	61°	28	Application complete. 40 gallons applied on 3200 s.f. for an average application rate of 80 s.f./gal.

BITUMINOUS CONCRETE WEARING SURFACE

Placement - Two 1 inch thick courses with the first course placed with a rubber tired paver.

Aggregate Size - 3/8" maximum.

Asphalt - AC-5 viscosity grade. First course designed with 8% asphalt content and 1-1/2% asbestos fibers.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment -	240 gallons	@	$35.00/gal.	= $8,400.00
Bituminous Concrete -	109 tons	@	$10.00/ton	= $1,090.00

FIGURE 2

I-91 Southbound over State Aid #9

Cracks in Concrete Deck

Fifty-three percent of the cracks noted on the deck surface were also visible on the bottom of the deck. Length of cracks and their locations are to scale. Vertical scale 40'/in. Horizontal scale 10'/in.

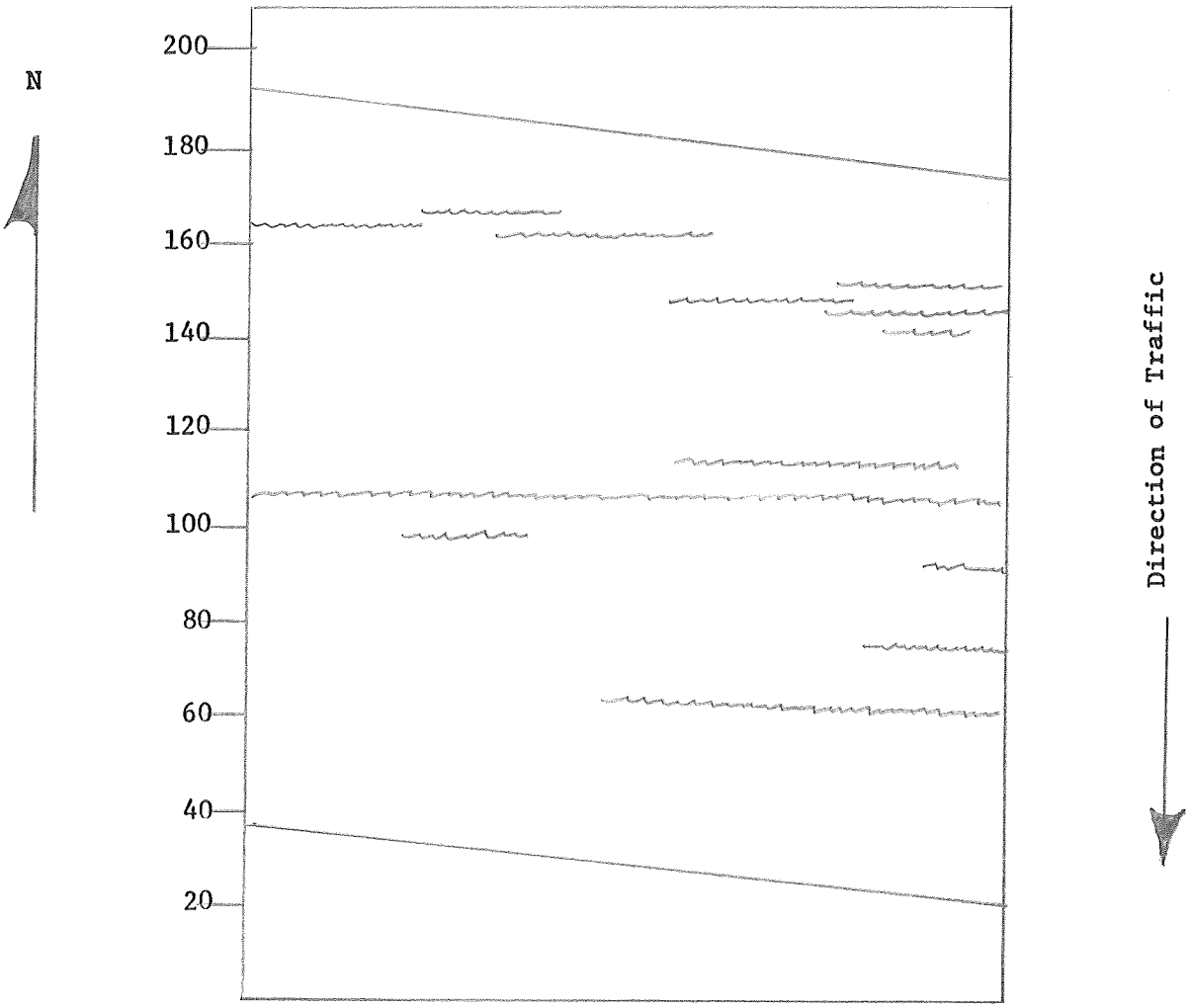


TABLE I

Electrical Resistance Readings and Pinholes in Membrane

All locations checked were 6 inches square in area opposite a point 50 feet from the beginning of the guard rail on the north-easterly end of the deck.

Curb Offset	Concrete Surface Texture	Holes per square foot			Data on 1st coat		Ohms/sf Resistance
		1st coat	2nd coat	3rd coat	hole size	coating thickness	
1	Rough	88	48		Med	Heavy	30,000
2	Rough	80	38		Med	Heavy	
3	Moderate	124	53		Small	Heavy	31,000
8	Moderate	188	112		Large	Light	
10	Rough	82	44		Med	Light	
11	Moderate	104	48		Small	Med	28,000
14	Smooth	56	52		Small	Med	
16	Moderate	60	56		Small	Med	
18	Rough	36	36		Small	Med	
20	Rough	64	40	8	Small	Light	
22	Moderate	104	8	4	Small	Light	
24	Smooth	24	20	8	Med	Light	110,000
26	Moderate	60	16	8	Med	Light	12,000
28	Smooth	52	4	4	Med	Light	
30	Smooth	232	4	4	Small	Light	
32	Smooth	*48	12	4	Small	Light	
34	Smooth	* 8	4	0	Small	Light	
36	Moderate	*60	0	0	Med	Med	38,000
38	Smooth	* 8	8	0	Small	Heavy	
	Average	78	32	4			41,500

*Area treated after 3 P.M. when air temperature no longer rising.

DISCUSSION

The epoxy was mixed in four gallon batches and spread with squeegees over the deck surface. Air bubbles which quickly formed in the liquid coating were reduced somewhat by reworking the material with squeegees. The application of a light coat of Ottawa sand cast into the first two coats of epoxy also reduced the number of bubbles although many seemed to reappear a short time later. One hundred and twenty gallons of epoxy was applied in the first coat for an average application rate of 51.3 square feet per gallon. This amounted to a dry film thickness of 31 mils.

Inspection of the coating 24 hours after application disclosed an average of 78 holes per square foot (see Table 1, page 16). Such holes in the coating were believed to be primarily caused by the outgassing of air and moisture vapor from pores in the concrete surface which normally occurs when air temperatures are on the increase or barometric pressures are declining. This is illustrated by the fact that the areas treated between 3:00 P.M. and 5:30 P.M. when air temperatures were stable had an average of 31 holes while the areas treated earlier during a period of rising air temperature had an average of 90 holes per square foot. The crater shaped holes ranged from 1/4 inch to 1/32 inch in diameter. Although concrete was visible at the bottom of only a few holes, electrical resistance readings were low averaging 11,700 ohms per square foot which indicates that moisture was able to pass through the coating at many locations.

A second coat of epoxy was applied 24 hours later at the average rate of 76.9 square feet per gallon. Inspection of the 21 mil thick coating disclosed an average of 32 holes per square foot which was a 59 percent reduction in the number of holes detected in the first coat at the same locations. Electrical resistance readings on the two coat system averaged 11,700 ohms per square foot.

The continued existence of a sizeable number of holes in the coating prompted the application of a third coat of epoxy on the low side of the banked deck. The application was made at the rate of 80 square feet per gallon over an area aver-

aging 20.5 feet in width. Inspection of the 20 mil thick coating prior to the pavement application disclosed an average of four holes per square foot with electrical resistance readings averaging 53,000 ohms per square foot.

A strip approximately one foot wide was left open along the low side of the deck for the purpose of periodic visual observations. Inspection of the epoxy upon removal of the compacted bituminous concrete from one location did not reveal any damage to the coating or change in its flexibility or bond to the concrete. Earlier attempts to strip the epoxy from the concrete on the approach slabs had disclosed that the pliability of the material resulted in cohesive failures in the coating rather than loss of adhesion to the concrete.

Electrical resistance readings taken on the completed pavement-membrane system ranged from 15 million to infinity. Such readings indicate that the combined system initially provides an impervious barrier to moisture.

RAMBOND 620-S EPOXY

I-91 SB Over State Aid No. 9

April 1973

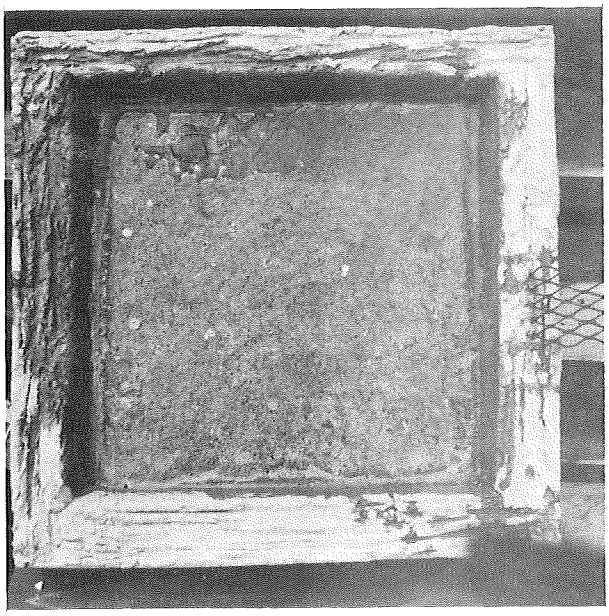
The application of multiple coats of epoxy reduced but did not eliminate all pinholes.

Electrical resistance readings averaged 41,500 ohms per square foot which indicates that some of the holes were open to the concrete.

POLYASTIC'S EPOXY

I-91 NB Over Town Highway No. 9

Bubbles formed in the epoxy coating 16 to 20 hours after application.



Blisters and cohesive cracks occurred on field treated test slabs 6 months after application.

WORK PLAN #14 - INITIAL REPORT
HOT MOPPED ASPHALT AND GLASS FABRIC

PROJECT

Lyndon-Barton I 93-3(18) Stage II

PROJECT LOCATION

In the counties of Orleans and Caledonia, Vermont, beginning approximately 5.416 miles southeast of the Lyndon-Wheelock town line and extending northwesterly 18.741 miles.

WORK LOCATION

I-91 northbound bridge over Vt Rte 122 at station 1285+86.70 - 1288+32.87, 2.6 miles north of the Rte 5 interchange at Lyndon.

BRIDGE CONSTRUCTION DATA

Type of Structure - Continuous, non-composite spans 1 & 4, composite spans 2 to 3.

Span Lengths - 49.25 - 81.0' - 69.0' - 42.0'

Overall Length - 246.17' Curb to curb width - 39'- 4"

Skew - 66°- 00' Horizontal curvature - Tangent

Grade - 1.4499% Superelevation - 1/4" per foot

DECK CONSTRUCTION DATA

Deck Thickness - 8" Concrete - Class AA

Cement - Type I 6 1/2 bags per c.y.

Aggregate Size - 3/4" maximum Retarding admixture - None

Finishing Method - Rotating cylinder screed

Surface Texture - Burlap drag

Curing - Water spray and polyethylene sheets

Pour Sequence -

Sections 1 and 6 poured on May 22, 1972
Sections 3 and 4 poured on May 23, 1972
Sections 2 and 5 poured on May 25, 1972

DECK CONSTRUCTION DATA - cont'd

SECTIONS 1 AND 6

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

Temperature - Low 60°F High 80°F

Concrete Cover Over Reinforcing Steel - 2"- 2 1/4" 2" average on 24 tests

Concrete Test Results:

Percent Air - 5 1/2% - 6 1/2% 6% average on 11 tests

Slump - 3" - 3 1/2" 3 1/4" average on 11 tests

Compressive Strength - 3115 psi average on 2 cylinders at 14 days

SECTIONS 3 AND 4

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

Temperature - 60° - 80°F

Concrete Cover over Reinforcing Steel - 1 1/2" - 2 3/8" 2" average on 36 tests

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

Concrete Test Results:

Percent Air - 6%-7 1/4% 6 1/2% average on 14 tests

Slump - 3"-4" 3 1/2" average on 14 tests

Compressive Strength - 3160 psi average on 2 beams at 14 days

SECTIONS 2 AND 5

Weather Conditions - Clear 30% humidity 3-5 mph breeze

Temperature - High 80°F

Concrete Cover over Reinforcing Steel - Low 1 3/4" High 2 3/8"

2" average on 12 tests

Air Entraining Admixture - Darex 9 oz/cy

Concrete Test Results:

Percent Air - 6% - 7% 6-1/2% average on 8 tests

Slump - 2-1/2" - 3" 2-3/4" average on 8 tests

DECK CONSTRUCTION DATA - cont'd

SECTIONS 2 AND 5 - Concrete Test Results

Compressive Strength - 2840 psi on 1 cylinder at 14 days

DECK CONDITION

Surface texture from south to north was as follows:

Section #1 Moderate to rough finish particularly along the easterly side. Many holes in the deck surface and some screed marks.

Section #2 Smooth to moderately rough finish with some screed marks in the deck surface.

Section #3 Smooth to moderately rough finish. First three sections have somewhat gritty surface texture in passing lane wheel paths possibly due to construction traffic.

Sections #4, 5, 6 Smooth finish.

Laitance - Heavy laitance was noted along the easterly curb on the third section.

Cracks - Thirty-three transverse cracks ranging from 1.2' to 35.4' in length were noted in the deck. All cracks observed on the surface could also be detected on the bottom of the deck where heavy calcium carbonate deposits were visible along the edges of many of the cracks. See crack layout on Figure 3 , Page 26.

Average Initial Chloride Level - 26 parts per million.

PROTECTIVE TREATMENT

Product - Hot mopped asphalt and woven glass fabric.

Test Results - None. Samples not available. System specified due to positive recommendations from other Highway Departments.

RECOMMENDED APPLICATION PROCEDURE

(1) Apply a prime coat of cutback asphalt at the rate of approximately 100 square feet per gallon.
(2) Apply asphalt flashing cement along the base of the curb after the prime coat has dried.
(3) Apply a mopping of asphalt over an area approximately 20 inches wide on the low side of the deck and place a half width of glass fabric in it.
(4) Apply a mopping of asphalt over the half width of fabric and an equal width of the primed concrete. Place a full width strip of fabric in the mopping so that half of the area has 2 layers of fabric.
(5) Continue the "shingling" process until the entire surface to be treated is covered.

APPLICATION PROCEDURE - cont'd

(6) Apply a final mopping of hot asphalt over the entire area. Each coat of asphalt shall be applied at the rate of 0.33 gallons per square yard for a total coverage of 1 gallon per square yard.
(7) Apply a coat of asphalt flashing cement at the top edge of the membrane along the vertical curb face.

DECK PREPARATION PRIOR TO MEMBRANE APPLICATION

Deck washed clean, protrusions removed with chisels and grass edging tools. Chisels used to remove paint from the concrete adjacent to the drain scuppers.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humid.	Asphalt Temp	
	5/23/73			Air temperatures recorded in shade. 40%-75% cloud cover.
2:30	69°	21		Applying prime coat on northerly half of deck.
3:30	68°	23		45 gallons applied on 4520 s.f. Many bubbles of varying sizes appeared in the prime coat.
	5/24/73			Cloud cover varying from 40%-80%.
8:00	44°			Chipping paint from concrete adjacent to drain scuppers and blowing cantaminates off the deck.
11:35	66°	22		Began applying prime coat on southerly half of deck.
12:20	69°	20		20 gallons applied on 2400 s.f. for application rate of 122 s.f./gal.
1:35	72°	17		Application complete. 43.5 gallons applied on 5300 s.f. for an average application rate of 122 s.f./gal. Air bubbles ranging up to 3/4 inch in diameter noted in the prime coat with the greatest number occurring on the northerly end of the span where the application began.
	5/30/73			Overcast A.M. Clear P.M.
6:00				Began heating Type 3 Built-Up Roofing Asphalt in kettle.
8:00	60°	50	350°	Few moist spots remaining on the deck. Placing asphalt cement along the base of the curb. Began applying hot asphalt along the curb line on the north end of the deck.
9:35	62°	30		Using wooden shingles to smooth out 18" wide strips of glass fabric and remove wrinkles. Necessary to remove a few of the large wrinkles by cutting glass fabric with a knife. Copper foil strips placed 3' from curb at a point 62' to 67' from the northerly end of the curb.
11:10	65°	31	350°	Approximately half of the northerly span treated with two layers of glass fabric.
2:20	66°	20	350°	Began applying final coat of asphalt.
3:34	66°	19		Application complete on northerly span. Air bubbles noted in the completed system.
4:30				Began applying hot asphalt along the westerly curb

OBSERVATIONS MADE DURING MEMBRANE APPLICATION - cont'd

Time	Temp	% Humid.	Asphalt Temp	
				line on the southerly span.
5:30				Application stopped with treatment complete along one curb.
		6/1/73		80%-100% cloud cover. 3-5 mph breeze.
8:15				Placing half strips along easterly curb between drain scuppers.
9:00	60°	40	385°	Copper foil strips placed 2.5' from the curb at a point 154' to 159' from the northerly end of the curb.
9:45	61°	38	385°	Using spreader box to apply asphalt after application completed adjacent to curb drains.
11:00	62°	30	430°	First 2 coats of asphalt and glass fabric complete along easterly half of deck.
12:10	67°	28	395°	Placing copper strips over high point near centerline of deck.
12:50	67°	27	480°	Applying final coat of asphalt with mops.
2:00	65°	32	405°	Application complete. Very few wrinkles visible in southerly span. See discussion for information on bubbles and pinholes in the system. A total of 9245 pounds of asphalt was applied on a 1110 s.y. area for an average asphalt application rate of 0.97 gallons per square yard.

BITUMINOUS CONCRETE WEARING SURFACE

Placement - Two 1 inch thick courses with the first course placed with a rubber tired paver.

Aggregate Size - 3/8" maximum.

Asphalt - AC-5 viscosity grade. First course designed with 8% asphalt content and 1-1/2% asbestos fibers.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 1110 s.y. @ $3.75/s.y. = $4,162.50

Bituminous Concrete - 139 tons @ $10.00/ton = $1,390.00

DISCUSSION

The deck was primed with a cutback asphalt applied at an average rate of 111 square feet per gallon. Air bubbles ranging up to 3/4 inch in diameter were noted in the prime coat during the application but were not visible after the coating had dried.

Ten gallons of asphalt roofing cement was placed along the base of the curb prior to placing the hot asphalt and later along the edge of the completed membrane system at the curb lines as an added precaution to prevent leakage at this point.

The mopped application of hot asphalt began along the curb on the north end of the deck. Wooden shingles were used to smooth the glass fabric into the hot asphalt and prevent wrinkles. Initially, it was necessary to remove a few large wrinkles by cutting the glass fabric with a knife but as the work progressed fewer wrinkles occurred.

Two sets of moisture sensing copper foil strips were placed on the bridge deck at 2-1/2 and 3 foot offsets from the curb prior to the membrane application. The strips are designed to indicate the passage of moisture and deicing chemicals through the membrane system by a reduction in the electrical resistance values recorded between the parallel strips.

A total of 9245 pounds of asphalt was placed on a 1110 square yard area for an average application rate of 0.97 gallons per square yard (asphalt weight equals 8.6 pounds per gallon). This was 3 percent under the specified asphalt application rate.

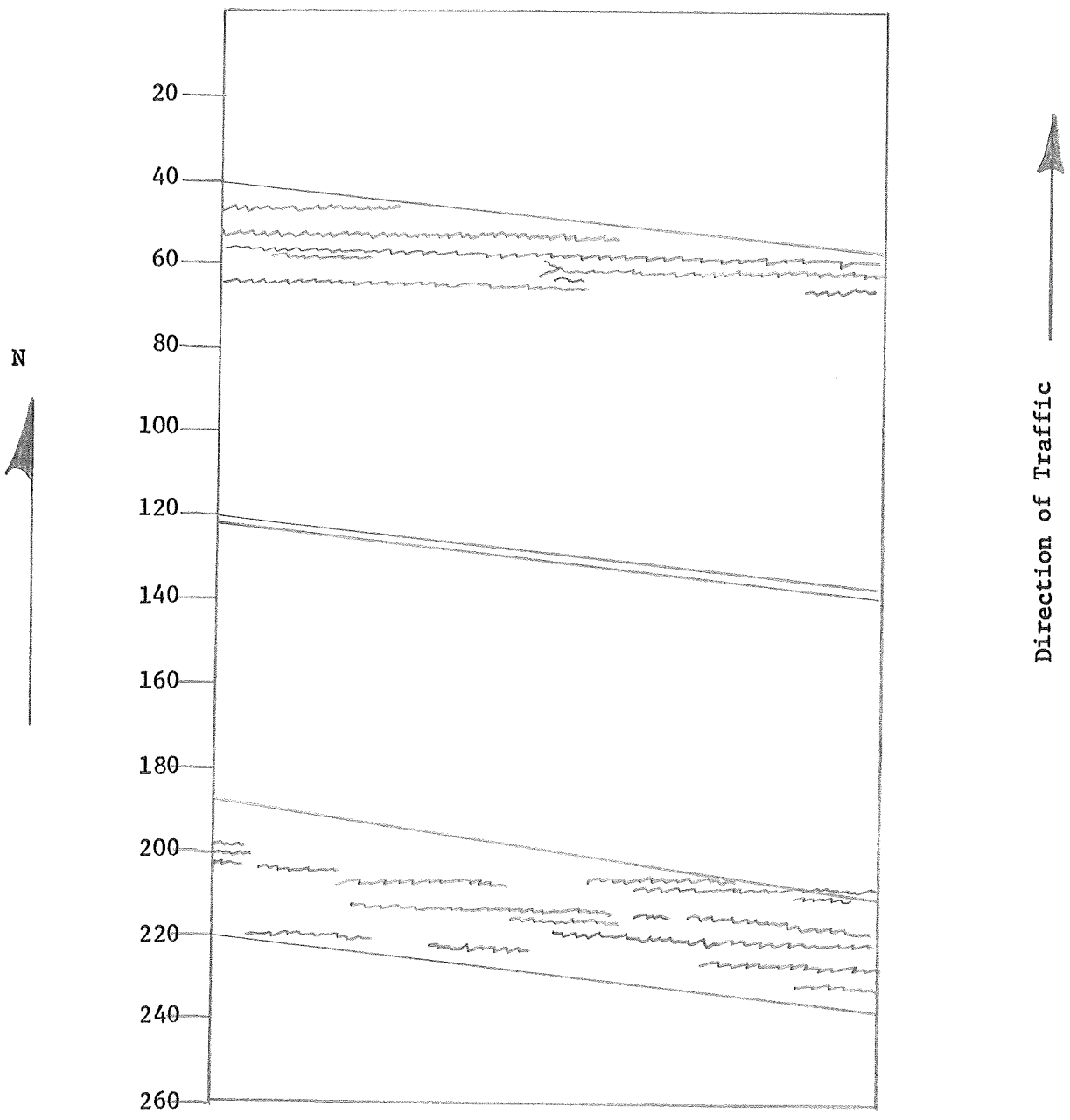
Inspection of the system upon completion disclosed an average of 180 pinholes per square foot. Four percent of the pinholes ranged from 1/16 inch to 3/32 inch in diameter while the remainder ranged from 1/64 inch to 1/16 inch in size. A few of the holes were in the form of bubbles with very small pinholes at the top. Such areas contained a very thin coating of asphalt which was easily penetrated with the point of a pencil. Electrical resistance readings taken on the completed membrane system ranged from 42,000 to 88,000 ohms per square foot with an average of 71,000 ohms. The pavement was placed without any visual damage to the membrane system. Electrical resistance readings taken on the membrane and completed pavement were recorded at infinity indicating that the combined system was impervious.

FIGURE 3

I-91 Northbound over Vt Rte 122

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.



WORK PLAN #15 - INITIAL REPORT
TAR EMULSION AND GLASS FABRIC

PROJECT

Lyndon-Barton I 91-3(18) Stage II

PROJECT LOCATION

In the counties of Orleans and Caledonia, Vermont, beginning approximately 5.416 miles southeast of the Lyndon-Wheelock town line and extending northwesterly 18.741 miles.

WORK LOCATION

I-91 southbound bridge over Vt Rte 122 at station 1286+22.32 - 1288+68.49, 16.3 miles south of the Vt Rte 16 interchange at Barton.

BRIDGE CONSTRUCTION DATA

Type of Structure - Continuous, non-composite span 1 and 4
Composite span 2 and 3

Span Lengths - 49.25 - 81.0 - 69.0 - 42.0

Overall Length - 246.17 Curb to Curb Width - 39'- 4"

Skew - 66° - 00 Horizontal Curvature - Tangent

Grade - 1.4502% Superelevation - 1/4" per foot

DECK CONSTRUCTION DATA

Deck Thickness - 8" Concrete - Class AA

Cement - Type I 6 1/2 bags per c.y.

Aggregate Size - 3/4" maximum Retarding Admixture - None

Finishing Method - Rotating cylinder screed

Surface Texture - Burlap drag

Curing - Water spray and polyethylene sheets

Pour Sequence -

Sections 1 and 6 poured on May 10, 1972
Sections 3 and 4 poured on May 11, 1972
Sections 5 and 2 poured on May 17, 1972

DECK CONSTRUCTION DATA - cont'd

SECTIONS 1 AND 6

Weather Conditions - 70% humidity 5-10 mph breeze

Temperature - Low 40°F High 75°F

Concrete Cover over Reinforcing Steel - 2"- 2 1/2" 2 1/4" average on 30 tests

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

Concrete Test Results:

Percent Air - 6%- 7 1/2% 6 3/4% average on 12 tests

Slump - 2 1/2"- 3 1/2" 3" average on 12 tests

Compressive Strength - 2929 psi on 1 cylinder at 14 days
3575 psi on 1 cylinder at 28 days

SECTIONS 3 AND 4

Weather Conditions - 2 - 3 mph breeze

Temperature - Low 40°F High 70°F

Concrete Cover over Reinforcing Steel - 2"- 2 1/2" 2 1/4" average on 20 tests

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

Concrete Test Results:

Percent Air - 6%- 7 1/4% 6 1/2% average on 15 tests

Slump - 2 1/2"- 4" 3" average on 15 tests

Compressive Strength - 3482 psi average on 3 cylinders at 14 days
3895 psi average on 2 cylinders at 28 days

SECTIONS 2 AND 5

Weather Conditions - 2 - 5 mph breeze

Temperature - Low 40°F High 75°F

Concrete Cover over Reinforcing Steel - 2"- 2 5/8" 2 1/4" average on 10 tests

Air Entraining Admixture - Darex 8 oz/c.y.

Concrete Test Results:

Percent Air - 6% - 7% 6 1/2% average on 7 tests

Slump - 3" - 4" 3 1/2" average on 7 tests

Compressive Strength - No test

DECK CONDITION

Surface Texture from South to North was as follows:

Section #1 Travel lane has gritty surface texture. Travel and breakdown lane has 75% gritty and 25% smooth surface plus some screed and drag marks.

Section #2 Moderate laitance with lingitudinal drag marks and some areas with a gritty surface texture.

Section #3 Slightly gritty surface texture with some drag and screed marks.

Section #4 Gritty to pitted surface texture.

Section #5 Gritty surface texture with heavy laitance over 1/2 of the travel and breakdown lanes.

Section #6 70% gritty and 30% smooth surface texture with some screed marks.

Cracks - Nine transverse cracks ranging from 1' to 8.5' in length were noted in the deck. See crack layout on Figure 4, Page 32.

Average Initial Chloride Level - 32 parts per million.

PROTECTIVE TREATMENT

Product - Tar emulsion and woven glass fabric.
The brand of coal tar emulsion used was Flintar 990-03 Coating manufactured by the Flintkote Company, 480 Central Ave., East Rutherford, New Jersey 07073.
The glass fabric was manufactured by Burlington Glass Fabrics Co.

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

RECOMMENDED 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 1/2 gallon per square yard.

DECK PREPARATION PRIOR TO MEMBRANE APPLICATION

Deck washed clean, protrusions removed with chisels and grass edging tools.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humidity	
	5/7/73		Air temperatures recorded in shade. Clear. 0-5 mph breeze.
10:00	54°	39	Applying prime coat on northerly end of deck following water application on concrete.
11:35	58°	24	Northerly half of deck complete.
2:15	70°	15	Prime coat application complete. 102 gals. applied on 1100 s.y. for application rate of 0.093 gal/s.y.
2:50	70°	15	Placing second coat of emulsion and longitudinal strips of fabric.
6:35	60°	21	Second coat of emulsion and fabric complete on northerly half of deck.
	5/8/73		
9:30	54°	62	Placing emulsion and fabric along the skew of the deck.
11:25	66°	33	Emulsion very caustic. One workman taken to hospital for emulsion burns.
1:20	74°	25	Working out most of the fabric wrinkles with squeegees.
4:00	70°	22	Second layer of fabric complete.
	5/10/73		Clear.
10:00	65°	70	Painting emulsion along curbs where glass fabric was not bonded to earlier coats of tar emulsion.
10:45	66°	62	Applied 100 gallons tar emulsion on two final coats. Application rate for the northerly half of the deck was 0.522 s.y./gal.
11:00	66°	62	Began priming southerly span. Copper foil strips placed 3 feet from the westerly curb at a point 105 to 110 ft. from the southerly end of the deck.
2:00	73°	30	Longitudinal strips completed.
3:30	70°	33	10% cloud cover. Placing transverse strips.
5:00	73°	33	Some holidays noted down to the concrete surface through 2 coats of tar emulsion.
6:45	66°	48	Began applying fourth coat.
8:15	59°	62	Finished fourth coat and touchup along curbs and expansion dam.
	5/12/73		10 to 20% cloud cover.
7:00	52°		Rain showers which occurred on the evening of 5/10/73 resulted in a loss of part of the fourth coat of tar emulsion.
7:45	58°	46	Retreating washed areas.
9:15	58°	47	Began fifth coat.
10:05	60°	45	Final coat complete. 278 gallons applied on southerly half of deck for an application rate of 0.497 gal/sy.

BITUMINOUS CONCRETE WEARING SURFACE

Placement - Two 1 inch thick courses with the first course placed with a rubber tired paver.

Aggregate Size - 3/8" maximum.

Asphalt - AC-5 viscosity grade. First course designed with 8% asphalt content and 1-1/2% asbestos fibers.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment -	1102 s.y.	@	$3.50/sy	= $3,857.00
Bituminous Concrete -	102.7 tons	@	$10.00/ton	= $1,027.00

DISCUSSION

Inspection of the completed membrane system revealed many areas along the curbing which were not properly sealed even though most areas had been given extra paint brush applications of tar emulsion. Nearly all of the horizontal surface area of the deck appeared to have sufficient coverage with the overall application rate averaging 0.51 gallons per square yard.

Electrical resistance readings were taken on the membrane system three days after completion. The readings averaged 315 ohms per square foot, slightly less than the normal average on untreated concrete. Such low readings may have been due to excellent electrical conductance between water remaining in the tar emulsion and adjacent steel drain scuppers along the curb lines.

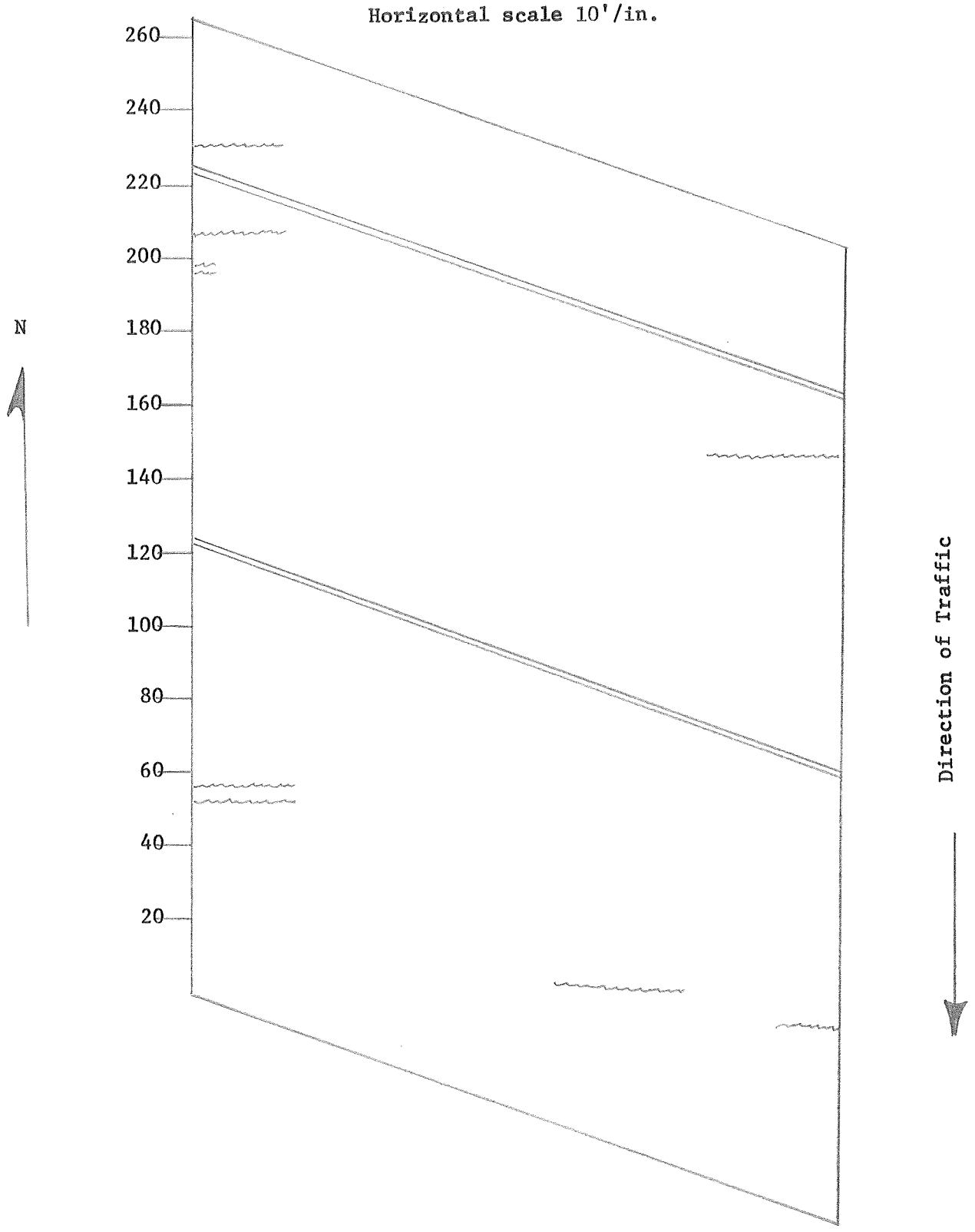
The first 1 inch course of asbestos modified pavement was placed without any visible damage to the membrane system. Electrical resistance readings taken on the completed pavement-membrane system ranged between seven million and infinity. Such readings indicate that the combined system can initially be expected to protect the concrete from moisture and deicing chemicals.

FIGURE 4

I-91 Southbound over Vt Rte 122

Cracks in Concrete Deck

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



WORK PLAN #16 - INITIAL REPORT

POLYASTIC'S CONCRETE POXY MEMBRANE SEALER

PROJECT

Lyndon-Barton I 91-3(18) Stage II

PROJECT LOCATION

In the counties of Orleans and Caledonia, Vermont, beginning approximately 5.416 miles southeast of the Lyndon-Wheelock town line and extending northwesterly 18.741 miles.

WORK LOCATION

I-91 northbound bridge over Town Highway #9 at station 1372+34.91 - 1372+66.91, 4.3 miles north of the Route 5 interchange at Lyndon.

BRIDGE CONSTRUCTION DATA

Type of Structure - Concrete Tee Beam

Span Lengths - 29'- 0"

Overall Length - 32'- 0"

Curb to Curb Width - 39'- 4"

Skew - 9° 31' rt.

Horizontal Curvature - Tangent

Grade - 4.00%

Superelevation - 1/4" per foot

DECK CONSTRUCTION DATA

Date Poured - November 11, 1971

Weather Conditions - Overcast with snow, calm

Temperature - 32°- 45°F

Deck Thickness - 12"

Concrete - Class AA

Concrete Cover over Reinforcing Steel - No record

Cement - Type I 6-1/2 bags per c.y.

Aggregate Size - 3/4" maximum

Air Entraining Admixture - Darex first 17 c.y. - 7 oz/sack
last 78 c.y. - 8 oz/sack

Retarding Admixture - None

DECK CONSTRUCTION DATA - cont'd

Pour Sequence - South to north

Finishing Method - Gomaco Finishing Machine

Surface Texture - Burlap drag

Curing - Straw and polyethylene for 10 days

Concrete Test Results:

Percent Air - 5-1/2% - 7-1/2% 6% average on 10 tests

Slump - 2-3/4" - 4" 3-1/8" average on 6 tests

Compressive Strength - 4494 psi average on 2 cylinders at 28 days

DECK CONDITION

Surface Texture - Smooth, dense surface with transverse screed marks at 4 to 5 inch intervals.

Cracks - None

Laitance - Very little

Average Initial Chloride Level - 27 parts per million

PROTECTIVE TREATMENT

Product - Polyastic's Concrete Poxy Membrane Sealer. A two component, solvent cut, polyamide epoxy manufactured by the Polyastics Corporation, 203-205 State Road, Croydon, Pennsylvania 19020.

Test Results - Samples of the epoxy ranging from several mils to 1/8" in thickness displayed excellent flexibility at room temperature and nearly as good flexibility at -10°F. The crack bridging ability of the epoxy was not satisfactory due to the thinness of the coating. Concrete samples treated with the epoxy displayed low moisture absorption (0.91%) after 165 days immersion in water.

RECOMMENDED APPLICATION PROCEDURE

Sandblast or acid etch concrete surfaces. Dampen surface with water prior to application. Mix epoxy components in equal parts and apply 1 to 3 coats with a rubber squeegee leaving approximately an 8 mil deposit per coat.

DECK PREPARATION PRIOR TO MEMBRANE APPLICATION

The bridge deck was sandblasted clean.

OBSERVATIONS MADE DURING MEMBRANE APPLICATIONS

Time	Temp	% Humidity	
	5/7/73		Air temperatures recorded in shade.
3:00	68°	10	Began applying first coat of epoxy by squeegee. All areas fogged with light application of water prior to epoxy application. Fourteen gallons of epoxy applied on 1494 s.f. for application rate of 107 s.f./gal. Very few air bubbles or pinholes visible.
5:45	58°	10	Applying second coat. First coat still slightly tacky.
6:10	57°	12	10 gallons applied in second coat for application rate of 149 s.f./gal.
7:05	55°	15	Began final coat.
7:30			6 gallons applied in final coat for application rate of 250 s.f./gal. 30 gallons applied on 1494 s.f. for a total coverage of 50 s.f./gal. No pinholes or bubbles noted in completed system.

BITUMINOUS CONCRETE WEARING SURFACE

Placement - Two 1 inch thick courses with the first course placed with a rubber tired paver.

Aggregate Size - 3/8" maximum.

Asphalt - AC-5 viscosity grade. First course designed with 8% asphalt content and 1-1/2% asbestos fibers.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 30 gallons @ $40.00/gal. = $1,200.00

Bituminous Concrete - 57.9 tons @ $10.00/ton = $579.00

TABLE 2

Electrical Resistance Readings and Bubbles in Membrane

All locations checked were 6 inches square in area opposite guard rail post number 4 on the easterly side of the deck. Posts were numbered south from the northerly end.

Curb Offset	BUBBLE SIZE 1/2"-3/4"	1/4"-1/2"	1/8"-1/4"	1/16"-1/8"	1/16"-	Bubbles Per *Square Foot	Ohms/sf Resistance
1	1	5	7	13	9	140	26,250
3		4	5	10	2	84	28,950
5		2	16	18	15	204	19,900
7		2	6	7	1	64	31,500
9	1		14	13	6	136	14,250
11	1	3	7	2	1	56	54,500
13		2	8	8	1	76	47,000
17		3	7	1	1	56	75,000
19		4	2	1		28	50,000
21		1	6	3	6	64	60,000
					Average	91	40,735

*In addition to the number noted a few very small air bubble clusters were suspended in the coating at many locations.

DISCUSSION

The epoxy was applied by squeegee in three separate coats at rates of 107, 149, and 250 square feet per gallon. The total coverage amounted to 50 square feet per gallon for a dry film thickness of 13 mils.

The application was made late in the afternoon in an attempt to avoid the occurrence of pinholes or bubbles which normally result from rising air temperatures and the subsequent escape of air or moisture vapor from the concrete. Although a few bubbles and pinholes were visible in the first two coats, none were detected in

the system when the final coat was applied. When the system was inspected the following morning there still were no pinholes or bubbles; however, when the system was checked later that afternoon, many air bubbles were noted throughout the coating. The failure of the epoxy to resist the air and moisture vapor pressure from the concrete was believed due to lack of sufficient overnight cure prior to the rise in air temperature the following day. Inspection of the coating the following day disclosed that most of the air bubbles had receeded and were in the shape of craters. Spot checks of the membrane system revealed an average of 91 bubbles or craters per square foot with the size ranging from 1/16 to 3/4 inch in diameter (see table 2 page 36).

Electrical resistance readings on the epoxy ranged from 14,250 to 75,000 ohms per square foot with an average of 40,735 ohms per square foot. Such readings indicate openings in the coating although testing with hydrochloric acid did not reveal any visual evidence of effervescence from exposed concrete.

The first one inch course of bituminous pavement was placed nine days after the epoxy was applied. The bituminous mix averaged 245°F in place. 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. A one foot wide area along the easterly curb was left unpaved so that the epoxy coating can be periodically inspected for signs of cracking or loss of bond to the concrete. Electrical resistance readings taken on the membrane and completed pavement were recorded at infinity indicating that the combined system was initially impervious.

See pictures of Polyastic's Epoxy application on page 19.

WORK PLAN #17 - INITIAL REPORT
DURALKOTE 306 EPOXY

PROJECT

Lyndon-Barton I 91-3(18) Stage II

PROJECT LOCATION

In the counties of Orleans and Caledonia, Vermont, beginning approximately 5.416 miles southeast of the Lyndon-Wheelock town line and extending northwesterly 18.741 miles.

WORK LOCATION

I-91 southbound bridge over Town Highway #9 at station 1369+34.00 - 1369+66.00, 14.8 miles south of the US Rte 16 interchange at Barton.

BRIDGE CONSTRUCTION DATA

Type of Structure - Concrete Tee Beam Span Length - 29'- 0"

Overall Length - 32'- 0" Curb to Curb Width - 39'- 4"

Skew - 12°- 11'- 10" Horizontal Curvature - Tangent

Grade - 4.00% Superelevation - 1/4" per foot

DECK CONSTRUCTION DATA

Date Poured - May 20, 1972

Weather Conditions - Partly cloudy, calm Temperature - 70°F-75°F

Deck Thickness - 12" Concrete - Class AA

Concrete Cover over Reinforcing Steel - 2"- 3" 2 3/8" average on 24 tests

Cement - Type I 6 1/2 bags per c.y.

Aggregate Size - 3/4" maximum

Air Entraining Admixture - Darex First 36 c.y. - 9 oz/cy
Last 60 c.y. - 8 oz/cy

Retarding Admixture - None

Pour Sequence - South to north

Finishing Method - Gomaco Finishing Machine

Surface Texture - Burlap drag

DECK CONSTRUCTION DATA - cont'd

Curing - Polyethylene for 10 days

Concrete Test Results:

Percent Air - 7% on 4 tests

Slump - 2 1/4"- 3" 2 1/2" average on 3 tests

Modulus of Rupture - 707 psi average on 2 beams at 28 days

DECK CONDITION

Surface Texture - Smooth, no visible laitance

Cracks - None

Miscellaneous - A few small bits of wood noted in the deck surface

Average Initial Chloride Level - 26 parts per million

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 epoxy displayed low moisture absorption and good flexibility at various temperature ranges in laboratory tests. Application of the product on a bridge deck in July 1972 (see Report 73-1) was considered successful. The system provided a good seal at the curb lines, contained few bubbles or pinholes, and had an average electrical resistance of 30 million ohms per square foot without the bituminous overlay.

RECOMMENDED APPLICATION PROCEDURE

Concrete surfaces should be sandblasted or acid etched. Combine one part by volume of Base with one part by volume of Hardner and mix thoroughly. The material may be applied by brush, roller, spray or squeegee. Sand should be broadcast into the resin within 5 minutes of application.

DECK PREPARATION PRIOR TO MEMBRANE APPLICATION

The deck surface was sandblasted on April 19, 1973 and was blown clean with a compressor just prior to the epoxy application.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humidity	Cloud Cover	
	4/21/73			Air temperature recorded in shade.
9:58	58°	49	100%	Began applying epoxy with squeegee. Material mixed in 2 gallon batches. 1/2 pint xylol solvent added per batch to lower viscosity and increase penetration into concrete pores.
10:15	62°	44	70%	50 to 75 bubbles per s.f. noted in the epoxy at many locations shortly after application.
10:55	62°	35	50%	Application complete. 17 gallons applied on 1490 s.f. for an average application rate of 87.6 s.f./gal.
3:35	74°	32	20%	200 to 280 air bubbles and 4 to 6 pinholes per s.f. noted in the first coat of epoxy.
4:10	73°	34	75%	13 gallons applied on 750 s.f. for an application rate of 58 s.f./gal.
5:00	66°	41	100%	Final coat complete. 23 gallons applied for application rate of 64.8 sf/gal. Overall application rate amounted to 37.2 s.f./gal.

BITUMINOUS CONCRETE WEARING SURFACE

Placement - Two 1 inch thick courses with the first course placed with a rubber tired paver.

Aggregate Size - 3/8" maximum.

Asphalt - AC-5 viscosity grade. First course designed with 8% asphalt content and 1-1/2% asbestos fibers.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 40 gallons @ $30.00/gal. = $1,200.00

Bituminous Concrete - 62 tons @ $10.00/ton = $620.00

TABLE 3

Electrical Resistance Readings, Pinholes and Bubbles in Membrane

All locations checked were 6 inches square in area opposite guard rail post number 3 on the westerly side of the deck. Posts were numbered south from the northerly end.

Curb Offset	Pinholes	Bubbles	Combined number of pinholes & bubbles per square foot	Ohms/s.f. Resistance
1	*12	**1	52	33,000
2	27	2	116	
3	54	12	264	72,000
5	45	6	204	95,000
7	41	4	180	149,000
9	79	5	336	
11	78	15	372	49,000
13	32	12	176	132,000
15	45	5	200	
17	27	5	128	
19	39	5	176	
21	36	10	184	
Average	43	7	199	88,300

*The size of the pinholes ranged from 1/4 inch down with most 1/64 inch or less in diameter at the surface of the membrane.

**The size of the air bubbles ranged from 1/8 inch to 3/8 inch with an average diameter of 3/16 inches.

DISCUSSION

The first coat of coal tar modified epoxy was applied at the rate of 87.6 square feet per gallon. Although pinholes were anticipated, the quick setting property of the epoxy resulted in a cure at a point when air bubbles had formed

in the coating and had not yet broken to form the more common crater shaped holes. The bubbles ranged up to 1/2 inch in diameter and numbered in excess of 200 per square foot at some locations. Attempts to break the bubbles with a squeegee were only partially successful.

The second coat of epoxy was applied at a heavier rate averaging 64.8 square feet per gallon. The total coverage for both coats amounted to a dry film thickness of 44 mils.

Inspection of the completed system disclosed an average of 28 bubbles and 172 holes per square foot (see table 3 page 41). The holes ranged from 1/4 inch down with most 1/64 inch or less in diameter at the surface of the membrane. The bubbles ranged from 1/8 inch to 3/8 inch with most averaging 3/16 inches in diameter. The number of bubbles might have been reduced significantly if a sand had been broadcast into the epoxy shortly before it had cured. Such a procedure is recommended by the manufacturer but was inadvertantly omitted during the application.

Electrical resistance readings on the epoxy ranged from 33,000 to 149,000 ohms per square foot with an average of 88,300 ohms. Such readings indicate that some of the holes are open to the deck surface although a visual inspection did not disclose any exposed concrete.

No difficulties were encountered during the application of the bituminous mix nor was any damage to the epoxy observed when the pavement was removed from several areas for inspection. A one foot wide area along the westerly curb was left unpaved so that the coating can be periodically inspected for signs of cracking or loss of adhesion to the concrete. Electrical resistance readings taken on the membrane and completed pavement were recorded at infinity indicating that the combined system was initially impervious.

WORK PLAN #18 - INITIAL REPORT

ROYSTON BRIDGE MEMBRANE #10

PROJECT

Lyndon-Barton I 91-3(18) Stage II

PROJECT LOCATION

In the counties of Orleans and Caledonia, Vermont, beginning approximately 5.416 miles southeast of the Lyndon-Wheelock town line and extending northwesterly 18.741 miles.

WORK LOCATION

I-91 northbound bridge over State Aid Highway #1 at station 1592+40.28 - 1593+85.26, 8.4 miles north of the Rte 5 interchange at Lyndon.

BRIDGE CONSTRUCTION DATA

Type of Structure - Three span continuous Span Lengths - 40'- 62'- 40'

Overall Length - 142' Curb to Curb Width - 39.3'

Skew - 47°- 50'- 40" Horizontal Curvature - Tangent

Grade - 1.6% Superelevation - 1/4" per foot

DECK CONSTRUCTION DATA

Deck Thickness - 8" Concrete - Class AA

Concrete Cover over Reinforcing Steel - Not recorded

Cement - Type I Aggregate Size - 3/4" maximum

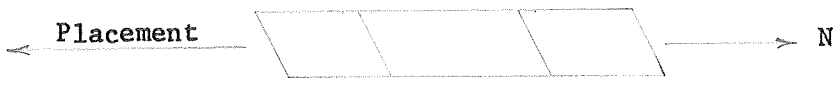
Air Entraining Admixture - Darex 8 oz/c.y.

Retarding Admixture - Sections 1 and 3 - none. Section 2 - Plastiment.

Finishing Method - Capitol finishing machine on beams

Surface Texture - Burlap drag Curing - Water and polyethylene sheets

Pour Sequence -



Sections 1 & 3 poured on June 22, 1972

Section 2 poured on June 27, 1972

DECK CONSTRUCTION DATA - cont'd

SECTIONS 1 & 3

Weather Conditions - Partly cloudy 14% humidity 0-25 mph breeze

Temperature - Low 65°F High 75°F

Concrete Test Results:

Percent Air - 5-1/2% - 6% 5-3/4% average on 10 tests

Slump - 2"- 3" 2-1/2" average on 10 tests

Compressive Strength - Records not available

SECTION 2

Weather Conditions - Partly cloudy 0-25 mph breeze

Temperature - Low 55°F High 75°F

Concrete Test Results:

Percent Air - 5-1/2% - 7% 6-1/2% average on 12 tests

Slump - 2"- 3-1/2" 2 3/4" average on 12 tests

Compressive Strength - Records not available

DECK CONDITION

Surface Texture - Smooth finish, very few protrusions or holes in the surface.

Cracks - Short Transverse cracks noted in curb sections over pier ends and fine pattern type shrinkage cracks scattered over deck surface.

Miscellaneous - Surface grade not constant at construction joint between slab pours. Epoxy mortar has sagged down from bottom of granite curb at some locations. Lack of bond also noted between epoxy mortar and deck at some points as indicated by continuous moisture seepage from beneath curb after deck surface had dried.

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

Average Initial Chloride Level - 28 parts per million.

PROTECTIVE TREATMENT

Product - Royston Bridge Membrane No. 10.

An 80 mil thick preformed sheet membrane composed of an impregnated fiber-

PROTECTIVE TREATMENT - cont'd

glass mesh sandwiched between layers of a bituminous mastic and coated with a polyester film. The membrane is manufactured by Royston Laboratories, Inc., Pittsburgh, Pennsylvania 15238.

Test Results - The membrane was not damaged by puncture or heat when subjected to the application of 275°F to 325°F bituminous mixes applied at a load of 200 pounds per square inch. The material displayed good cold temperature flexibility when bent around a 1 inch mandrel at -10°F and satisfactorily bridged cracks in cement mortar slabs when broken over a 3/16 inch anvil at 0°F.

RECOMMENDED APPLICATION PROCEDURE

Concrete surfaces should be dry and free from dust, dirt, grease or other contaminants. Apply Royston Roybond Primer 713 by roller, brush or squeegee at the rate of approximately 10 square yards per gallon. Allow the primer to dry thoroughly before applying the membrane. Place the membrane sheet with the sticky surface down by removing the release paper as the application progresses. Place the sheets in such manner that a shingling effect will be achieved and that any water which accumulates will drain toward the curb and the drain pipes. Each strip will be overlapped a minimum of 4 inches. Hand rollers or other satisfactory pressure apparatus shall be used on the applied membrane to assure firm and uniform contact with the primed concrete surface. Sheet end and side laps should be fused to the underlying membrane by melting the polyester film with a propane torch. This heat fusion method should also be used to bond the membrane to the curb by pressing or rolling the heated membrane into intimate contact with the primed curb surface. Any torn or cut areas, or narrow overlaps shall be patched by the heat fusion method, overlapping a minimum of six inches. The bituminous pavement should be between 275° and 340°F at the time of application to insure adequate bond between the membrane and the deck.

DECK PREPARATION PRIOR TO MEMBRANE APPLICATION

Deck washed clean after protrusions and heavy laitance had been removed with chisels and grass edging tools.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humidity	
	5/2/73		Air temperatures recorded in shade. 65-100% cloud cover.
8:30	58°	66	Deck surface wet from earlier shower.
11:30	66°	62	Contractor using torches to dry curb areas.
1:05	67°		Applying Royston Primer with squeegees. Stiff bristled broom used to spread primer in puddled area to prevent entrapment of solvents.
1:30	69°	53	Air bubbles numbering up to 75/s.f. noted in the primer at some locations. Copper foil strips placed 3 feet from the westerly curb.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION - cont'd

Time	Temp	% Humidity	
5/2/73 cont'd			
1:40	70°	53	Prime coat complete on westerly side of deck. 21.5 gallons applied on 3160 s.f. for an application rate of 147 s.f./gal. Squeegees and street brooms used to break air bubbles in primer.
2:40	74°	51	Placing first 48 inch by 50 foot long roll along westerly curb. Size of sheet makes it difficult to obtain desired 1 inch lap up onto curb.
3:20	72°	52	Placing successive strips with 2-1/2 inch overlap. Working air out from beneath sheets by applying pressure with squeegees.
4:30	69°	53	Fourth strip complete. Began sealing sides and end overlaps by melting the underlying sheet with a propane torch and then pressing the top sheet down into the softened membrane.
6:10	66°	53	Began priming easterly side of decks. Royston Roskote A-938 and 712 XXP mastics placed along the top edge of the membrane at the curb line after heat sealing completed at the same location.
6:45	60°	57	Prime coat complete. 18 gallons applied on 2810 s.f. for an application rate of 156 s.f./gal.
5/3/73			100% cloud cover.
7:30	59°	77	Removing rain water from primed concrete with squeegees, air blowers and towels.
10:15	61°	72	48 inch wide roll cut in half for placement along easterly curb. Copper foil strips placed 3 feet from the easterly curb at a point 50'- 55' from the northerly end.
11:10	62°	72	Second strip complete. Weight of membrane (approximately 100 pounds per roll) tends to prevent entrapment of air although some ripples do occur at points where the sheets do not remain in complete contact with the primed concrete.
12:25	66°	61	Four man-crew placing the sheet membrane at the rate of 1400 square feet per hour. Two men holding and unrolling, one man removing release paper and one man positioning the sheet at the start and then working out wrinkles and air with a squeegee.
1:10	68°	62	Sheet application complete.
3:05	70°	58	Heat sealing membrane along the curb. Having some difficulty with the sheet pulling away from the right angle joint at the base of the curb when pressure is applied at the top edge.
3:20			Beginning to rain as mastic is being applied along the curb.
5/5/73			Additional mastic placed along the curbs at several locations which were not completely sealed earlier. Sheet edge and end overlaps sealed by heating.

BITUMINOUS CONCRETE WEARING SURFACE

Placement - Two 1 inch thick courses with the first course placed with a rubber tired paver.

Aggregate Size - 3/8" maximum.

Asphalt - AC-5 viscosity grade. First course designed with 8% asphalt content and 1-1/2% asbestos fibers.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment -	685 s.y.	@	$6.00/s.y.	=	$4,110.00
Bituminous Concrete -	94 tons	@	$10.00/ton	=	$ 940.00

DISCUSSION

The installation began with the application of Royston primer on the westerly half of the deck. The solvent cut primer was applied by squeegee at an average rate of 147 square feet per gallon. Air bubbles numbering up to 75 per square foot were noted in the primer at some locations shortly after application. As the primer was drying, a stiff bristled broom was used to open and spread thick or puddled areas to prevent the entrapment of any solvent. The procedure also broke any air bubbles which had remained in the prime coat.

The 100 pound weight and 48 inch width of the membrane roll made it difficult to handle and obtain the desired one inch lap up onto the curb. Repositioning of the sheet was necessary and possible due to very little tack occurring between the primed concrete and the membrane sheet prior to the application of pressure (the system requires bituminous overlay temperatures in excess of 275°F to insure complete bond with the concrete).

A squeegee was used to force air out from beneath the membrane and to reduce the amount of wrinkles and ripples in the sheets. This procedure worked satisfactorily although the membrane did not remain in contact with the primed concrete at all locations. Additional rolling with a hand roller did little to remove the re-

maining ripples.

Successive rolls of the membrane were placed with a 2-1/2 inch overlap at the suggestion of the technical representative on the project. When the membrane had been placed nearly to the mid-point of the parabolic deck, the workman began sealing the side and end overlaps by heating the membrane with a propane torch. This was accomplished by turning back the top sheet, softening the underlying membrane with the heat and then pressing the top layer down onto the tacky underlayer. The Royston representative noted that their material currently under production was being made with a self-sealing edge (no polyester film along the edge of the sheet) and would not require heat sealing on the side laps. Sealing the membrane along the curb was accomplished by softening the material with the torch and then pressing it against the granite with a spatula or gloved hand. The heat seal along the curb was followed by a coat of Royston mastic along the top edge of the membrane.

The primer application on the easterly side of the deck averaged 156 square feet per gallon. The membrane installation along the curb line was made easier by cutting a roll in two 24 inch wide strips. As the four man-crew became accustomed to working with the material, their rate of installation increased to an average of 1400 square feet per hour.

Electrical resistance readings taken on the completed membrane system were all recorded at infinity. This included tests taken at several locations which had been patched to give added protection due to defects in the manufacturer of a portion of one roll.

The first course of bituminous mix was placed at an average compacted thickness of 1-1/16 inches. The temperature of the mix averaged 300°F in the trucks. A single eight inch diameter boil which occurred in the bituminous mix was removed by puncturing the membrane with a knife. Ripples which were present in the membrane prior to paving were apparently flattened and sealed down by the weight and heat of the bituminous mix. No damage was visible in the membrane material when the bituminous mix was removed from several locations for inspection.

No depressions or ruts were noted in the first course of pavement or membrane system when the bridge was inspected two months after the membrane had been placed. Electrical resistance readings taken on the membrane and completed pavement were recorded at infinity.

See pictures of Royston application on page 57.

WORK PLAN #19 - INITIAL REPORT

PROTECTO WRAP M-400

PROJECT

Lyndon-Barton I 91-3(18) Stage II

PROJECT LOCATION

In the counties of Orleans and Caledonia, Vermont, beginning approximately 5.416 miles southeast of the Lyndon-Wheelock town line and extending northwesterly 18.741 miles.

WORK LOCATION

I-91 southbound bridge over State Aid Highway #1 at station 1590+54.51 - 1591-91.49, 10.6 miles south of the Vt Rte 16 interchange at Barton.

BRIDGE CONSTRUCTION DATA

Type of Structure - Three span continuous Span Lengths - 39'- 56'- 39'

Overall Length - 134' Curb to Curb Width - 39.3'

Skew - 47°- 50'- 40" lt. Horizontal Curvature - Tangent

Grade - -0.46% Superelevation - 1/4" per foot

DECK CONSTRUCTION DATA

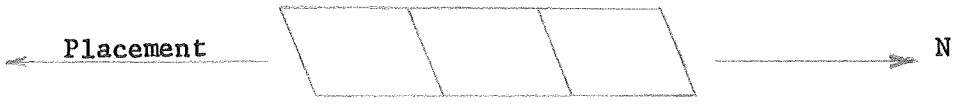
Deck Thickness - 8" Concrete - Class AA

Cement - Type I Aggregate Size - 3/4" maximum

Finishing Method - Capitol finishing machine on beams

Surface Texture - Burlap drag Curing - Water and polyethylene sheets

Pour Sequence -



Sections 1 and 3 poured on May 16, 1972
Section 2 poured on May 19, 1972

SECTIONS 1 & 3

Weather Conditions - Showers 5 mph breeze

DECK CONSTRUCTION DATA

SECTIONS 1 AND 3 - cont'd

Temperature - 55°- 65°F

Concrete Cover Over Reinforcing Steel - 1-1/2"- 2-1/2" 2" average on 40 tests

Air Entraining Admixture - Darex 8 oz/cy

Retarding Admixture - None

Concrete Test Results:

Percent Air - 5-1/2% - 7% 6% average on 10 tests

Slump - 2-3/4"- 3-1/2" 3" average on 10 tests

Compressive Strength - 3076 psi average on 5 cylinders at 14 days

SECTION 2

Weather Conditions - Clear 35% humidity 5 mph breeze

Temperature - 55°- 75°F

Concrete Cover Over Reinforcing Steel - 1-1/2"- 2-1/2" 2" average on 41 tests

Air Entraining Admixture - Darex 8 oz/cy

Retarding Admixture - Plastiment 3 and 2 oz/cy

Concrete Test Results:

Percent Air - 6-1/2%- 7-1/2% 7-1/4% average on 12 tests

Slump - 3"- 5" 4" average on 13 tests

Compressive Strength - 3390 psi average on 3 cylinders at 28 days

DECK CONDITION

Surface Texture - Slightly pitted surface texture on end spans due to rain showers.
Middle span 40% smooth, 50% light texture and 10% moderately rough including areas along the curb.

Cracks - None

Laitance - Very little

Miscellaneous - A few small pieces of wood were noted in the surface of the concrete.

Average Initial Chloride Level - 28 parts per million.

PROTECTIVE TREATMENT

Product - Protecto Wrap M-400
A 70 mil thick preformed sheet membrane composed of coal tar modified with synthetic resins and reinforced with a synthetic non-woven fabric. The membrane is manufactured by the Protecto Wrap Company, 2255 South Delaware Street, Denver, Colorado 80223.

Test Results - The membrane was not damaged by puncture or heat when subjected to the application of 275°F to 325°F bituminous mixes applied at a load of 200 pounds per square inch. The membrane displayed sufficient flexibility to resist cracking when bent around a 5 inch diameter mandril at -10°F, however, cracks occurred in the material when it was bent around mandrils of a smaller diameter. The membrane bridged cracks in cement mortar slabs when broken over a 3/16 inch anvil on 75 percent of the samples tested at 0°F.

RECOMMENDED APPLICATION PROCEDURE

Concrete surfaces should be dry and free from dust, dirt, grease or other contaminants. Ambient temperature of the surface to be covered, the air, and the material should not be less than 40°F. Apply Protecto Wrap Number 80 Primer by roller, brush, or squeegee at a rate not exceeding 150 square feet per gallon. Allow the primer to dry to a tack free condition prior to applying the membrane. Reprime areas not covered within 24 hours. Apply #80 Primer or 1200 Mastic on the curb as high as the planned overlay thickness. Place the membrane wrinkle free with a minimum of 3 inch overlaps in a manner that will provide a shingling effect toward the low side of the deck. Apply a bead of mastic along the upper outside edge of the membrane along the curb to form a seal. Remove the polyethylene release film from the surface of the membrane prior to placing the bituminous overlay. The temperature of the bituminous mix should not exceed 280°F at the time of application.

DECK PREPARATION PRIOR TO MEMBRANE APPLICATION

Deck washed clean after protrusions and heavy laitance had been removed with chisels and grass edging tools.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humid.	
	4/16/73		30% cloud cover A.M. 20% in P.M. 15-25 mph breeze
9:50	64°		Began applying Protecto Wrap #80 with squeegees on the southwesterly end of the deck. Application along the curb made with a paint brush.
10:55	67°		25 gallons of primer applied on 3175 s.f. for an application rate of 127 s.f./gal. Numerous air bubbles in the primer were broken with a squeegee after the material became tack free.
11:30	66°		Applying No. 1200 mastic 2 inches up onto curb and 2-3 inches onto deck with stiff bristled paint brush. Mastic designed to seal voids and help membrane bridge rough areas along the curb.
11:55	68°		Placing 30 inch wide roll of membrane along curb line in tack

OBSERVATIONS MADE DURING MEMBRANE APPLICATION - cont'd

Time	Temp	% Humid.	
			free mastic. One inch diameter wallpaper roller used to press membrane into joint between deck and curb. Copper strips placed on the primed concrete 3 feet from the westerly curb at a point 46'- 51' from the northerly end of the curb.
12:30	69°		Number 1200 mastic placed between sheets at overlaps at the end of each roll. Membrane sheet cut over 3-1/2 inch wide polyurethane joints between approach slabs and the deck. Width of joints make it doubtful that the system will remain waterproof at the two locations.
12:45	69°		Membrane application along the curb line complete. Attempting to remove entrapped air with a garden hand roller.
1:35	70°		Placing membrane supplied in 60 inch wide rolls. Initial tack between sheet membrane and primer results in some stripping of the primer from the concrete if the sheet is lifted to correct for alignment.
2:10	70°		Reducing the amount of entrapped air beneath the membrane by using a squeegee to apply pressure on the sheet at the point where initial contact is made with the primed concrete.
3:10	70°		Fourth strip complete. Finished placing membrane on concrete test slabs.
4:00	68°		Placed mastic along edge of membrane on curb face.
	4/17/73		Clear.
9:00	60°	38	Began priming easterly side of deck.
10:20	61°	35	24 gallons of primer applied on 2475 s.f. plus area reprimed near center of deck. Air bubbles in primer broken with squeegee.
10:50	64°	30	Placing 30 inch wide sheet into mastic along cub line. Copper foil strips placed 3 feet from the easterly curb at a point 104'- 109' from the northerly end of the curb.
1:45	72°	23	Fourth strip complete. Self sealing edges of in-place sheets aid in obtaining proper alignment of each new roll.
3:00	70°	25	Application complete.

BITUMINOUS CONCRETE WEARING SURFACE

Placement - Two 1 inch thick courses with the first course placed with a rubber tired paver.

Aggregate Size - 3/8" maximum.

Asphalt - Ac-5 viscosity grade. First course designed with 8% asphalt content and 1-1/2% asbestos fibers.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 627 s.y. @ $5.50/s.y. = $3,448.50

Bituminous Concrete - 94 tons @ $10.00/ton = $ 940.00

DISCUSSION

The installation began with the squeegee application of Protecto Wrap Primer on the westerly side of the deck. The application along the vertical face of the curb was made with paint brushes. The application rate for the primer averaged 127 square feet per gallon. As the primer became tack free along the curb, a generous application of Protecto Wrap No. 1200 mastic was placed approximately 2 inches up the curb face and 2 to 3 inches onto the deck with a stiff bristled paint brush. Its purpose was to seal voids and help the sheet membrane bridge rough areas along the curb face.

Air bubbles developed in the solvent cut primer shortly after application. The bubbles ranged up to 3/4 of an inch in diameter and numbered up to 175 per square foot. When the primer had cured enough to allow foot traffic, all of the bubbles were broken with squeegees.

The membrane was supplied in 60 inch widths for application on the deck and 30 inch widths for placement along the curb lines. A one inch diameter wallpaper roller was used to seal the membrane against the curb face. This was followed by a final coat of mastic along the top edge of the sheet. Initially, an unsatisfactory amount of air was trapped beneath the membrane sheets during application. However, as the work progressed, it was found that the amount of entrapped air could be reduced by using a squeegee to apply pressure at the point where the sheet first made contact with the primed concrete. The amount of entrapped air was further reduced by rolling each strip with a hand roller prior to placing the next sheet.

Electrical resistance readings taken on the completed membrane system were all recorded at infinity.

The first 1 inch course of bituminous pavement was placed with a rubber tired paver 3 days after the membrane system had been completed. The temperature of the bituminous mix ranged from 260° to 275°F at the time of application. Three or four boils were noted in the bituminous mix in one area after the first pass was made

with the break down roller. The 4 to 8 inch diameter bubbles were removed by puncturing the mix and the membrane with a knife so that the trapped air could escape. Small pockets of air which had remained beneath the membrane at scattered locations did not cause any other problems with the pavement application.

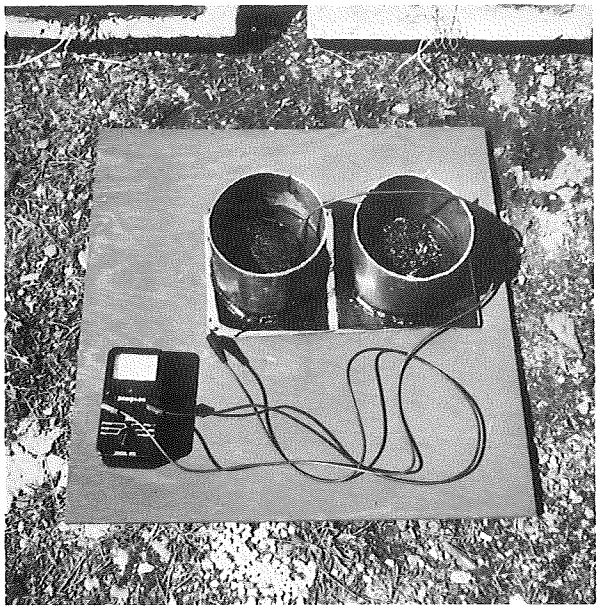
Inspection of the deck on July 3rd, 74 days after the first course of bituminous pavement was placed, revealed migration and rutting of the pavement. Depressions in the wheel paths were recorded at 3/8 to 3/4 of an inch in the 1 inch overlay. The cause of the pavement damage was basically due to a high volume of construction traffic hauling crushed stone and bituminous materials for 8.4 miles of roadway base south of the subject bridge. High ambient temperatures and a lack of stability in the low viscosity asphaltic mix contributed to the deformation problem. Electrical resistance tests were taken on areas showing the most visible damage. Readings averaged 430,000 ohms per square foot indicating some damage to the membrane system. Repair consisted of partial leveling of rutted areas by additional rolling prior to placing the final inch of pavement.

Electrical resistance readings taken on the membrane and completed pavement were recorded at infinity indicating that the combined system was initially impervious.

PROTECTO-WRAP M-400

I-91 SB Over State Aid No. 1

April 1973



Checking the puncture resistance of preformed sheet membranes subjected to applications of 275° - 325°F bituminous mixes applied at a load of 200 psi.

Air bubbles in the solvent cut prime coat were broken with a squeegee prior to placing the membrane sheets.

Pressing the membrane into the mastic at the curb line with a one inch diameter wallpaper roller.

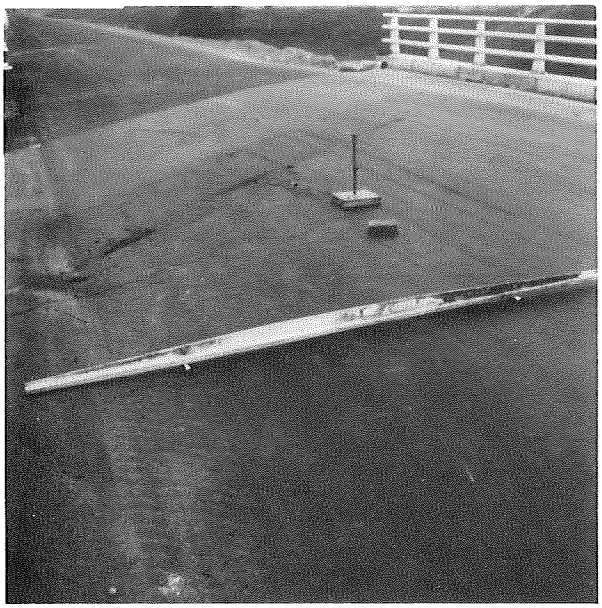
Rolling the membrane and removing the polyethylene film to expose the self sealing edge.

PROTECTO-WRAP M-400

I-91 SB Over State Aid No. 1

April 1973

Using squeegees to prevent entrapment of air beneath the membrane during application.



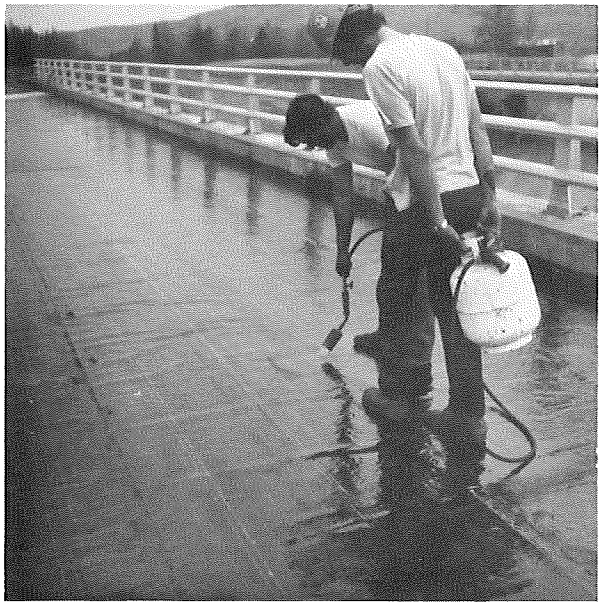
High construction traffic volumes on the first one inch course of pavement resulted in migration from the wheel paths. Resistance tests indicated slight damage to the membrane at several locations.

ROYSTON BRIDGE MEMBRANE #10

I-91 NB Over State Aid No. 1

May 1973

Placing 48 inch wide membrane sheet with 2-½ inch edge overlap. Ripples which remained in the membrane did not cause any difficulties with the pavement application.



Heat sealing edges and ends of the membrane sheets with a torch. Material now under production is supplied with a self sealing edge.

SUMMARY OF FINDINGS & RECOMMENDATIONS

The following discussions summarize the good and bad characteristics of each of the seven systems tried and conclude with recommendations on further use. It is emphasized that the recommendations are tentative since long term evaluations will be required to draw definite conclusions on the overall effectiveness of each product.

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 minimum 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.

HOT MOPPED ASPHALT AND WOVEN GLASS FABRIC

SUMMARY OF FINDINGS

The system does not require extensive surface preparation of the concrete surface but is moisture sensitive. The solvent cut prime coat should be allowed to dry for 24 hours prior to the application of the hot mopped asphalt. Air bubbles and pinholes occurred in the prime coat and each of the three coats of hot asphalt. The two membrane systems contained an average of 121 pinholes per square foot with most in the range of 1/16 inch or less diameter at the surface of the membrane. Electrical resistance readings on the 2 systems averaged 58,500 ohms per square foot which indicate some of the holes are open to the concrete. Asphalt temperatures often exceeded the 350°F maximum specified due to local overheating in the kettle and because the applicators were accustomed to heating the asphalt in excess of 450°F for roofing applications. Such overheating could decrease the material's flexibility and life span. Application rates were difficult to control and the asphalt and glass fabric did not seal all areas along the vertical curb face although such areas were at least initially sealed with a roofing cement. Low moisture absorption has been noted on concrete samples coated in the field with the hot asphalt and fabric. The asphalt does not have sufficient flexibility to resist cracking when flexed at cold temperatures.

RECOMMENDATION

Hot mopped asphalt and woven glass fabric is not recommended for further use as a bridge deck membrane.

RAMBOND 620-S EPOXY

SUMMARY OF FINDINGS

The system required a sandblasted concret surface. The epoxy was applied in three coats using squeegees. Pinholes occurred in each of the three coats although the number of pinholes was reduced with each successive coat. Electrical resistance readings on the completed coating averaged 53,000 ohms per square foot indicating that the system is not waterproof. The $12.30 per square yard cost of the epoxy system was approximately double the cost of the other materials tried. Initial laboratory tests disclosed that the epoxy had good flexibility at all temperature ranges and average resistance to moisture absorption, however, extended testing on laboratory specimens has since disclosed that the epoxy will soften under continuous immersion.

RECOMMENDATION

Rambond 620-S epoxy is not recommended for further use as a bridge deck membrane.

TAR EMULSION AND WOVEN GLASS FABRIC

SUMMARY OF FINDINGS

The system requires little surface preparation of the concrete and is not moisture sensitive but is subject to damage by any rain showers shortly after placement. The normal rough configuration of the mortar and granite curb face made it impossible to obtain a complete seal along these surfaces. Electrical resistance readings were very low indicating that the system allows moisture to pass through it. The material did not have sufficient flexibility to resist cracking when bent around a 1 inch diameter mandril at -10°F. Earlier tests disclosed that concrete samples treated with the system developed blisters and delaminations of the individual layers when exposed to water or freeze-thaw cycles. It should be noted that the effectiveness of the membrane system would depend upon the quality of the specific brand of tar emulsion used.

RECOMMENDATION

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

POLYASTIC'S CONCRETE POXY MEMBRANE SEALER

Summary of Findings

The system requires that the concrete surface be sandblasted or acid etched. Air bubbles formed in the coating although the application was made late in the day in an attempt to avoid the outgassing problem. Electrical resistance readings averaged 40,735 ohms indicating that some of the 90 plus bubbles per square foot were open to the concrete. Samples of the epoxy which initially displayed good flexibility have become inflexible with age. Coatings applied on concrete test slabs in the laboratory and in the field have developed blisters and cohesive cracks.

Recommendation

Polyastics Epoxy is not recommended for further use as a bridge deck membrane.

DURALKOTE 306

Summary of Findings

The system requires that the concrete surface be sandblasted or acid etched. Air bubbles and pinholes occurred in both the initial and final coat of epoxy. Electrical resistance readings averaged 88,300 ohms per square foot indicating that some of the bubbles and pinholes were open to the concrete. Low moisture absorption has been recorded on concrete samples coated with the epoxy and immersed in water for a 20 month period. A loss of adhesion has been noted on the vertical curb face of concrete test slabs treated during a field application in July 1972.

Recommendation

Duralkote 306 is not recommended for further use as a bridge deck membrane.

ROYSTON BRIDGE MEMBRANE #10

SUMMARY OF FINDINGS

The system requires that the concrete be dry but no extensive surface preparation is required. Adjustment of individual rolls to correct for alignment was accomplished without difficulty. The seal along the curbs was attempted by softening the edge of the membrane with a torch and pressing it against the curb face. This was followed by a coat of mastic. Obtainment of a complete seal at all locations was questionable. Pockets of entrapped air and ripples in the membrane did not result in problems with the pavement application. Electrical resistance reading on the membrane and the completed pavement-membrane system were recorded at infinity, indicating that the system is waterproof. Laboratory tests indicated the membrane was not damaged by puncture or heat when subjected to the application of 275°F - 325°F bituminous mix applied at a load of 200 psi. The material had sufficient flexibility to resist cracking when bent around a 1 inch mandrel at -10°F and satisfactorily bridged cracks in cement mortar slabs when broken over a 3/16 inch anvil at 0°F.

RECOMMENDATION

Royston Bridge Membrane #10 is recommended for further use.

PROTECTO WRAP M-400

Summary of Findings

The system requires that the concrete be dry but no extensive surface preparation is required. Numerous air bubbles which formed in the prime coat were broken with a squeegee prior to placing the sheet membrane. Adjustment of individual rolls to correct for alignment was accomplished without difficulty. Excessive amounts of air were initially trapped beneath the membrane but as work progressed the bubbles and wrinkles were reduced by using a squeegee to apply pressure at the point where the sheet first made contact with the concrete. Electrical resistance readings were recorded at infinity on the completed membrane indicating that the system was waterproof. Air trapped beneath the membrane in one area resulted in 3 or 4 boils in the first 1 inch course of bituminous mix during placement. A high volume of construction traffic hauling materials over the bridge resulted in pavement rutting and migration in the wheel paths. Electrical resistance on the membrane and completed pavement indicated the combined system was waterproof. Laboratory test indicated the membrane was not damaged by puncture or heat when subjected to the application of 275°F to 300°F bituminous mixes applied at a load of 200 psi. The material does not have sufficient flexibility to resist cracking when bent over a 1 inch mandrel at -10°F but has sufficient flexibility to pass the same test at temperatures above 10°F.

Recommendation

Protecto Wrap M-400 is recommended for further use.
If a high volume of construction traffic is anticipated over the membrane and first 1 inch course of bituminous mix, some other form of protection should be provided until the final course of pavement can be placed.

PRODUCT EVALUATION SUMMARY

Field Observations	Hot Mopped Asphalt and Glass Fabric	Tar Emulsion and Glass Fabric	Rambond 620-S Epoxy	Polyastic's Concrete Poxy Membrane Sealer	Duralkote 306 Epoxy	Royston Bridge Membrane #10	Protecto Wrap M-400
Surface preparation required	Wash & Sweep	Wash & Sweep	Sandblast or Acid etch	Sandblast or Acid etch	Sandblast or Acid etch	Wash & Sweep	Wash & Sweep
Moisture sensitive	Yes	No	Yes	No	Yes	Yes	Yes
Ease of application	Difficult	Average	Easy	Easy	Easy	Average	Average
Bond & seal at curb	Fair	Poor	Fair	Fair	Fair	Fair	Good
Bubbles and/or pinholes in membrane	Yes/Yes	No/Yes	No/Yes	Yes/Yes	Yes/Yes	Yes/No	Yes/No
Electrical resistance prior to pavement overlay in ohms/sf	46,000 71,000	3,900	41,500	40,735	88,300	Infinity	Infinity
Bond between pavement and membrane	Good	Good	Poor	Poor	Poor	Fair	Good
Difficulty with pavement application over membrane	No	No	No	No	No	No	No
Loss of pavement stability under traffic	No	No	No	No	No	No	*Yes
Cost per s.y. not including pavement	$3.75	$3.50	$12.30	$7.23	$7.23	$6.00	$5.50

*Would not have occurred under normal conditions

Lab Observations

Flexibility @ -10°F	Failed	Failed	Passed	Failed	Failed	Passed	Failed
Moisture absorption	1.4%	No Test	5.0%	1.6%	1.5%	No Test	No Test
Elongation over cracks @ 0°F	Failed	Failed	Failed	Failed	Failed	Passed	Passed

Recommendations

Recommended for further use	No	No	No	No	No	Yes	Yes
Await follow-up evaluations							

SUMMARY OF MEMBRANE SYSTEMS APPLIED IN 1971 & 1972

(See Reports 72-10 and 73-1)

Field Observations	Bon-Lastic Membrane (Polyurethane)	Polytok Membrane 165 (Polyurethane)	Polytok Membrane 165 (with roofing sheet overlay)	Uniroyal Liquid Membrane 6125 (Rubberized Asphalt)	Heavy Duty Bitu-thene (Sheet Membrane)
Surface preparation required	Wash & Sweep	Wash & Sweep	Wash & Sweep	Wash & Sweep	Wash & Sweep
Moisture sensitive	Yes	Yes	Yes	Yes	Yes
Ease of application	Average	Average	Average	Difficult	Difficult
Bond & seal at curb	Good	Good	Good	Fair	Fair
Bubbles and/or pin-holes in membrane	Yes/Yes	Yes/Yes	Unknown	Yes/Yes	Yes/No
Electrical resistance prior to pavement overlay in ohms/sf	480,000	60,000 to 2,600,000	1,300,000 to 8,000,000	51,600	Infinity
Bond between pave-ment and membrane	Poor	Poor	Fair	Good	Good
Difficulty with pavement applica-tion over membrane	No	No	No	Yes	Yes
Loss of pavement stability under traffic	No	No	No	Yes	No
Cost per s.y. not including pavement	$4.50	$4.50	$4.50	$9.00	$7.25
Lab Observations					
Flexibility @ -10°F	Passed	Passed	No Test	Failed	Passed
Moisture absorption	3.0%	2.9%	No Test	No Test	No Test
Elongation over cracks @ 0°F	Failed	Failed	No Test	Failed	Passed
Recommendations					
Recommended for further use	No				Yes
Await follow-up evaluations		X	X	X	

SUMMARY OF MEMBRANE SYSTEMS APPLIED IN 1971 & 1972

(See Reports 72-10 and 73-1)

Field Observations	Duralkote 304 (Epoxy Paint)	Duralbond 102 (Epoxy Bonding Compound)	Rambond 223 (Epoxy)	Ramcoat Epoxy Paint	Tar Emulsion (2 Coats)
Surface preparation required	Sandblast or Acid Etch	Sandblast or Acid Etch	Sandblast or Acid Etch	Sandblast or Acid Etch	Wash & Sweep
Moisture sensitive	Yes	No	No	Yes	No
Ease of application	Easy	Average	Difficult	Easy	Easy
Bond & seal at curb	Good	Good	Fair	Fair	Poor
Bubbles and/or pin-holes in membrane	Yes/Yes	Yes/Yes	Yes/Yes	No/Yes	No/Yes
Electrical resistance prior to pavement overlay in ohms/sf	41,000	1,200,000	5,100	1,100	No Test
Bond between pave-ment and membrane	Poor	Poor	Poor	Poor	Good
Difficulty with pavement applica-tion over membrane	No	No	No	No	No
Loss of pavement stability under traffic	No	No	No	No	No
Cost per s.y. not including pavement	$5.73	$9.99	$22.15	$1.32	$1.40
Lab Observations					
Flexibility @ -10°F	Failed	Failed	Failed	Passed	Failed
Moisture absorption	3.6%	1.4%	No Test	0.8%	1.9%
Elongation over cracks @ 0°F	Failed	Failed	Failed	Failed	Failed
Recommendations					
Recommended for further use	No	No	No		No
Await follow-up evaluations				X	

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