NATIONAL EXPERIMENTAL & EVALUATION PROGRAM

BRIDGE DECK PROTECTIVE SYSTEMS

WORK PLANS #1-#3 - INITIAL REPORT

REPORT 72-10

May 1972

Fair Haven-Castleton F 020-1 (8)

Castleton F 020-1 (7)

Fairlee-Bradford I 91-2 (10)

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INTRODUCTION

The information in this initial report covers the application of three different membrane systems on six bridge decks located in Fair Haven, Castleton, and Bradford, Vermont. The experimental applications and the following evaluations are being made in an attempt to find a membrane system which will protect concrete bridge decks from moisture and deicing chemicals. Surveillance of the experimental and control treatments shall continue until valid conclusions can be obtained on the effectiveness of each system. Visual observations will be supplemented with electrical resistance readings on the bridge decks, chloride analysis of concrete cores, and the use of a steel corrosion detection device. A final report will include information gathered during semi annual inspections and test results plus recommendations with respect to further use of each system.

WORK PLAN #1 - INITIAL REPORT

UNIROYAL LIQUID MEMBRANE

PROJECT

Fair Haven-Castleton F 020-1 (8), Stage II, Relocated US 4.

PROJECT LOCATION

In the towns of Fair Haven and Castleton, Rutland County, Vermont, beginning at a point approximately 0.010 miles east of the New York-Vermont State Line and proceeding easterly on Relocated US 4 for a distance of 7.413 miles.

WORK LOCATION #1

Eastbound bridge over Vt Rte 22-A at station 1075+83.81 - 1077+75.19.

CONTROL SECTION

Westbound bridge over Vt Rte 22-A. See data on pages 8 to 10.

BRIDGE CONSTRUCTION DATA

Type of Structure - Simple span, welded plate girder - composite with voided abutments

Span Length - 143' - 0

Overall Length - 191' - 5" (approach slabs not included)

Curb to Curb Width - 36' - 8"

Skew - 9^{o} 28'

Horizontal Curvature - 3^{o}

Grade - +0.943%

Superelevation - 15/16"/ft

DECK CONSTRUCTION DATA

Date Poured - October 17, 1970

Weather Conditions - Windy with occasional snow flurries

Temperature - Low 34^{o}F High 38^{o}F

Deck Thickness - 8"

Concrete Cover Over Reinforcing Steel - 2"-2½"

Concrete - Class AA

Cement - Type I 6½ bags per c.y.

DECK CONSTRUCTION DATA - cont'd

Aggregate Size - 3/4" maximum

Air Entrainment - Darex 9½ to 10 oz per c.y.

Retarder - None

Pour Sequence - West to east

Finishing Method - Capital finishing machine on outside beams, screed position 90° to centerline

Surface Texture - Broomed finish

Curing - Wet down and covered with polyethelene

Concrete Test Results

Concrete Temperature - 60°F (no hot water or heated aggregate used)
Air Entrainment - Low 5.5% High 6.5% 6.38% average on 8 tests
Slump - Low 3" High 3½" 3.12" average on 4 tests

DECK CONDITION

There were no noticeable cracks in the deck or areas of laitance on the concrete surface. A chemical analysis of concrete dust samples taken from the deck revealed no detectable amounts of sodium chloride. The samples were taken from the top inch of concrete with the aid of a power drill shortly before the protective membrane was applied.

PROTECTIVE TREATMENT

Product - Uniroyal Liquid Membrane Waterproofing System.

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

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

RECOMMENDED APPLICATION PROCEDURE

A surface conditioner is applied on the concrete at a rate of 300 to 600 square feet/gal. Fifty pound cakes of the waterproofing membrane are melted in a double walled kettle until the material can be drawn free flowing at a temperature not exceeding 425°F. The material is applied evenly with a squeegee at

the rate of one pound per square foot for an average thickness of 3/16". Rubber sheets (Elastosheet T.M.) are rolled down into the hot membrane along the curbs and over roadway joints. A second coat of the membrane is then applied over the rubber sheet. After cooling, the membrane is dusted with Portland Cement at a rate of approximately 1,000 square feet per sack to prevent tracking.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 786.6 sy at $9.00/sy = $7,079.40

Bituminous Concrete - (two - one inch thick courses)
159 tons @ $8.50 per ton = $1,351.50

Shoulder Treatment - (tar emulsion on pavement along curb - 3' width)
32 gals @ $3.50/gal = $112.00

Approach Slabs - (two coats of tar emulsion)
79 gals @ $3.50/gal = $276.00

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	Humidity	Liquid Membrane Temp	Oil Bath Temp	
		8/18/71			Air temperatures recorded in shade
7:00	62°	76	210°	330°	Clear, wind velocity 0 - 4 mph. Began sweeping deck.
9:30	74°	68	425°	500°	Began priming the deck using an RC 20-50
10:30	76°	66	410°	520°	asphalt applied with a portable hand sprayer.
11:30	79°	61	385°	510°	Uniroyal application complete on slab over easterly voided abutment.
12:50	84°	54	415°	570°	Material approximately 30' along mid span.
1:30	83°	51	425°	500°	Bubbles, which had formed in the area covered before lunch, all revealed concrete when broken open.
2:30	84°	50	405°	525°	102° air temperature on the deck surface.
3:00	85°	48	410°	515°	Approximately 50' of center span treated.
4:00	88°	41	395°	540°	
5:30	85°	38	365°	510°	Began applying material on slab over voided abutment.
6:30	86	45	365°		Application complete. 6840 pounds of Uniroyal Liquid Membrane applied on 7080 square feet of deck for application rate of 0.97 lbs/sf. Approach slabs treated with 79 gallons of tar emulsion.

DISCUSSION

Uniroyal Liquid Membrane 6125 was applied as originally recommended (see page 3) with one exception. A surface conditioner was fogged on the concrete surface at the rate of approximately 2500 square feet per gallon as recommended by the Uniroyal representative on the project.

Seven inch wide strips of Elastosheet were placed on the liquid membrane at the joint between the curb and deck so that two inches of the rubber sheet lapped up on the granite curbing. Strips of Elastosheet approximately 15" wide were placed over construction joints between the main span and the slabs over the voided abutments and at the approach slab joints. The rubber sheeting was also placed along the sides of the expansion dam.

Bubbles were noted in the membrane surface shortly after the material was applied. The bubbles were believed to be caused by air expanding out of the concrete due to the rise in air temperature as the day progressed. The area treated in the morning had a greater number of bubbles which ranged in size up to one-half inch in diameter, while areas treated in the late afternoon had fewer and smaller bubbles. Subsequent inspection of the membrane surface during early morning hours always revealed depressions in place of the bubbles. When individual bubbles were broken open, visible areas of concrete were detected in all cases. However, open areas of concrete were not always detected when the bubbles were checked six days after the membrane was applied. This would indicate that the material is partially self-sealing.

The bond between the membrane and concrete varied at different locations. At times it was possible to uncover from 25% to 50% of the concrete in a given area by peeling the membrane away with the rolling action of a fingertip. Greater bond at other locations prevented stripping of the membrane down to the bare concrete.

A total of 7080 square feet of concrete surface was treated with 6840 pounds of liquid membrane. The application rate averaged 0.97 pounds per square foot. The 211 square yards of concrete approach slabs were treated with 79 gallons of tar emulsion for an average coverage of 0.37 gallons per square yard.

Inspection of the membrane system on August 24, 1971, six days after its application, revealed that water was trapped under the Elastosheet in a number of areas on the low side of the deck. When several of the areas were cut open, a lack of bond was noted between the Elastosheet and the first coat of liquid membrane. Several open areas at the top of the Elastosheet had apparently allowed water to enter the system during periods of heavy rain. The failure to obtain a complete bond between the Elastosheet and the first coat of liquid membrane in the juncture between the deck and granite curb resulted in water traveling under the Elastosheet along the low side of the deck. The planned bituminous paving operation was postponed, and the repair of leaking areas was attempted with an application of tar emulsion several days later.

Inspection prior to paving on September 15, 1971, 28 days after the membrane system was applied, revealed that approximately 85% of the original bubbles still remained on the membrane surface. The remaining 15% had receeded and were noted as depressions in the membrane surface. Although only about half of the bubbles revealed concrete when broken open for inspection, it was assumed that the rest were similar with the holes in the membrane simply too small to detect visually.

A check of areas covered with Elastosheet showed that water had entered the system at several new locations and appeared to have loosened the Elastosheet from the first layer of liquid membrane at many locations. Water was detected under the Elastosheet on the low side of the deck at the following locations: 9'-11', 27', 30'-32', 37', 63'-64', 67', 72'-75', 90'-92', 114'-118', and 129'-131' from the expansion dam and at 29'-30', 38', and 62' on the high side of the deck. Water was also found in several areas on both sides of the finger plate expansion device.

During the paving operation, movement of the steel track paver over the bridge deck resulted in about 20 small ½" by 1" breaks in the membrane surface. The material was also compressed by the steel tracks. This resulted in a thin layer of membrane on the concrete at points of contact. As the paver moved over the construction and deflection joints, the tracks stretched the Elastosheet covering the joints. After the paver had traveled on, distortion of the bituminous material occurred as the Elastosheet regained its original shape and position. When the problem first occurred on

the westerly joint on the low side of the deck, a ten foot strip of Elastosheet was removed from the deck. However, when the problem reoccurred, the bituminous material was smoothed out with rakes and the rubber sheet was left in place.

Attempts to obtain initial compaction of the pavement with a large steel wheel roller resulted in the roller cutting into the bituminous material. This was believed due to the flexibility caused by the reheated membrane. The problem was eliminated when a small sidewalk roller was used to obtain initial compaction.

WORK PLAN #1 CONTROL SECTION

TAR EMULSION

Project

Fair Haven-Castleton F 020-1 (8) Stage II

Control Section

Westbound bridge over Vt Rte 22-A at station 1076+49.96 - 1078+53.45

Bridge Construction Data

Type of Structure - Simple Span, Welded Plate Girder - Composite With Voided Abutments

Span Length - 143'- 0"

Overall Length - 203'- 6" (approach slabs not included)

Curb to Curb Width - 36'- 8"

Skew - 8^{o}- 23'

Horizontal Curvature - 3^{o}

Grade - +0.856%

Superelevation - 15/16"/ft full bank

Deck Construction Data

Date Poured - October 8, 1970

Weather Conditions - Good

Temperature - Low 55^{o}F High 65^{o}F

Deck Thickness - 8"

Concrete Cover Over Reinforcing Steel - 2" - 2½"

Concrete - Class AA

Cement - Type I 6½ bags per c.y.

Aggregate Size - 3/4" maximum

Air Entrainment - Darex 9 to 9½ oz per c.y.

Retarder - None

Pour Sequence - East to West

Finishing Method - Capital finishing machine on outside beams Screed position $90^{o}$to centerline

Deck Construction Data - cont'd

Surface Texture - Broomed finish

Concrete Test Results

Percent Air -	Low 5%	High 7%	Average 5.93% on 19 tests
Slump -	Low 3"	High 4%	Average 3½" on 6 tests

Deck Condition

Surface Texture - The deck and approach slabs had a broomed surface with the depth of the grooves averaging 1/8 inch. Areas along the granite curb were typically rough due to difficulty in finishing and spillage of mortar used to grout beneath the granite curb.

Laitance - Along the low side of the deck, 2' to 12' from the curb at an area 42' to 54' from the westerly end of the bridge rail and over several other smaller areas.

Cracks - There were no noticeable cracks in the deck. Very fine cracks were noted at 2' to 6' intervals in the curb sections.

Miscellaneous - Paint spillage along the curb on the high side of the deck. The area extended 6' out from the curb at a location 60' to 69' from the expansion device.

Chloride Analysis - A chemical analysis of concrete dust samples taken from the deck revealed no detectable amounts of sodium chloride. The samples were taken from the top inch of concrete with the aid of a power drill shortly before the protective membrane was applied.

Control Treatment

Product - Tar Emulsion for bridge floors - Item 318
The cold tar emulsion is brushed or squeegeed on, in two applications at the rate of 0.1 to 0.2 gallons per square yard per application.

Test Results - Specific gravity averaged 1.27
Water content averaged 48.8 percent

Flexibility - Two coats of tar emulsion placed on an aluminum panel and allowed to dry for two hours showed no signs of cracking, flaking, or loss of adhesion when the panel was bent 180°.

Application Procedure

The concrete surface was sprayed with a light application of water. Tar emulsion was then poured on the concrete from five gallon buckets which were filled from a 500 gallon trailer mounted tank. The material was then spread evenly over the deck with squeegees. After the first coat had dried sufficiently, a second coat was applied.

Cost of Protective Membrane and Bituminous Concrete Wearing Surface

Membrane Treatment - 405 gallons at $3.50/gal = $1,417.50

Bituminous Concrete - (two - one inch thick courses)
132 tons @ $8.50/ton = $1,122.00

Shoulder Treatment - (tar emulsion on pavement along curb - 3' width)
32 gals at $3.50/gal = $112.00

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	Humidity	Cloud Cover	(Air temperatures recorded in shade)
		7/20/71		
9:15	65°	78	Partly Cloudy	Wet down deck surface. Areas had been washed clean previous day.
9:45	67°	76	Partly Cloudy	Began applying tar emulsion with squeegees.
10:25	67°	72	Partly Cloudy	Deck half covered.
10:50	71°	72	Partly Cloudy	First coat completed. 240 gallons applied on the 1018 square yards for an application rate of 0.236 gal/sy.
3:45	74°	47	Partly Cloudy	Began applying second coat.
4:45	74°	49	Cloudy	Second coat completed. 165 gallons applied for an application rate of 0.162 gal/sy.

DISCUSSION

The 1018 square yards of concrete deck and approach slabs were treated with 405 gallons of tar emulsion for an average coverage of 0.398 gallons per square yard.

Inspection of the membrane prior to the bituminous paving operation revealed no pinholes or other open areas but some shrinkage cracks were noted in the tar emulsion along the curb areas. The cracks occurred in areas where the application was too thick.

Considerable damage was done to the tar emulsion in the process of placing the first course of pavement with a steel track paver on August 17, 1971. The paver traveled the full length of the deck seven times with damage occurring to the membrane at high points on the broomed concrete surface.

WORK LOCATION #2

Eastbound bridge over Vt Rte 30 at station 1274+77.43 - 1277+17.85

CONTROL SECTION

Westbound bridge over Vt Rte 30. See data on pages 16 to 18.

BRIDGE CONSTRUCTION DATA

Type of Structure - Simple span, welded plate girder - composite with voided abutments

Span Length - 150' - 0

Overall Length - 240' - 5" (approach slabs not included)

Curb to Curb Width - 36' - 8"

Skew - 39^{o} - 24'

Horizontal Curvature - 1^{o}

Grade - +1.358% in vertical curve

Superelevation - 5/16"/ft.

DECK CONSTRUCTION DATA

Date Poured - November 3, 1970

Weather Conditions - Overcast, 10 m.p.h. wind

Temerature - Low $40^{o}F$ High $45^{o}F$

Deck Thickness - 8"

Concrete Cover Over Reinforcing Steel - 1 3/4" - 2 3/4"

Concrete - Class AA

Cement - Type I 6½ bags per c.y.

Aggregate Size - 3/4" maximum

Air Entrainment - Darex 9 oz per c.y.

Retarder - None

Pour Sequence - West to east

Finishing Method - Bidwell finishing machine on outside beams, screed position 90^{o} to centerline

DECK CONSTRUCTION DATA - cont'd

Surface Texture - Bullfloat finish

Concrete Test Results -

Concrete Temperature - 68°F to 80°F (hot water used in the concrete)

Air Entrainment - Low 6% High 6.25% 6% average on 21 tests

Slump - Low 3" High 3¼" 3 1/8" average on 2 tests

DECK CONDITION

There were no noticeable cracks in the deck or areas of laitance on the concrete surface. A chemical analysis of concrete dust samples taken from the deck revealed no detectable amounts of sodium chloride. The samples were taken from the top inch of concrete with the aid of a power drill shortly before the protective membrane was applied.

PROTECTIVE TREATMENT

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

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

RECOMMENDED APPLICATION PROCEDURE

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

RECOMMENDED APPLICATION PROCEDURE - cont'd

Portland Cement at a rate of approximately 1,000 square feet per sack to prevent tracking.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 989.6 sy @ $9.00/sy = $8,906.40

Bituminous Concrete - (two - one inch thick courses)
164 tons @ $8.50 per ton = $1,394.00

Shoulder Treatment - (tar emulsion on pavement along curb - 3' width)
31 gals @ $8.50/gal = $108.00

Approach Slabs - (two coats of tar emulsion)
119 gals @ $3.50/gal = $416.00

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	% Humidity	Liquid Membrane Temp	Oil Bath Temp	Air temperatures recorded in shade
		8/17/71			Clear Wind variable 3-8 m.p.h.
9:30	62°				Began priming the deck using an RC 20-50 asphalt applied with a portable hand sprayer.
10:00	65°	67	445°	580°	Began Uniroyal application. 15" wide strip of Elastosheet placed over joint between approach slab and slab over voided abutment, easterly end of deck
11:00	70°	65	475°	570°	
12:00	74°	62	405°	500°	Application complete on span over voided abutment (1710 s.f.). Bubbles are starting to appear on the membrane surface.
1:30	77°	57	400°	580°	325 sq ft covered on main span.
3:30	81°	55	290°	580°	Applicators are getting uniform coverage on all areas although some of the liquid membrane being drawn from the kettle is lumpy. Lumps apparently due to the lower temperature.
4:30	81°	56	330°	560°	7330 sq ft covered with approximately 7000 lbs of material.
5:00	82°	56	365°	560°	Placing 15" strip of Elastosheet over joint between center span and slab over voided abutment.
5:30	83°	56	395°	530°	Air temperature in sun 93°.
6:00	83°	55	345°	440°	Finished application by placing 15" strip of Elastosheet over deflection joint at westerly end of deck. With the exception of the first area treated, there are very few bubbles in the liquid membrane at this time.
		8/18/71			
8:00	67°	76	320°	440°	Applying liquid membrane over areas where pinholes occurred in the initial coverage.
8:30	69°	75	430°	575°	Spreading cement dust over the membrane to prevent tracking. 8620 lbs of liquid membrane applied on 8906 sq ft of concrete for an average application rate of 0.968 lbs/sq ft. 119 gals of tar emulsion applied on the approach slabs.

DISCUSSION

Uniroyal Liquid Membrane 6125 was applied as originally recommended (see page 12) with one exception. A surface conditioner was fogged on the concrete surface at the rate of approximately 2500 square feet per gallon as recommended by the Uniroyal representative on the project.

Seven inch wide strips of Elastosheet were placed on the liquid membrane at the joint between the curb and deck so that two inches of the rubber sheet lapped up on the granite curbing. Strips of Elastosheet approximately 15" wide were placed over construction joints between the main span and the slabs over the voided abutments and at the approach slab joints. The rubber sheeting was also placed along the sides of the expansion dam.

Bubbles began to appear in the membrane surface about two hours after the application began. The bubbles were believed to be caused by air expanding out of the concrete due to the normal rise in air temperature as the day progressed. Areas covered in the afternoon had a noticeable decrease in the number of bubbles in the membrane. Visible areas of concrete were noted in most cases when individual bubbles were broken open for inspection.

A total of 8906 square feet of concrete surface was treated with 8620 pounds of liquid membrane. The application rate averaged 0.97 pounds per square foot. The 286 square yards of concrete approach slabs were treated with 119 gallons of tar emulsion for an average coverage of 0.42 gallons per square yard.

The membrane system was inspected prior to paving on August 24, 1971. The only noticeable change was the existence of a network of alligator or pattern type cracks on the membrane surface. The cracks, which were believed due to shrinkage, would probably not reduce the membranes effectiveness due to their shallow depth.

The bituminous mix was placed with a rubber tired paver. Although rain had washed some of the cement dust from the membrane surface, the material did not stick to the truck or paver tires. Application of the $300^{o}\pm$ bituminous mix caused the membrane to return to a liquid state. Initial compaction of the bituminous mix was obtained with a small sidewalk roller prior to compaction with a 2 axle steel wheel roller.

Since the heavy breakdown roller could not be used until the temperature of the bituminous material had dropped well below the 300°F application temperature, it may be assumed that the final compacted density of the pavement was less than the desired density. The lower density would reduce the pavement's resistance to the passage of moisture thereby subjecting the membrane to water and chloride solutions in a shorter period of time than what might otherwise be expected.

Upon completion of the paving operation, several areas were detected where the Elastosheet and liquid membrane were stripped from the granite curb down to the top of the pavement.

Inspection of the bridge deck on September 15, 1971, 22 days after the pavement was placed, revealed several areas where the Uniroyal liquid membrane had bled through the first one inch course of pavement. Adjacent areas of the pavement were soft and flexible to the touch. Several longitudinal cracks were noted next to the sawed bituminous pavement at the joint between the center span and the slab over the westerly abutment. A number of depressions in the pavement were believed to have been caused by vehicles left parked on the bridge deck during periods of warm temperature. A check of the finger plate expansion device revealed a lack of bond between the Elastosheet and the easterly side of the dam with bituminous mix and other foreign matter trapped along the entire length.

Inspection of the deck shortly after the application of the top inch of pavement disclosed no undesirable conditions.

WORK PLAN #1 CONTROL SECTION

TAR EMULSION

Project

Fair Haven-Castleton F 020-1 (8) Stage II

Control Section

Westbound bridge over Vt Rte 30 at station 1275+98.82 - 1278+32.28

Bridge Construction Data

Type of Structure - Simple span, Welded Plate Girder-Composite With Voided Abutments

Span Length - 150'- 0

Overall Length - 233'- 6" (approach slabs not included)

Curb to Curb Width - 36'- 8"

Skew - 38°- 35'

Horizontal Curvature - 1°

Grade - +0.613% in vertical curve

Superelevation - 15/16"/ft

Deck Construction Data

Date Poured - October 29, 1970

Weather Conditions - Sunny

Temperature - Low 30°F High 60°F

Deck Thickness - 8"

Concrete Cover Over Reinforcing Steel - 1 7/8" - 2 1/8"

Concrete - Class AA

Cement - Type I 6½ bags per c.y.

Aggregate Size - 3/4" maximum

Air Entrainment - Darex 10 oz per c.y.

Retarder - None Hot water used in the concrete mix Concrete temperature at time of placement was 60°F to 64°F

Pour Sequence - West to east

Finishing Method - Bidwell finishing machine

Deck Construction Data - cont'd

Curing - Burlene mats

Surface Texture - Bullfloat finish

Concrete Test Results -

Percent Air	- Low 5%	High 6%	5.8% average on 5 tests
Slump	- Low 3"	High 3¼"	

Deck Condition

There were no noticeable cracks in the concrete or evidence of laitence on the surface.

Control Treatment

Product - Tar Emulsion for bridge floors - Item 318
The cold tar emulsion is brushed or squeeged on, in two applications at the rate of 0.1 to 0.2 gallons per square yard per application.

Test Results - Specific gravity averaged 1.27
Water content averaged 50.3%

Flexibility - Two coats of tar emulsion placed on an aluminum panel and allowed to dry for two hours showed no signs of cracking, flaking, or loss of adhesion when the panel was bent 180°.

Application Procedure

The concrete surface was sprayed with a light application of water. Tar emulsion was then poured on the concrete from five gallon buckets which were filled from a 500 gallon trailer mounted tank. The material was then spread evenly over the deck with squeegees. After the first coat had dried sufficiently, a second coat was applied.

Cost of Protective Membrane and Bituminous Concrete Wearing Surface

Membrane Treatment - 460 gallons at $3.50/gal = $1,610.00

Bituminous Concrete - (two-one inch thick courses)
155.0 tons @ $8.50/ton = $1,317.50

Shoulder Treatment - (tar emulsion on pavement along curb - 3' width)
20 gal at $3.50/gal = $70.00

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	Cloud Cover	(Air temperatures recorded in shade)
	7/19/71		
8:30	65°	Clear	Air blower used to clean concrete surface.
9:30	68°	Clear	Began spraying water on deck prior to tar emulsion application.
10:15	70°	Partly cloudy	Easterly span and approach slab covered.
11:45	74°	Overcast	First coat completed. 180 gallons used for an application rate of 0.146 gal/sy.
12:30			Rain showers washed the tar emulsion away in areas where it had not dried sufficiently.
	7/20/71		
1:30	72°	Cloudy	Recovering areas where the tar emulsion was washed away.
2:15	78°	Cloudy	Finished treating washed areas.
5:45	76°	Partly cloudy	Began applying second full coat.
7:00	73°	---	Deck half completed.
8:30	67°	---	Second coat completed. 280 gallons used for an application rate of 0.227 gal/sy.

DISCUSSION

The smoothness of the concrete surface made it difficult to obtain the desired 0.2 of a gallon per square yard application rate on the first coat. The exact coverage of tar emulsion is unknown due to the loss of approximately one-half of the first coat caused by rain showers. Assuming that washed areas were retreated at an equal rate, the 1,235 square yards of concrete surface were covered with an average application of 0.373 gallons per square yard.

Inspection of the membrane on August 24, 1971 prior to the placement of the first of two courses of bituminous pavement revealed only one small area where the tar emulsion was no longer bonded to the concrete. This may have been caused by dust on the concrete. The first course of pavement was placed with a rubber tired paver with no apparent damage occuring to the membrane.

PROJECT

Castleton F020-1 (7), Stage I, Relocated U.S. 4

PROJECT LOCATION

In the town of Castleton, Vermont, beginning at a point 5.763 miles easterly of the New York-Vermont State Line and proceeding easterly on relocated U.S. 4 for a distance of 1.661 miles.

WORK LOCATION

Town Highway #17 over relocated U.S. 4 at main line stations 1348+90 eastbound and 1352+40 westbound. Structure begins at Town Highway station 13+98.88 and ends at station 18+07.02.

CONTROL SECTION

US 4 westbound bridge over Vt Rte 30. See data on pages 16 - 18.

BRIDGE CONSTRUCTION DATA

Type of Structure - Five span continuous, rigid frame

Span Lengths - 46' - 111' - 90' - 111' - 46'

Overall length - 404'

Curb to Curb Width - 30' 8"

Skew - 55^{o}

Horizontal Curvature - 1^{o}

Grade - Crest Vertical +5.00% to -2.39%

Superelevation - Full Bank ¼"/ft.

DECK CONSTRUCTION DATA

Deck Thickness - 8½"

Concrete - Class AA

Cement - Type I 6½ bags per c.y.

Aggregate Size - 3/4" maximum

Finishing Method - Capital finishing machine on outside beams, screed position 90^{o} to centerline.

Curing - Polyethylene for 10 days

DECK CONSTRUCTION DATA - cont'd

Surface Texture - Broomed finish

Date Poured - June 22, 1971 (Section 1 from northerly abutment to a point 226' south)

Weather Conditions - Sunny Wind Velocity - 10 mph

Temperature - Low 60°F High 90°F

Concrete Cover Over Reinforcing Steel - 1 3/4" - 2¼" 2.04" average on 15 tests

Air Entrainment - Darex 1 to 11 oz per c.y.

Retarder - Daratard 18 oz decreasing to 6 oz Initial set - 7 hr to 3 hr

Pour Sequence - From the northerly abutment to approximate mid point of structure

Percent Air - Low 4% High 9% 6.63% average on 24 tests

Slump - Low 3" High 3½" 3.42 average on 6 tests

Modulus of Rupture - Average 838 psi on 2 tests

Date Poured - June 25, 1971 (Section 2 mid point of structure to southerly abutment)

Weather Conditions - Sunny Wind Velocity - calm

Temperature - Low 65°F High 80°F

Concrete Cover Over Reinforcing Steel - 2 1/8" - 2½" 2.23 average on 12 tests

Air Entrainment - Darex 2 to 11 oz per c.y.

Retarder - Daratard 18 oz decreasing to 6 oz Initial set - 7 hr to 3 hr

Pour Sequence - From southerly abutment to approximate mid point

Percent Air - Low 5% High 7% 6.25% average on 19 tests

Slump - Low 3" High 4" 3.60" average on 6 tests

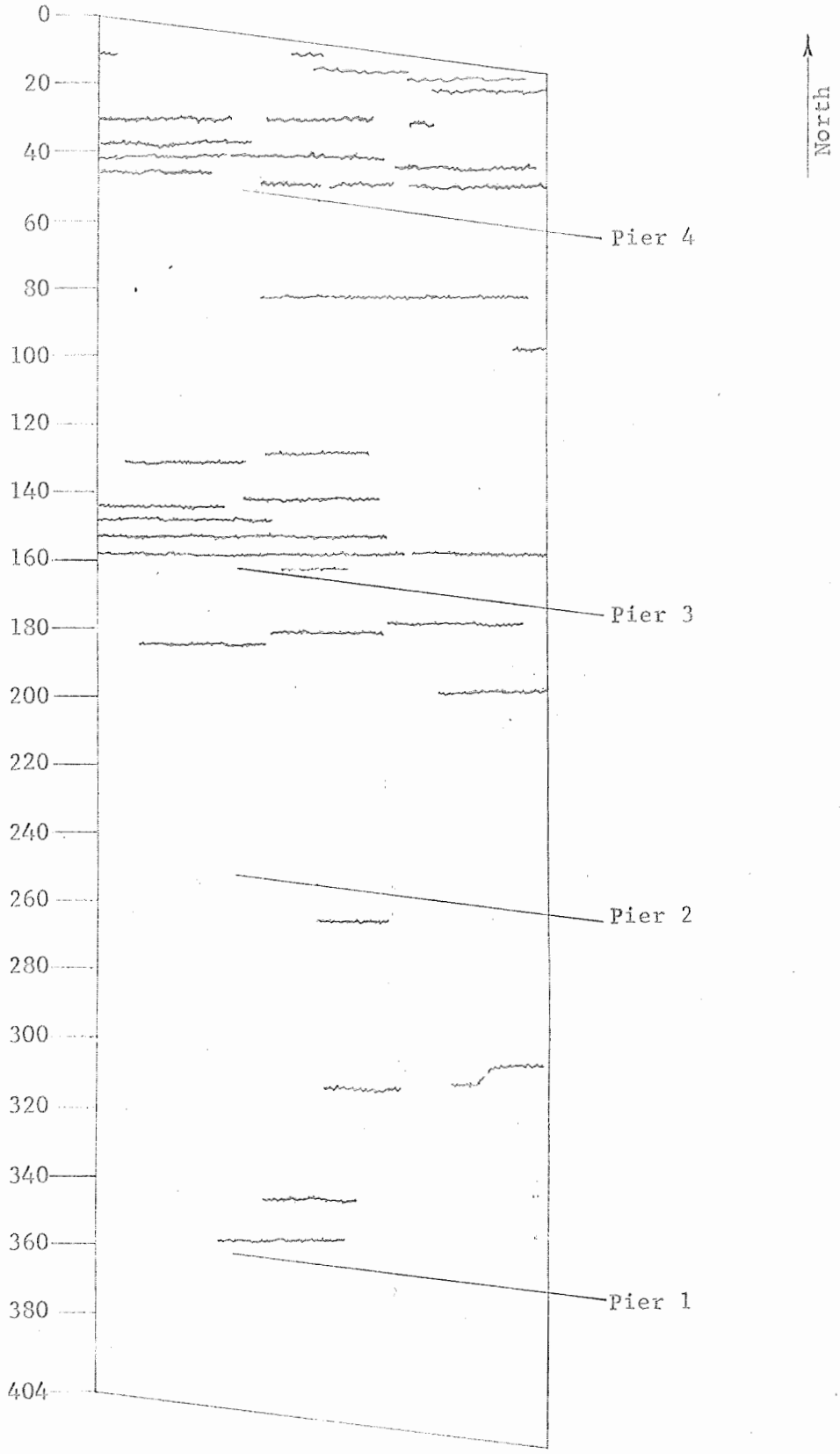
Modulus of Rupture - 733 psi

DECK CONDITION

A total of 33 transverse cracks were logged on the concrete deck. The cracks ranged in length from one foot to the full width of the deck. See Figure I, Page 21 for additional information.

Figure I 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 50'/in. Horizontal Scale 10'/in.**



PROTECTIVE TREATMENT

Product - Uniroyal Liquid Membrane Waterproofing System.

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

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

RECOMMENDED APPLICATION PROCEDURE

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

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 1230 sy at $10.00/sy = $12,300

Bituminous Concrete - (two - one inch thick courses)

152.7 tons @ $15.00 per ton = $2,290

OBSERVATIONS MADE DURING APPLICATION OF UNIROYAL LIQUID MEMBRANE ON CASTLETON TH #17 BRIDGE OVER US 4

Time	Temp	Humidity	Cloud Cover	Wind MPH	Liquid Membrane Temp	
			8/12/71			
7:00						Heating liquid membrane
9:05	64°	65	PC	10		Began placing liquid membrane & Elasto-
9:30	66°	63	PC	10		sheet along NE corner of deck 250 sq ft
10:00	66°	62	PC	10		covered including 75' of curb 1130 sq ft
11:30	66°	59	PC	0-5		covered 3 man operation Elastosheet
12:30	67°	55	PC	0-2	400°	placed 1 3/4"-2" up the side of the
1:30	71°	50	PC	3-6	390°	granite curb Oil bath temp 575°
3:00	83°	45	clear	0-3	380°	3600 sq ft covered Coverage is now
4:30	80°	34	clear	0-3		more uniform than earlier application
5:15	77°	35	clear	0-5	440°	Easterly side of deck treated with a 0.76 lbs/sq ft application (4310 lbs of membrane applied to 5670 sq ft)
			8/13/71			
7:00	58°	68	clear	calm		Began re-heating material in kettle
7:30	60°	68	clear	calm		membrane placed previous day is tacky to walk on
9:30	68°	65	clear	0-3	385°	Began placing liquid membrane along ex- pansion device north end of bridge
10:00	68°	62	clear	0-3	420°	Sampled liquid membrane
11:00	70°	60	clear	2-5	410°	850 sq ft covered - includes second coat on easterly side which was necessary to cover numerous pinholes
12:00	73°	58	clear	2-5	390°	Air bubbles noted in membrane placed
1:00	77°	54	clear	5-10	385°	previous day NE side of deck has 2
1:30	77°	52	clear	5-10	390°	coats for a length of 110' An RC asphalt was applied to the concrete in an attempt to eliminate air bubbles Light appli- cation of primer applied from 175'-220' and 230'-250' Heavy applica- tion from 220'-230' (distances measured along westerly curb from northerly ex- pansion device)
3:30	86°	45	clear	5-10	400°	Sampled liquid membrane
4:15	85°	45	clear	5-10	400°	Operation stopped for week end 4330 sq ft coverage for the day included 2930 sq ft new and 1400 sq ft given second coat to cover pinholes
			8/16/71			
7:00	58°	72	cloudy	3-5	200°	Area given heavy coat of primer on 8/13/71 appears to have as many air bubbles as unprimed areas although none are large bubbles 25% of the larger bubbles revealed concrete when opened up
8:15	62°	74	cloudy	3-5	390°	Touching-up pinholes in treated areas
10:30	63°	68	clear	10-15	375°	Bubbles which were recessed earlier in AM are starting to rise again
12:00	67°	60	clear	5-15	370°	Treating area along expansion device
1:00	69°	60	clear	5-10	345°	Application complete

OBSERVATIONS (cont'd)

Time	Temp	Humidity	Cloud Cover	Wind MPH	
	8/16/71 cont'd				
1:30	69°		clear	5-10	(2) 94 lb bags of cement spread over the deck to prevent tracking of the membrane - 11,025 lbs of liquid membrane used on 11,072 sq ft deck for an average application rate of 0.9958 lbs/sq ft.
4:00	74°		clear	5-10	Began paving over membrane The paver tracks compressed the dusted membrane but did not appear to break through to the concrete
5:00	74°		clear	2-5	Moving hot mix trucks caused only occasional tracking or pulling of the membrane When the trucks stopped, the tires sunk into the membrane and slid sideways in areas
6:00	74°		clear	2-5	where the deck was banked and on a grade Hot mix was shoveled in front of the paver tracks to prevent it from sliding sideways in banked areas Dual rear truck tires pulled the membrane from the concrete in 2 small areas (2"x 6" & 1"x 4") The area had been given 2 coats of membrane to cover pinholes Compaction of the pavement delayed for about 1 hour due to the fluid effect caused by the re-heated membrane

DISCUSSION

The Uniroyal Liquid Membrane application began on the northerly end of the deck and progressed southerly along the easterly side. A surface conditioner or primer was not used on the deck since the Uniroyal representative felt the concrete surface did not require it. A lack of application experience by the three-man crew and a liquid membrane temperature below 400°F resulted in an uneven application over the first 1100 square feet. As the work progressed, a more uniform coverage was achieved. This was due in part to the increased workability of the material with higher material, air and concrete temperatures.

A total of 5670 square feet of deck was covered the first day with 4310 pounds of liquid membrane for an average coverage of 0.76 lbs/s.f.

During the second day's application, bubbles were noted in the membrane surface placed the previous day. The bubbles were believed to be caused by the expansion of air in the concrete brought about by a rise in atmospheric temperature. Visible areas of concrete were often noted when individual bubbles were broken open for inspection. The lack of bond between the membrane and concrete at the site of each bubble may have been due in some cases to dust particles on the concrete surface. In an attempt to eliminate bubbles, an RC asphalt was applied over a 55 foot by 10 foot area of the deck. Subsequent inspection of the area revealed that the primer application, which ranged from light to heavy, did not reduce the number of air bubbles on the membrane surface.

Coverage for the second day amounted to 4330 square feet. This included a second coat on the first 1400 square feet covered the previous day. The second application was considered necessary to cover numerous holes in the initial treatment of the area.

An inspection of the membrane system early in the morning revealed many small depressions on the surface. However, with the normal rise in air temperature as the day progressed, the depressions all became bubbles again.

The system was completed on the third day with the application of the membrane over the final 2470 square feet of deck. A total of 11,025 pounds of liquid membrane was applied on the 11,072 square foot deck for an average application of 0.996 pounds per square foot.

The bituminous paving operation began several hours after the membrane treatment was completed. Truck tires and the paver tended to track the cement-dusted membrane somewhat, while actual separation of the membrane from the concrete occurred only in two small areas. Most of the tracking and the two ruptured areas occurred when the vehicles remained stationary for a short period of time.

The transfer of heat from the bituminous pavement to the membrane coating caused the material to return to a liquid state. It may be assumed that the weight and heat of the bituminous pavement may have eliminated the air bubbles from the membrane at this time. However, the membrane thickness at the former site of the bubbles remains unknown.

Compaction of the pavement was delayed about one hour due to the fluid effect caused by the re-heated membrane.

WORK PLAN #3 INITIAL REPORT

RAMBOND 223 EPOXY

PROJECT

Fairlee-Bradford I 91-2 (10) Stage I

PROJECT LOCATION

In the towns of Fairlee and Bradford beginning at a point approximately 3.741 miles southerly of the Fairlee-Bradford Town Line and extending northerly 5.201 miles.

WORK LOCATION

Northbound bridge over Vt Rte 25 at station 5177+09.96 - 5179+34.53

CONTROL SECTION

Southbound bridge over Vt Rte 25 at station 5177+61.96 - 5179+86.53

BRIDGE CONSTRUCTION DATA

Type of Structure - Three span continuous welded plate girder, composite

Span Lengths - 66'-103'-52'

Overall Lengths - 221' - 0"

Curb to Curb Width - 39'- 4"

Skew - 54°- 53'- 49"

Horizontal Curvature - Tangent

Grade - Minus 2.4886%

Superelevation - ¼" per foot

DECK CONSTRUCTION DATA

Date poured - May 6, 1971

Weather Conditions - Fair with low humidity Wind velocity - 1 - 5 mph

Temperature - Low 35°F High 60°F

Deck Thickness - 8"

Concrete cover over reinforcing steel - 2"-2½" 2.25" average on 15 tests

DECK CONSTRUCTION DATA - cont'd

Concrete - Class AA

Cement - Type I 6½ bags/cy

Aggregate size - 3/4" maximum

Water-cement ratio - 0.55

Air entrainment - Darex 6½ oz/cy

Retarder - Daratard HC

Pour sequence - Continuous starting at 7:20 AM completed at 5:00 PM Concrete placed simultaneously from both ends Full depth on northerly end (abutment #4) but only to top of steel on southerly end (abutment #3) No retarder used on top lift of abutment #3 end.

Finishing Method - Capital finishing machine on beams Screed position 90° to centerline Deck was screeded from abutment #4 to abutment #3

Surface Texture - Broomed finish

Concrete Test Results

Air entrainment - Low-high 5-7.25% Average 6.22% on 29 tests
Slump - low-high 2.25-4.5" Average 3.42" on 16 tests
Yield - low-high 99-99.3% Average 99.2% on 2 tests
Modulus of rupture - average 916 psi on 5 tests

DECK CONDITION

Cracks in concrete - (1) At 183' offset, left curb, 2 inches south of preformed joint sealer in curb Crack extended one foot out onto deck.
(2) In northerly approach slab, beginning at a point along the deflection joint 11.3 feet from the easterly curb and extending towards the end of the curb for a distance of four feet.
(3) Numerous fine cracks extending across the top of the curb and down the facia.

Surface Texture - Broomed finish The surface of the concrete varied between a relatively smooth and a very open, rough texture. Pictures were taken of typical conditions. The surface was free of any laitence.

PROTECTIVE TREATMENT

Product - Rambond 223 Epoxy
A 100% solids epoxy resin system

Test Results - None Previous tests of the materials had met Vermont Department of Highways Specifications for Item 438 b Epoxy Membrane Sealer.

PROTECTIVE TREATMENT - cont'd

Application Procedure -

One gallon of catalyst was added to a bucket containing four gallons of epoxy resin. The material was then mixed for four minutes using a power drill and jiffy blade. Upon completion of the mixing process, the material was poured onto the concrete and spread with a notched trowel. After all of the material had been spread, a plastic disk or spatula was used to go over the material a second time to level off areas with an excess of epoxy and to reduce the number of pinholes in the membrane. When an area the full width of the deck and approximately five feet in depth had been covered with epoxy, a washed sand grit was cast onto the liquid surface.

CONTROL SECTION

The control deck shall be treated under a future construction contract.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Temp	Humidity	
	OCTOBER 15, 1971		
10:30	62°	68	Began placing epoxy in joint between northerly approach and deck - partly cloudy until noon - clear in P.M. - wind velocity 2-5 mph
12:30	67°	73	
2:30	72°	60	
4:00	74°	55	1325 sq ft northerly approach slab covered with 45 gal for application rate of 29.5 sq ft/gal - sundown at 5:30 - stopped at 237' right offset - 25 gals on 600 sq ft for 24 sq ft/gal
6:30	60°	69	2 men for 7½ hrs - 75 gals applied to 1925 sq ft plus joint (the 600 sq ft of deck which was covered with epoxy on Oct 15, 1971 was coated with 4 gals of Ramcoat Epoxy paint on Oct 17, 1971 so that grits could be applied to the surface - Ottawa Sand had been used on the epoxy but did not appear to be as satisfactory)
	OCTOBER 18, 1971		
11:45	53°	60	Began application at 11:45 - sunny - 2-5 mph wind
1:00	55°	58	
3:00	60°	44	2 men for 4 3/4 hrs - 50 gals applied to 1050 sq ft for an application rate of 21.0 sq ft/gal -
4:30	60°	50	stopped at 211' right offset
	OCTOBER 19, 1971		
11:30	53°	58	Clear - wind velocity 0-2 mph - noted air bubbles in epoxy placed previous day - most common in the last area covered - the bubbles do not appear until the sun begins warming the deck and they do not reappear the following day
2:00	65°	52	2 men for 4 hrs - 60 gals applied to 1100 sq ft for an
3:30	62°	65	application rate of 18.4 sq ft/gal - stopped at 182.3' right offset

OBSERVATIONS MADE DURING MEMBRANE APPLICATION - cont'd

Time	Temp	Humidity	
	OCTOBER 20, 1971		
11:30			Inspection by Construction Division personnel
			weather conditions same as previous day
3:30			2 men for 4 hrs 45 gal applied to 700 sq ft for an application rate of 15.6 sq ft/gal
	OCTOBER 21, 1971		
2:30	60°	61	Clear wind velocity 0-3 mph
4:00	61°	70	started applying epoxy at 1:30 P.M.
5:00	58°	76	2 men for 3½ hrs 50 gal applied to 867 sq ft for an application rate of 17.3 sq ft/gal
	OCTOBER 22, 1971		
9:45	46°	76	Foggy until 11:30 clear in P.M. wind velocity 0-2 mph
11:30	48°	81	
1:30	55°	78	2 men for 6 hrs 100 gal applied to 1773 sq ft for an
3:00	62°	72	application rate of 17.7 sq ft/gal
	OCTOBER 23, 1971		
12:00	65°	60	85% clear wind velocity 2-5 mph
2:00	67°	60	2 men for 4 hrs 60 gal applied to 1162 sq ft for an
4:00	65°	61	application rate of 19.4 sq ft/gal
	OCTOBER 27, 1971		
10:00	59°	75	Overcast until noon partly cloudy in P.M.
11:30	63°	71	
1:30	64°	69	2 men for 5½ hrs 80 gal applied to 1540 sq ft for an
3:30	65°	65	application rate of 19.3 sq ft/gal

TABLE I QUANTITIES & COVERAGE

Station	Date Applied	Gallons Applied	Sq. Ft. Covered	Coverage
0.0				
			No Treatment	
18.0				
	10/27/71	75	1470	19.6 sf/gal 0.49 lbs/sf
68.0				
	10/23/71	60	1160	19.3 sf/gal 0.51 lbs/sf
97.5				
	10/22/71	100	1770	17.7 sf/gal 0.54 lbs/sf
142.5				
	10/21/71	50	865	17.3 sf/gal 0.57 lbs/sf
164.5				
	10/20/71	45	700	15.6 sf/gal 0.63 lbs/sf
182.3				
	10/19/71	60	1100	18.3 sf/gal 0.54 lbs/sf
210.3				
	10/18/71	50	1050	21.0 sf/gal 0.47 lbs/sf
237.0				
	10/15/71	70	1925	27.5 sf/gal 0.36 lbs/sf
289.0				
	Totals	510 gal	10,040 sf	Average 19.7 sf/gal

South

Quantity applied does not include 10 gallons used in deflection joint between northerly approach slab and deck and areas adjacent to expansion devices on both NB and SB structures

TABLE II

INFORMATION ON PINHOLES IN EPOXY MEMBRANE SURFACE

All locations checked were one square foot in area at a point three feet from the granite curb on the easterly side of deck. The stationing is from the beginning of the granite curb at the southerly end of the deck.

Station Inspected	No. of Pinholes	% of Pinholes Open To Concrete	Size of Pinholes		
			1/16+	1/32-1/16	1/32-
284	116	45%	5%	45%	50%
250	81	17	4	26	70
230	37	54	33	67	0
215	35	60	25	45	30
200	66	30	38	47	15
190	26	23	12	19	69
175	49	37	38	46	16
155	21	43	33	43	24
140	124	47	47	44	9
120	23	57	87	13	0
100	40	13	10	10	80
90	51	65	35	55	10
80	9	56	0	100	0
70	6	0	20	0	80

The 14 areas checked had an average of 49 holes per square foot with an average of at least 40% of the holes open to the concrete.

DISCUSSION

The entire bridge deck was sand blasted, prior to the membrane application, to insure that the concrete surface was free of laitence or other foreign matter. Shortly after the epoxy application had begun, air bubbles were detected in the membrane coating. A close examination disclosed that the surface of the concrete was not coated with epoxy at the site of each bubble. Continued observation revealed that the air bubbles worked their way out of the epoxy during the first few minutes after application, but holes were left in their place. Attempts to eliminate bubbles and pinholes by constantly working and reworking the epoxy within selected small areas did not significantly reduce the number of holes. It was noted that the number of pinholes varied with differences in air and concrete temperature (see air temperatures on Pages **29** and **30.** Areas treated in the morning during the cooler temperatures always had a greater number of pinholes than areas treated during the warmer afternoon hours. This was believed due to the increase in air temperature causing the air in the concrete to expand. The resulting air pressure from within the concrete was then able to force its way out through the liquid epoxy leaving pinholes in the membrane. The areas treated late in the day when the concrete deck was cooling were not subject to expanding air and the epoxy may have actually been drawn into the pores of the concrete with the vacuum created by the decreasing air pressure. The number of air bubbles and resulting pinholes appeared to be only slightly higher on areas of concrete which had a rougher surface texture.

Inspection of the epoxy membrane 20 to 24 hours after application revealed numerous pinholes and large air bubbles on the surface. The air bubbles were believed to be caused by air expanding out of the concrete at locations where the epoxy has sealed over the top of some pinholes during the first few hours of curing but had not bonded to the concrete. The air bubbles did not reappear the following day after the epoxy had cured to a solid coating.

Inspection of the membrane surface to determine the size and number of pinholes revealed from 6 holes per square foot to a maximum of 124 holes per square foot within the specific areas checked. The size of the holes ranged up to a maximum of 5/32 of an inch. Because the number of pinholes was known to vary with the air and concrete surface temperature, the locations checked were near the starting (cooler temperatures) and ending points (warmer temperatures) of the days application or at the mid-point to insure that the number of holes could be considered average for the days application. The average of all areas checked was 49 pinholes per square foot. See Table II on Page **32 for** additional data on the number of holes at specific locations.

Visual observations and testing with a 20% solution of hydrochloric acid indicated that 13% to 65% of the pinholes within the specific areas checked were definitely open to the concrete surface. However, it may be assumed that the inspection did not detect all of the holes which were open to the concrete surface due to the difficulty in checking the smaller sized holes.

The application of a second coat of epoxy (Ramcoat Epoxy Paint) on a 600 square foot area of the deck adjacent to the northerly approach slab eliminated all pinholes within the area. The epoxy paint was used so that a sand grit could be applied on the membrane surface to improve its appearance. Ottawa sand had been used on the initial epoxy coating, but because it was smaller in size and lighter in color than the sand grit, it did not appear as satisfactory.

The coverage per gallon of epoxy ranged from a low of 15.6 square feet per gallon to a high of 27.5 square feet per gallon. See Table I on Page **31** for daily application rates. The surface texture of the concrete deck had a direct bearing on the quantity of epoxy used. The coverage on the roughest surface area of the deck, 90' to 180' north of the expansion device, averaged 17.1 square feet per gallon while the smoother areas on either side averaged 21.3 square feet per gallon. A decrease in coverage per gallon was also noted with an increase in the viscosity of the epoxy resin brought about by cooler air, component, and concrete surface temperatures.

A sieve analysis of the washed sand grits which were broadcast on the epoxy membrane surface indicated that 100% passed the No. 10 sieve, 13% passed the No. 20 sieve, with the remainder retained on the No. 40 sieve.

The epoxy was paid for at a cost of $47.50 per gallon. The estimated cost of the treatment had been $8,550 based on a coverage of 50 square feet per gallon. However, due to the decrease in coverage per gallon, the final cost of the treatment was $24,700. This amounted to a cost of $2.46 per square foot or $22.15 per square yard.

PRELIMINARY CONCLUSIONS

The excessive number of pinholes in the epoxy membrane surface suggests that the treatment may not be effective in preventing moisture or chloride solutions from entering the Portland cement concrete. The elimination of pinholes achieved by applying a second coat of epoxy resin over a 600 square foot area suggests that consideration be given to the use of a two coat system on future applications. The cost of a two coat system would probably increase with the additional labor required even though the quantity of epoxy used would not necessarily increase.

The cost of $24,700 for the epoxy treatment was over 60% of the cost of the concrete and reinforcing steel which it was designed to protect. The cost of the latter was approximately $39,800. Using the best days application rate of 27.5 square feet per gallon, the cost would have been a more reasonable but still expensive $17,300 or $15.48 per square yard.