EXPERIMENTAL BRIDGE DECK MEMBRANE

APPLICATIONS IN VERMONT

REPORT 78-5

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Project - Ryegate-Barnet I 91-2 (27) Stg. II

NATIONAL EXPERIMENTAL & EVALUATION PROGRAM
BRIDGE DECK PROTECTIVE SYSTEMS
WORK PLANS #46 - #48
INITIAL REPORT

STATE OF VERMONT
AGENCY OF TRANSPORTATION

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ABSTRACT

This report covers the application of four membrane systems on eight new bridge decks in 1977. Information includes data on the membrane systems, laboratory test results, condition of the bridge decks, observations made during the membrane applications, cost information, preliminary field test results and discussions on the applications. The report also includes summaries of field and laboratory observations on membrane systems applied in the years 1971 through 1976.

Two of the three experimental membrane systems discussed in this report were applied in an attempt to reduce or eliminate the formation of initial and post-construction blisters. Both products were basically successful in reducing the amount of air entrapped beneath the materials during placement and in doing so probably reduced the occurrence of blistering during the pavement application. The reduction in entrapped air was accomplished by the presence of self sealing vent holes in the Royston No. 10PV membrane and by the increased adhesion developed by the Royston No. 15 system.

The Tri-Ply system shows merit although a more definite means of obtaining adhesion between membrane and substrate would be desired on any future application.

Four of five control decks treated with the standard Royston Membrane No. 10 were free of significant concentrations of entrapped air and remained free of blisters or cracks during the pavement applications. All three types of Royston Membrane will be inspected periodically for any sign of post construction blistering.

INTRODUCTION

Applications of experimental bridge deck membrane systems have been carried out by the Vermont Agency of Transportation since 1971. Through the 1976 construction season, 28 different membrane systems have been experimentally placed on 56 new bridge decks. All applications were closely monitored and the results were reported. Annual field evaluations have been conducted on the experimental membrane systems after the bridges have been exposed to two years of deicing salt applications. The evaluations include resistivity tests, steel potential readings, moisture strip readings, and the recovery of concrete samples for the determination of chloride content. Paved but otherwise unprotected approach slabs of the experimental bridges are used as control sections. Comments on the effectiveness of the various systems, based on test results and service life to date, are shown on pages 37 to 41.

In August 1973, a specification was written which covered the use of three preformed sheet membrane systems, namely, Heavy Duty Bituthene, Royston No. 10 and Protecto Wrap M-400. The specification, which has since been used on nearly all non-experimental bridges, allows the contractor the option of selecting one of the three proprietary systems. All three products feature controlled membrane thickness, good cold temperature flexibility, ease of application and low in place cost. Such properties combined with the satisfactory performance indicated by field testing continues to make the systems the most desirable membrane type for use in Vermont.

Two potential problem areas recognized with the use of preformed membranes are the curb line seal and the formation of blisters in the pavement-membrane system. It is believed that the curb seal problem has been alleviated by modifying the specification to include the use of a compatible liquid polyure-

thane sealant along the membrane perimeter and the vertical curb face.

The problem of blister formations remains to be solved. The blisters may occur during paving or after construction has been completed and are often the results of several different conditions. Blisters which occur in the bituminous mix during paving are often caused by concentrations of air which were trapped beneath the membrane during the installation. In many cases, such blister formations can be prevented by puncturing the larger air bubbles and then bonding the membrane to the deck after the air has been forced out the vent hole. Blisters are also caused by small concentrations of moisture which collect beneath the membrane due to outgassing of moisture vapor from the concrete. Such moisture may subsequently turn to a vapor or gas when exposed to the high temperature of the bituminous overlay. The blistering can often be reduced by requiring that the overlay be placed within several days of the membrane application and by reducing the temperature of the bituminous mix to the lowest practical level.

Post-construction blistering is believed to be the result of moisture vapor pressures outgassing from the concrete. The occurrence of such blisters can be reduced by improving membrane adhesion to the concrete and by increasing the thickness of the bituminous overlay. Post-construction blistering can become a serious problem since it may lead to wearing course failures which can become a safety hazard to the traveling public. Such failures have been reported in FHWA Region 5 and have resulted in several states discontinuing the use of several or all of the standard preformed sheet systems.

Initial and post-construction blistering has been noted on a number of preformed membrane installations made in Vermont but the occurrences have never become serious problems. In many cases, the blisters have been noted only after the pavement has become slightly polished by snow plow wear on the high spots.

Royston Laboratories, Incorporated has attempted to eliminate the blistering problem by offering two membranes (No. 10 P.V. and No. 15) which contain 1/16 inch diameter holes punched at 1 1/2 inch intervals. The vent holes are designed to allow vapors to escape from beneath the membrane following the installation. The holes then become sealed upon application of heat and pressure during the paving operation.

When the contractor indicated that Royston No. 10 would be used on eight new interstate bridges in a 1977 contract, the cooperation of Royston Labs and the waterproofing contractor, were enlisted in order to substitute the No. 10 P.V. and No. 15 membranes on two bridges. A third experimental membrane, TRI-PLY, was also added to the project with the cooperation of the contractor.

The main purpose of this report is to discuss and document the initial experiences involved with the prevented membranes. Future experience relating to post-construction blistering and waterproofing effectiveness of the systems will be documented in follow-up reports.

WORK PLAN - NO. 46

TRI-PLY

DESCRIPTION

A 62-mil thick preformed sheet membrane composed of butyl neoprene scrim and various other elastomers and extenders. The material is manufactured for Triram Corporation, 721 Waverly Street, P.O. Box 642, Framingham, Mass. 01701.

TEST RESULTS

VT AOT - MD 8 - Cold temperature flexibility (1 inch mandril @ 0° F)- Failure noted in scrim but underlying butyl ok.

VT AOT - MD 12 - Moisture absorption and effect of water - Satisfactory

VT AOT - MD 16 - Resistance to puncture - Satisfactory

VT AOT - MD 17 - Resistance to bubbling or pinholing due to vapor pressures - Satisfactory except blisters were created when heat was applied for too long a period.

VT AOT - MD 18 - Permeability (electrical resistance test) - Material impermeable.

VT AOT - MD 19 - Adhesion to concrete - good adhesion with the use of infrared heater.

RECOMMENDED APPLICATION PROCEDURE

1. Apply butyl primer by roller or squeegee at a rate of approximately 200 sf per gallon.

2. Roll the membrane into place over the tack free primer.

3. Heat the membrane to 175° F and roll with a hand roller insuring all air is forced from beneath the membrane before the material cools.

4. Apply a tack coat of RS-1 cut back an additional 50 percent with water to insure adhesion of the bituminous pavement.

WORK LOCATION

I 91 southbound bridge over SA#1 in Ryegate, 7.4 miles south of the Barnet Interchange.

DECK CONDITION AND PREPARATION PRIOR TO MEMBRANE APPLICATION

Surface Texture - Satisfactory finish, very little laitance.

Cracks - None visible.

Average Initial Chloride Level - 51 parts per million.

Preparation - The concrete was sand blasted 3 feet out from the curb face and the deck was blown clean the day of the application.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Air Temp.	% Humid.	
	9-23-77		100% cloud cover AM, 60% PM. Previous rain 9/21/77 AM.
9:35	55°	68°	Applying primer by squeegee. Application complete at 9:55. 16 gallons applied on 3543 sf for rate of 216 sf/gal.
10:20	57°	70°	Four man crew placing first sheet along southeast curb line.
11:00	60°	66°	7 strips complete. Overlapping 50' by 35" wide sheets approximately 1 3/4 inches. Overlapping end sections 4-5 inches after priming underlying membrane. The membrane does not have any wrinkles in it or visible air bubbles trapped beneath it.
11:50	63°	65°	Membrane application complete including cap strip. Good adhesion noted where primer applied at butt laps. Solvent in primer causes butyl to string.
12:45	67°	55°	Air bubbles noted beneath membrane where overlapped at butt joints.
2:00	57°	52°	Began heating membrane using a 44" by 12" 220 volt double probe heater run off a 5000 watt generator.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION (con't.)

Time	Air Temp.	% Humid.	
2:25	70°	52°	Heating at a rate of 7 feet per min. Rate of 2 feet per minute resulted in greater adhesion to the concrete but caused some smoke to come from the membrane.
4:05	65°	58°	Heating complete on 1/3 of deck.
5:35	65°	71°	Completed heating remainder of deck in 1 1/2 hrs. by speeding up rate of movement.
6:00	59°	72°	Finished applying Bituthene mastic along edge of membrane at curb line and 5 gallons of RS-1 emulsion over membrane.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment	394	s.y.	@	$ 4.00/s.y.	= $ 1,576.00
Bituminous Concrete	44	tons	@	$15.00/ton	= $ 660.00

DISCUSSION

A Triram Corporation representative was on the project during the application.

The membrane was supplied in 65 pound rolls with the material measuring 50 feet in length by 34 inches in width. The high solvent content primer was allowed to dry completely before the first strips of membrane were placed. Since the material did not develop any initial adhesion to the substrate, placement was very easy and the material remained wrinkle free without appearing to trap any air beneath it. Treatment at end laps consisted of coating the underlying membrane with primer just prior to continuing the next strip of membrane. Very good adhesion was noted between such strips due to the solvent in the primer softening the butyl bottom portion of the membrane. Side laps were primed only on the north-westerly portion of the deck for a length of approximately 50 feet.

DISCUSSION (con't.)

The heat source used to develop adhesion between the membrane and concrete consisted of a double probe electric heater with shield which covered an area of 44 inches by 12 inches. Two hundred-twenty volts of power was produced with a 5000 watt generator. The heating rate varied throughout the application. Movement of the heat source at a rate of 3 feet per minute produced some adhesion but still allowed the membrane to be pulled from the concrete. Movement at 2 feet per minute produced occasional wisps of smoke and the formation of some small blisters. However, after the heat was removed the blisters disappeared and the membrane pulled down onto the concrete with excellent adhesion resulting. Although the slow rate of movement produced the greatest adhesion, the company representative chose to move at a faster rate averaging approximately 3 feet per minute on the northerly third of the deck. As the heating process progressed, the rate of movement was further increased to an average of 7.5 feet per minute on the southerly two-thirds of the deck. Physical checks revealed varying amounts of adhesion in the area but in no case could the membrane be considered tightly bonded. A segmented linoleum roller was initially used to roll the membrane but it's use was abandoned after one hour when no difference could be detected between rolled and unrolled areas.

As the heating progressed, Bituthene mastic was applied over the edge of the membrane along the curb face. The final operation consisted of applying RS-1 emulsion diluted an additional 50 percent with water over the surface of the membrane.

The 394 square yard application was completed in approximately 20 man hours. The time required to place the membrane was less than that which

DISCUSSION (con't.)

would be required to place Royston No. 10 or Protecto Wrap M-400, however, the heat sealing process lengthened the overall installation time by approximately 25 percent.

The membrane system was inspected four days after the installation, just prior to paving. The only air blisters or bubbles noted were in the butt end overlay areas. Six, 6 to 8 foot long by 1 1/2 inch wide wrinkles were noted in the second sheet from the curb line on the northwesterly side of the deck. Their reason for occurring could not be determined. Edge laps were tightly adhered in the area where the primer was applied. Seventy-five percent of the remaining laps displayed good adhesion while 25 percent had only light adhesion.

The first course of bituminous pavement was placed without any evidence of blister formations, cracking, or shoving of the membrane. Truck and paver tires left slight imprints in the surface of the membrane but did not cause any damage. Mix temperatures in the trucks ranged from 285° F to 297° F and the uncompacted pavement averaged 1 1/2 inches thick. Removal of compacted pavement from a portion of the membrane revealed no evidence of punctures and satisfactory adhesion between the two materials.

TRI-PLY

I 91 SB OVER STATE AID #1 IN RYEGATE

Placing Tri-Ply Membrane

Priming Membrane at end laps

Heating Membrane to create adhesion to concrete

Applying RS-1 emulsion over membrane

WORK PLAN - NO. 47

ROYSTON BRIDGE MEMBRANE NO. 10-PV

DESCRIPTION

A 75-mil thick preformed sheet membrane composed of an impregnated fiberglass mesh sandwiched between layers of a polymer modified bitumen with a top surface of polyester film. The membrane is pre-vented with self-sealing vents 1/16 inch in diameter at 1 1/2 inch intervals to prevent blister formation by permitting entrapped vapors to escape.

TEST RESULTS

VT AOT - MD 8 - Cold temperature flexibility (1 inch mandril @ 0° F) - Partial depth cracks.Satisfactory at 10° F.

VT AOT - MD 12 - Moisture Absorption and effect of water - Satisfactory

VT AOT - MD 16 - Resistance to puncture - Satisfactory

VT AOT - MD 19 - Adhesion to concrete - Satisfactory

RECOMMENDED APPLICATION PROCEDURE

1. 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.

2. Place the membrane sheet with the sticky surface down by removing the release paper as the application progresses. Place the sheets in such a 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 should 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.

3. The membrane should be fused to the curb face by melting the polyester film with a propane torch and by pressing or rolling the heated membrane into intimate contact with the primed curb surface.

RECOMMENDED APPLICATION PROCEDURE (con't.)

4. Any torn or cut areas, or narrow overlaps shall be patched by the heat fusion method, overlapping a minimum of 6 inches.

5. The bituminous pavement should be between 300° F and 340° F at the time of application to insure adequate bond between the membrane and the deck.

WORK LOCATION

I 91 northbound bridge over TH 81 in Barnet, 7.8 miles north of the Rte. 302 interchange in Newbury.

DECK CONDITION AND PREPARATION PRIOR TO MEMBRANE APPLICATION

Surface Texture - Smooth finish, very little laitance.

Cracks - None visible.

Average Initial Chloride Level - 52 parts per million.

Preparation - Deck was washed clean at 10:00 AM August 11, 1977. The concrete was sandblasted 3 feet out from the curb face.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Air Temp.	% Humid.	
	8-11-77		
12:30	85°	59°	Began applying Royston Roybond Primer #173 with squeegees.
1:30	87°	56°	Crew of 5 men placing first strip along north-easterly curb line.
2:55	88°	52°	Application complete. Cutting membrane over drain tubes and heat sealing membrane along curb line.
4:00			Completed rolling membrane with a pick-up truck.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment	372 s.y.	@	$ 4.00/sy	= $1,488.00
Bituminous Concrete	40 tons	@	$15.00/ton	= $ 600.00

DISCUSSION

The entire application from priming to rolling the in-place membrane was completed by a crew of five men in 3 1/2 hours. The prevented membrane handled the same as the standard Royston membrane. The sheets were flexible due to high ambient temperatures. Visual inspection of random pieces of membrane revealed that approximately 10 percent of the 1/16 inch diameter holes had become sealed with membrane material prior to placement. The heat fusion method was used to seal the membrane at the curb line since the contractor did not have the correct type of polyurethane for the specified liquid seal at such areas.

Compaction of the membrane with a pickup truck placed most of the material in intimate contact with the concrete. Entrapped air was limited to blisters of 1 - 2 square inches in area which occurred at a rate of one per 3 - 4 square feet. It is believed that the blisters occurred at areas where the vent holes were not initially open to the concrete. The permeability of the exposed membrane was checked prior to the pavement application. Thirty-six of 40 electrical resistivity tests were recorded at infinity while the 4 readings under infinity ranged between 140,000 and 5 million ohms indicating that those areas were also basically impermeable. Such readings indicate that nearly all of the vent holes were sealed during compaction of the membrane with the pickup truck. Although the vent holes were designed to remain open and allow vapors to escape until the bituminous pavement was placed, premature sealing of the holes was not considered a serious problem since nearly all of the membrane was in close contact with the substrate.

The first course of pavement was placed on August 16, 1977, five days after the membrane was applied. Inspection of the membrane prior to paving

DISCUSSION (con't.)

revealed no change in the number or size of the blisters beneath the membrane. The bituminous mix temperature ranged between 296° F and 305° F. The uncompacted thickness averaged 1 1/4 inches. There were no visible blisters or cracks in the pavement during the application or upon completion.

WORK PLAN - NO. 48

ROYSTON BRIDGE MEMBRANE NO. 15

DESCRIPTION

A 60-mil thick preformed sheet membrane composed of an impregnated non-woven fiberglass fabric sandwiched between layers of a polymer modified bitumen with a top surface of polyester film. The membrane is pre-vented with self-sealing vents 1/16 inch in diameter to prevent blister formation by permitting entrapped vapors to escape.

TEST RESULTS

VT AOT - MD 8 - Cold temperature flexibility (1 inch mandril @ 0° F) - Failed. Material ok at 15° F.

VT AOT - MD 12 - Moisture absorption and effect of water - Satisfactory

VT AOT - MD 16 - Resistance to puncture - Satisfactory

VT AOT - MD 19 - Adhesion to concrete - Excellent

RECOMMENDED APPLICATION PROCEDURE

1. Apply Royston Roybond Primer 720 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.

2. Place the membrane sheet with the sticky surface down by removing the release paper as the application progresses. Place the sheets in such a 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 should 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.

3. The membrane should be fused to the curb face by melting the polyester film with a propane torch and by pressing or rolling the heated membrane into intimate contact with the primed curb surface.

4. Any torn or cut areas, or narrow overlaps shall be patched by the heat fusion method, overlapping a minimum of 6 inches.

RECOMMENDED APPLICATION PROCEDURE (con't.)

5. The bituminous pavement should be between 300° F and 340° F at the time of application to insure adequate bond between the membrane and the deck.

WORK LOCATION

I 91 southbound bridge over Town Highway #81 in Barnet, 2.3 miles south of the Barnet Interchange.

DECK CONDITION AND PREPARATION PRIOR TO MEMBRANE APPLICATION

Surface Texture - Normal with numerous screed marks on a skew. Light laitance only.

Cracks - None visible.

Miscellaneous - Compression seal in northerly approach, slab joint is recessed 3/4 inch below concrete surface.

Average Initial Chloride Level - 50 parts per million.

Preparation - Concrete sandblasted 3 feet out from the curb face and deck blown clean just prior to starting the membrane application.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Air Temp.	% Humid.	
	8-29-77		Air temperatures recorded in shade. Clear.
9:30			Sandblasting complete. 5 man crew on project.
10:15	74°	58°	Applying Primer #720 with paint rollers.
10:40	78°	56°	Priming complete. 13 gallons applied for application rate of 260 square feet per gallon.
11:35	88°	55°	Five strips in place. Membrane adheres well to the primed concrete. Unable to move material after it has been stepped on.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION (con't.)

Time	Air Temp.	% Humid.	
12:10	93°	54°	Application complete. Applying Duraflex M one-component polyurethane over edge of membrane at curb face. Membrane was cut over approach slab joint at northerly end of deck in order to allow proper compaction of pavement over the unsupported area.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment	376 s.y.	@	$ 4.00/sy =	$1,504.00
Bituminous Concrete	40 tons	@	$15.00/ton =	$ 600.00

DISCUSSION

The Royston No. 15 membrane handled much like the standard No. 10. The only disadvantages noted with it's application was that the material could not be repositioned after it was stepped upon or partially rolled and that the material would tear if a reasonable amount of care was not taken during handling. Excellent adhesion to the primed concrete appears to be the materials major advantage over the standard Royston membrane.

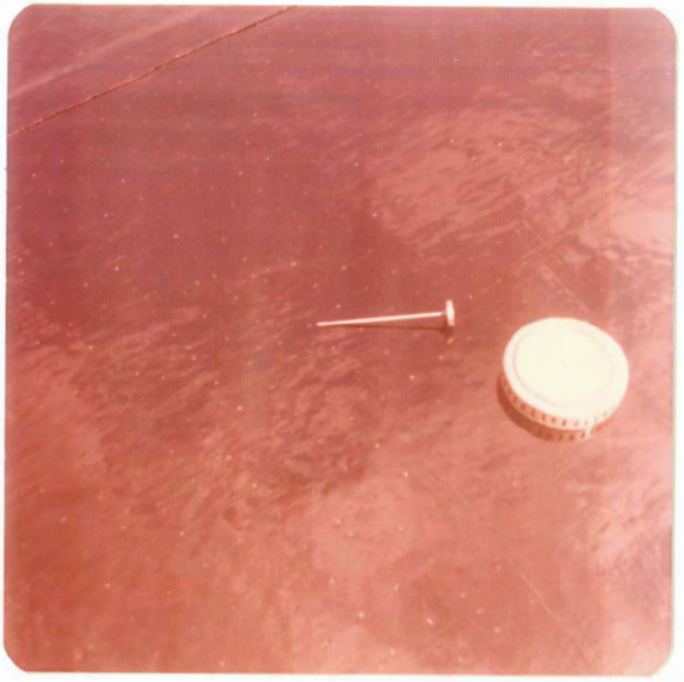
Visual inspection of samples prior to placement revealed that only about 5 percent of the vent holes were open. The manufacturer later acknowledged that the problem had occurred with much of the No. 15 membrane previously produced and was even more apt to happen when the material was stockpiled for a period of time. Consideration is now being given to the possibility of enlarging the size of the holes in order to obtain and maintain the desired venting condition. Even though few of the vent holes were open, air trapped beneath the membrane following placement and compaction was limited to a single 1 to 2 inch square bubble per 20 square feet of area. Electrical resistivity readings were taken at 108 locations. Seventy-six percent of the readings were recorded at infinity. The remaining readings ranged from 120,000 ohms

DISCUSSION (con't.)

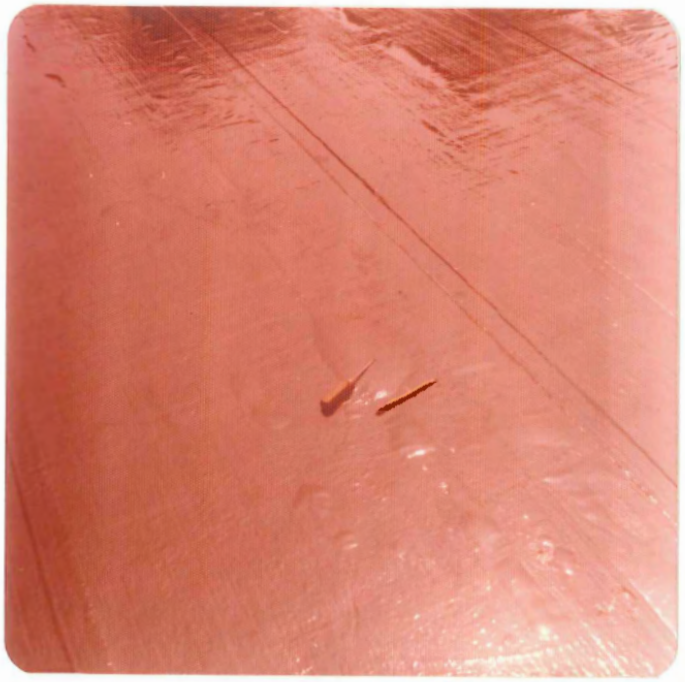
to 10 million ohms which would indicate that the membrane was basically impermeable prior to the pavement application.

The first course of pavement was placed two days after the membrane was applied. Bituminous mix temperatures ranged between 300° F and 310° F in the paver. A loose thickness of 1 3/8 to 1 5/8 inches was placed. With the exception of a single 6 inch long blister-crack noted 12 feet from the easterly curb, there were no problems during or following the pavement application.

Placing Polyurethane Sealant
along curb line



Vent holes in Royston No. 15



Air blister concentrations resulting
from compaction of the No. 10 membrane

Removal of compacted pavement
revealed no damage to the membrane

CONTROL BRIDGES FOR
WORK PLANS NO. 46, 47, & 48

ROYSTON BRIDGE MEMBRANE NO. 10

DESCRIPTION

A 75-mil thick preformed sheet membrane composed of an impregnated fiberglass mesh sandwiched between layers of a bituminous mastic and coated with a polyester film. The material is manufactured by Royston Laboratories, Inc., of Pittsburgh, Pennsylvania 15238.

TEST RESULTS

VT AOT - MD 8 - Cold temperature flexibility (1 inch mandril @ 0^{o} F) - Satisfactory.

VT AOT - MD 12 - Moisture absorption and effect of water - Satisfactory

VT AOT - MD 16 - Resistance to puncture - Satisfactory

VT AOT - MD 19 - Adhesion to concrete - Satisfactory

RECOMMENDED APPLICATION PROCEDURE

1. 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.

2. Place the membrane sheet with the sticky surface down by removing the release paper as the application progresses. Place the sheets in such a 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 should 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.

3. The membrane should be fused to the curb face by melting the polyester film with a propane torch and by pressing or rolling the heated membrane into intimate contact with the primed curb surface.

4. Any torn or cut areas, or narrow overlaps shall be patched by the heat fusion method, overlapping a minimum of 6 inches.

RECOMMENDED APPLICATION PROCEDURE (con't.)

5. The bituminous pavement should be between 300° F and 340° F at the time of application to insure adequate bond between the membrane and the deck.

WORK LOCATION #1

I 91 northbound bridge over State Aid #1 in Ryegate, 2.7 miles north of the Route 302 Interchange in Newbury.

DECK CONDITION AND PREPARATION PRIOR TO MEMBRANE APPLICATION

Surface Texture - Good to moderately coarse texture. Some areas appear to have been rained upon before initial set was obtained.

Cracks - None visible.

Average Initial Chloride Level - 45 parts per million.

Preparation - Curb line areas sandblasted and deck blown clean just prior to the membrane application.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Air Temp.	% Humid.	
	8-15-77		Air temperature recorded in shade 20-50% cloud cover.
11:00	72°	51°	Began applying Royston Bridge Membrane Primer 713.
12:00	72°	45°	22 1/2 gallons applied on 3660 s.f. for application rate of 163 s.f./gal.
1:15	76°	44°	Placing Duraflex M one-component polyurethane along curb line prior to placing first strip of membrane.
1:50	78°	45°	Membrane is flexible making placement easy. Do not appear to be trapping much air beneath the membrane in any concentrations but some air is present at almost all locations due to the normal roughness of the concrete surface.
3:20	75°	44°	Application complete.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment	407	s.y.	@	$ 4.00/sy	= $1,628.00
Bituminous Concrete	44	tons	@	$15.00/ton	= $ 660.00

DISCUSSION

The membrane application was completed without difficulty. Inspection was provided by the Construction Division during the pavement application. The inspector did not note any problems during the operation.

WORK LOCATION #2

I 91 northbound bridge over State Aid #1 at the Barnet Interchange.

DECK CONDITION AND PREPARATION PRIOR TO MEMBRANE APPLICATION

Average Initial Chloride Level - 52 parts per million.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment	494	s.y.	@	$ 4.00/sy	= $ 1,976.00
Bituminous Concrete	56	tons	@	$15.00/ton	= $ 840.00

DISCUSSION

Inspection during the membrane application was provided by the Construction Division. Visual inspection of the completed system revealed three areas along the upper curb line and 14 areas along the lower easterly curb line that were not completely sealed. The heat fusion method had been used to seal the membrane at the curb face in place of the specified polyurethane liquid sealant since the latter material was not available at the time of installation.

DISCUSSION (con't.)

The membrane on the easterly half of the deck was rolled with a pickup truck. However, when the procedure resulted in concentrating entrapped air into blisters, the applicator chose not to roll the westerly half of the deck. Two of the four largest blisters ranging up to one square foot in area were removed by puncturing the membrane and forcing the air out the vent hole.

The first course of pavement was placed on August 16, 1977. An uncompacted thickness of 1 1/4 inches was placed with mix temperatures recorded at 285° F to 295° F in the hopper. There were no problems with slippage of equipment on the rain dampened membrane even though the deck was in full bank on a 4.5 percent grade.

The two large air blisters which had not been vented remained visible during the pavement application and through initial compaction of the mix but disappeared prior to the final compaction. No other blisters or cracks were noted in the first course of pavement. The top course was placed on August 30, 1977.

WORK LOCATION #3

I 91 southbound bridge over U.S. Route 5 and Relocated 1, 0.6 miles north of the Barnet Interchange.

DECK CONDITION AND PREPARATION PRIOR TO MEMBRANE APPLICATION

Surface Texture - Typical surface texture except for numerous ridges left by leveling screed.

Cracks - None visible.

Laitance - Heavy laitance adjacent to ridges left by screed.

Preparation - Sandblasted areas with heavy laitance in addition to normal curb line areas.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Air Temp.	% Humid.	
	8-25-77		Air temperatures recorded in shade. 0-30% cloud cover.
12:30	61	54	Began applying primer with squeegees. Difficult to keep application light due to cool temperature.
1:15	63	55	Priming complete. 77 gallons applied on 5310 s.f. for application rate of 69 sf/gal. (normal rate averages 150 sf/gal.).
2:45	64	60	Placing Duraflex M one-component polyurethane along curb line.
4:35	66	62	Four strips complete.
6:10	68	62	Complete except for strip along upper curb line. Will heat fuse edge and wait until additional polyurethane sealant is obtained.
	8-26-77		
3:30	71	43	Placing final strip of membrane in polyurethane along curb line. Liquid sealant also placed along edge of membrane where the material butts the concrete header encasing the expansion dam.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment	488	s.y.	@	$ 4.00/sy =	$1,952.00
Bituminous Concrete	55	tons	@	$15.00/ton =	$ 825.00

DISCUSSION

There were no significant amounts of air trapped beneath the membrane during the application. The first course of bituminous pavement was placed on August 31, 1977. Mix temperatures ranged between 290° F and 320° F.

DISCUSSION (con't.)

The average thickness of the uncompacted mix was 1 1/2 inches. No blisters or cracks were noted in the pavement during placement or compaction.

WORK LOCATION #4

I 91 northbound bridge over U.S. Route 5 and Relocated 1, 0.6 miles north of the Barnet Interchange.

DECK CONDITION AND PREPARATION PRIOR TO MEMBRANE APPLICATION

Surface Texture - Normal to smooth surface. Little laitance.

Cracks - Some pattern cracks along concrete header at strip seal where surface finished by hand.

Average Initial Chloride Level - 51 parts per million.

Preparation - Concrete sandblasted 3 feet out from curb face.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Air Temp.	% Humid.	
	9-19-77		Air temperatures recorded in shade. 50% cloud cover.
10:50	74°	65°	Primer for Royston #15 applied on 52' long x 30' wide area on south westerly end of deck. 7.5 gallons applied for rate of 208 sf/gal.
11:20	76°	64°	Applying Primer #713 on remainder of deck. Material thinned with 1 quart of toluene per 4 gallons of primer to insure application rate exceeds 100 sf/gal.
1:00	76°	54°	2 strips (approximately 8' wide) of No. 10 PV membrane placed along easterly curb line adjacent to 8 strips of #15 membrane. An additional 4' by 50' strip was placed along the westerly curb line with Royston #10 placed on remainder of deck.
2:15	74°	57°	Application complete except for rolling.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment	589 s.y.	@	$ 4.00/sy =	$2,356.00
Bituminous Concrete	58 tons	@	$15.00/ton =	$ 870.00

DISCUSSION

Three different types of Royston membrane were placed on the deck. For detailed information refer to the previous observations made during the membrane application. The membrane was rolled with a pickup truck following the application. There were no significant concentrations of air trapped beneath the membrane.

The pavement application was monitored by Construction Division personnel. Pavement temperatures were reported at 290° F - 310° F. There were no blisters or cracks noted in the pavement during placement or compaction.

WORK LOCATION #5

I 91 southbound bridge over State Aid #1 at the Barnet Interchange.

DECK CONDITION PRIOR TO MEMBRANE APPLICATION

Surface Texture - Smooth texture on southerly half of deck, transverse screed marks on northerly half and open textured on northerly third of deck.

Cracks - None visible.

Miscellaneous - Very little laitance. 1-2 inch long cracks visible between epoxy mortar and granite curb along 5% of the westerly curb line.

Average Initial Chloride Level - 61 parts per million.

Preparation - Concrete sandblasted 3 feet out from curb face.

OBSERVATIONS MADE DURING MEMBRANE APPLICATION

Time	Air Temp.	% Humid.	
	8-26-77		Air temperatures recorded in shade. Clear.
11:10	64	49	Applying primer with paint rollers.
12:55	65	41	Placing first strip of membrane in Duraflex M one-component polyurethane along curb line.
2:00	71	39	7 strips complete. 5 man crew placing 120 lineal feet of membrane in 3 sections every 10 minutes.
3:10	71	43	Placing last strip of membrane in liquid seal at curb line. Heat sealing end laps. The membrane was not rolled with a pickup or by other means.

COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE.

Membrane Treatment	508	s.y.	@	$ 4.00/sy =	$2,032.00
Bituminous Concrete	57	tons	@	$15.00/ton =	$ 855.00

DISCUSSION

The pavement was placed on August 31, 1977, five days after the membrane system was completed. There were no significant concentrations of air beneath the membrane prior to paving and no blisters or cracks were noted in the completed pavement. Mix temperatures were recorded between 290° F and 320° F in the hopper and 265° F - 290° F on the bridge deck. The uncompacted thickness averaged 1 1/4 inches.

BRIDGE DECK CONSTRUCTION DATA

BRIDGE	MEMBRANE SYSTEM	TYPE	TOTAL LENGTH	CURVATURE	SUPER-ELEVATION	GRADE	DATE DECK CAST
I 91 SB over SA #1	TRY-PLY	Composite Rolled Beam	92' 1 7/8"	None	1/2"/Ft.	3.9%	6/9/76
I 91 NB over SA #1	ROYSTON #10	Composite Rolled Beam	92' 0 1/4"	None	1/2"/Ft.	3.9%	6/17/76
I 91 SB over TH #81	ROYSTON #15	Composite Rolled Beam	82' 3 1/4"	None	1/2"/Ft.	0.5%	5/17/76
I 91 NB over TH #81	ROYSTON #10 PREVENTED	Composite Rolled Beam	82' 3 1/4"	None	1/2"/Ft.	0.5%	5/20/76
I 91 SB over SA #1	ROYSTON #10	Composite Rolled Beam	119' 6"	2° 15'	3/4"/Ft.	4.5%	9/21/76
I 91 NB over SA #1	ROYSTON #10	Composite Rolled Beam	117' 0	2° 20'	3/4"/Ft.	4.5%	9/29/76
I 91 SB over U.S. 5 & Reloc. 1	ROYSTON #10	Composite Welded $\mathbb{P}_L$ Girder	137' 6"	2° 30'	3/4"/Ft.	4.4%	7/8/77
I 91 NB over U.S. 5 & Reloc. 1	ROYSTON #10, #10 P.V. & #15	Composite Welded $\mathbb{P}_L$ Girder	114'	2° 00'	3/4"/Ft.	4.5%	6/15/77

SUMMARY OF FINDINGS & RECOMMENDATIONS

The following discusssions summarize the good and bad characteristics of each of the four 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 desirable 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.

TRI-PLY

SUMMARY OF FINDINGS

Tri-Ply is designed to prevent the occurrence of initial and post-construction blistering by avoiding the entrapment of air beneath the membrane during it's installation. This is accomplished by placing the membrane without any initial adhesion. After insuring that the material is wrinkle free and in close contact with the substrate, adhesion is obtained by applying heat to the surface of the membrane which softens the uncured butyl underside of the material.

Placement of the membrane was very quick and easy. An electric heater was used as the heat source for obtainment of adhesion prior to the pavement application. No definite ideal temperatures were established for the development of maximum adhesion. Movement of the heat source at a rate which resulted in occasional wisps of smoke and the formation of some small blisters resulted in the maximum adhesion. The greater portion of the membrane installation was not heated enough to create the desired adhesion, however, no disbonding or slippage of the membrane was noted during the paving operation. Inspection of a portion of the membrane following removal of the compacted bituminous mix revealed no evidence of punctures and satisfactory bond between the overlay and membrane.

RECOMMENDATION

Tri-Ply is recommended for further trial use if the application-heat procedure can be revised to insure all areas of the membrane are adequately bonded to the concrete. This might be accomplished by placing the membrane before the primer has become tack free or by requiring a specific heating rate which will insure that the underside of the membrane is sufficiently softened.

ROYSTON BRIDGE MEMBRANE NO. 10-PV

SUMMARY OF FINDINGS

The pre-vented version of Royston No. 10 handled the same as the standard Royston membrane. Approximately 10 percent of the 1/16 inch diameter holes were not open prior to membrane placement. Air entrapped beneath the membrane was limited to 1 to 2 square inch blisters which occurred at a rate of one per 3-4 square feet. The blisters occurred at areas where the vent holes were not initially open to the concrete.

Electrical resistivity testing indicated that compaction of the membrane with a pickup truck resulted in sealing of nearly all of the vent holes. Although, the holes were designed to remain open until the bituminous pavement was placed, premature sealing was not considered a serious problem since nearly all of the membrane was in close contact with the concrete substrate. The bituminous pavement was placed and compacted without any visible signs of blisters or crack formations.

RECOMMENDATION

Royston No. 10 PV is recommended for further limited experimental use. Future wide-scale use will depend upon field performance as indicated by chemical analysis of recovered field cores after a minimum of two winters of deicing salt applications.

ROYSTON BRIDGE MEMBRANE NO. 15

SUMMARY OF FINDINGS

Royston No. 15 developed excellent adhesion to the substrate with a minimum of compaction. Visual inspection of the membrane prior to placement revealed that only about 5 percent of the vent holes were open. Air entrapped beneath the membrane was limited to an average of one bubble per 20 square feet of area. The absence of significant amounts of entrapped air was believed due to the adhesive quality of the membrane rather than the existance of a minimum number of vent holes. The manufacturer is considering the possibility of enlarging the size of the holes in the membrane in order to maintain the desired venting condition until the bituminous pavement is placed. Electrical resistivity readings indicated the membrane was basically impermeable prior to the pavement application. A single blister-crack was noted in the bituminous pavement during placement.

RECOMMENDATION

Royston No. 15 is recommended for further limited experimental use. Future wide-scale use will depend upon field performance as indicated by chemical analysis of recovered field cores after a minimum of two winters of deicing salt applications.

CONTROL SYSTEM - ROYSTON BRIDGE MEMBRANE NO. 10

SUMMARY OF FINDINGS

Royston No. 10 was placed on 4 structures and was used in combination with the No. 10-PV and No. 15 membranes on a fifth deck. The applications were generally free of significant concentrations of entrapped air due in part to good membrane flexibility resulting from warm ambient temperatures. Compaction of the membrane with a pickup truck resulted in the concentration of air into several large blisters on one of two decks rolled. Two large blisters in the membrane which were not punctured remained visible during the pavement application but disappeared prior to final compaction. No blisters or cracks were noted in the other pavement applications made over the Royston No. 10 membrane.

RECOMMENDATION

Royston Bridge Membrane No. 10 is currently included as one of three optional systems covered under Section 519 - Sheet Membrane Waterproofing. Continued use of the system is recommended.

CONCLUSION

Problems with the formation of air blisters beneath preformed sheet membranes and in pavement overlay systems have been reported by a number of agencies. The blisters may occur prior to or during paving or after construction has been completed and are often the result of several different conditions. Blisters which occur in the bituminous mix during paving are often caused by concentrations of air which were entrapped beneath the membrane during the installation. The blisters may also be caused by small concentrations of moisture which collect beneath the membrane due to outgassing of moisture vapor from the concrete. Such moisture may consequently turn to a vapor or gas when exposed to the high temperature of the bituminous mix. Post-construction blisters are the result of constant pressures generated by moisture vapors outgassing from the concrete.

Two of the three experimental membrane systems discussed in this report were applied in an attempt to reduce or eliminate the formation of initial and post-construction blisters. Both products were basically successful in reducing the amount of air entrapped beneath the materials during placement and in doing so probably reduced the occurrence of blistering during the pavement application.

Each system accomplished the reduction in entrapped air in a different manner. Self-sealing 1/16 inch diameter vent holes placed at 1 1/2 inch intervals in the Royston No. 10-PV membrane were effective in providing a means for air and vapor pressures to escape from beneath the system resulting in the elimination of nearly all entrapped air. Royston No. 15 was effective due to the excellent adhesion developed between the membrane and substrate. The vent holes which had been punched in the No. 15 membrane were of little value

CONCLUSION (con't.)

since nearly all were plugged prior to the installation of the material. The installation of the Tri-Ply membrane system was considered satisfactory although a more definite means of obtaining adhesion between membrane and substrate would be desired on any future application.

Four of five control decks treated with the standard Royston Membrane were free of significant concentrations of entrapped air and remained free of blisters or cracks during the pavement applications. Concentrations of air entrapped beneath one of two systems which had been compacted with a pickup truck resulted in two blisters remaining visible in the pavement until just prior to final compaction. All three types of Royston Membrane will be inspected periodically for any sign of post-construction blistering.

PRODUCT EVALUATION SUMMARY

Field Observations	Royston Bridge Membrane No. 15	Royston Bridge Membrane No. 10-PV	TRI-PLY
Surface Preparation Required	Wash & Sweep	Wash & Sweep	Wash & Sweep
Moisture Sensitive	Yes	Yes	Yes
Ease of Application	Easy	Easy	Easy
Bond & Seal at Curb	Good	Good	Good
Bubbles and/or pin-holes in Membrane	No	No	No.
Electrical Resistance prior to Pavement in ohms/s.f.	76% of tests @ Infinity	90% of tests @ Infinity	Infinity
Bond Between Pave-ment & Membrane	Fair to Good	Fair to Good	Fair to Good
Pavement Subject to Blistering and/or Cracking	Slight/No	No	No
Post Construction Problems with Pave-ment & Membrane	No	No	No
Cost per s.y. not Including Pavement	$4.00	$4.00	Manufacturer absorbed excess over $4.00
Lab Observations			
Flexibility @ 0°F	Failed	Partial Depth Cracks	Partial Depth Cracks
Moisture Absorption	Satisfactory	Satisfactory	Satisfactory
Recommendations			
Recommended for Further Use	Yes-limited	Yes-limited	Yes-limited
Await Follow-up Evaluations			

SUMMARY OF MEMBRANE SYSTEMS APPLIED IN 1974
(See Report 75-2)

Field Observations	Royston Bridge Membrane #10	Heavy Duty Bituthene	Duralseal 3100	Protecto Wrap M-400	NEA 4000	Hyload 125
Surface Preparation Required	Wash & sweep	Wash & sweep	Sandblast or Acid Etch	Wash & sweep	Wash & sweep	Wash & sweep
Moisture Sensitive	Yes	Yes	Yes	Yes	Yes	Yes
Ease of Application	Easy	Average	Average	Easy	Easy	Difficult
Bond & Seal at Curb	Fair	Fair	Excellent	Fair	Good	Fair
Bubbles and/or pin-holes in Membrane	No	Yes/No	Yes	No	Yes/No	No
Electrical Resistance prior to Pavement in ohms/s.f.	Infinity	Infinity	1,450,000	Infinity	Infinity	Infinity
Bond Between Pave-ment & Membrane	Fair to Good	Fair to Good	Poor	Good	Good	Fair
Pavement Subject to Blistering and/or Cracking	No/Slight	No/Yes	No	Slight/No	No/Yes	Yes
Post Construction Problems with Pave-ment & Membrane	Cracks in 1st course of pavement	Shoving in 1st course under traf.	No	No	Shoving in 1st course under traf.	Blisters in Memb. & Pavement
Cost per s.y. not Including Pavement	$ 4.25	$ 4.50	$ 7.25	$ 4.25	$ 4.00	$ 8.00
Lab Observations						
Flexibility @ 0°F	Passed	Passed	Passed	Failed	Passed	Passed
Moisture Absorption	No Test	No Test	1.6%	No Test	No Test	No Test
Elongation Over Cracks @ 0°F	Passed	Passed	Passed	Passed	Passed	Passed
Recommendations						
Recommended for Further Use	Yes	Yes	No	Yes	Yes	No
Await Follow-up Evaluations						

SUMMARY OF MEMBRANE SYSTEMS APPLIED IN 1974
(See Report 75-2)

Field Observations	Sure-Seal Butyl Membrane	Sure-Seal EPDM Membrane	Gacoflex N-3S Membrane	Butylfelt	Chevron's Bridge Deck Membrane	
Surface Preparation Required	Wash & sweep	Wash & sweep	Sandblast or Acid Etch	Wash & sweep	Wash & sweep	
Moisture Sensitive	Yes	Yes	Yes	Yes	Yes	
Ease of Application	Difficult	Difficult	Very Difficult	Difficult	Average	
Bond & Seal at Curb	Fair	Fair	Excellent	Fair	Excellent	
Bubbles and/or pin-holes in Membrane	No	No	No	No	Yes	
Electrical Resistance prior to Pavement in ohms/s.f.	14,000	109,000	5,000,000	1,000,000	Infinity	
Bond Between Pave-ment & Membrane	Good	Good	Good	Good	Fair	
Pavement Subject to Blistering and/or Cracking	Slight	Yes	Slight	Yes	No	
Post Construction Problems with Pave-ment & Membrane	Few cracks in 1st course of pavement	Cracks & blisters in 1st course	Cracks in Pavement	Cracks & blisters in 1st course	No	
Cost per s.y. not Including Pavement	$ 9.75	$ 9.75	$ 17.00	$ 8.75	$ 6.88	
Lab Observations						
Flexibility @ 0°F	Passed	Passed	Passed	Passed	Passed	
Moisture Absorption	No Test	No Test	No Test	No Test	1.5%	
Elongation Over Cracks @ 0°F	Passed	Passed	Passed	Passed	Passed	
Recommendations						
Recommended for Further Use		No	No	No	Yes	
Await Follow-up Evaluations	X					

SUMMARY OF MEMBRANE SYSTEMS APPLIED IN 1973

(See Report 74-4)

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 Compund)	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	