

EXPERIMENTAL BRIDGE DECK MEMBRANE

APPLICATIONS IN VERMONT

REPORT 76-1

MAY 1976

National Experimental & Evaluation Program  
Bridge Deck Protective Systems  
Work Plans #21 - #23  
Initial Report

Bennington RF 012 - 1 (2)

VERMONT DEPARTMENT OF HIGHWAYS

A. Ristau, Acting Commissioner

E. H. Stickney, Chief Engineer

R. F. Nicholson, Materials Engineer

This report was prepared  
by

J. A. Sumner  
Technician B

This report was developed for the use and benefit of the Vermont Department of Highways. Anyone, other than the Department, using this report does so with awareness that the Department does not guarantee the opinions, findings or conclusions contained therein.

## TABLE OF CONTENTS

	Page
Abstract-----	1
Introduction-----	2
Work Plan #21 Protecto Wrap M-400-----	3
Work Plan #22 Royston Bridge Membrane #10-----	8
Work Plan #23 Nordel Membrane-----	11
Work Plans #21-23 Heavy Duty Bituthene-----	14
Summary of Findings and Recommendations-----	19
Conclusions-----	21
Product Evaluation Summary-----	24
Chloride Concentrations Recorded in Bridge Decks Protected with experimental Membrane Systems-----	25
References-----	26

### ABSTRACT

This report covers the application of four membrane systems on six new bridge decks in 1974. 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. Summaries of findings on each membrane system are concluded with recommendations on further use. The report includes a summary of field results on membrane systems applied in the years 1971 through 1973, by showing chloride concentrations detected in the decks after two to four winters of deicing chemical applications.

Vermont currently specifies the use of the three standard preformed sheet membrane systems, namely Heavy Duty Bituthene; Royston #10; and Protecto Wrap M-400, on non-experimental bridges. With the possible exception of Bituthene, experiences obtained with the membrane systems discussed in this report and the latest results of continuous follow-up testing, do not indicate that any major shift should be made away from the standard preformed sheet systems.

## INTRODUCTION

Applications of experimental bridge deck membrane systems have been carried out by the Vermont Department of Highways since 1971. The applications made during the 1971-1973 construction seasons included the use of twenty systems. Materials included two polyurethane and two cold-applied built-up systems; three preformed sheet products; four hot-applied materials; and nine epoxy systems. All applications were closely monitored and recorded in the following reports:

"National Experimental & Evaluation Program - Bridge Deck Protective Systems"  
Initial Reports 72-10 & 73-1

"Experimental Bridge Deck Membrane Applications in Vermont"  
Report 74-4 & 75-2

Field evaluations of the membrane systems have included an annual series of tests after exposure to two years of traffic and 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 systems, based on test results and service life to date, are briefly discussed in the conclusion of this report and outlined on page 25.

The basic information in this report covers the application of four membrane systems on six new bridge decks in 1974. Surveillance of all bridge decks will continue until valid conclusions can be obtained as to the effectiveness of each protective system.

PROTECTO WRAP M-400

DESCRIPTION

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

LABORATORY TEST RESULTS

The membrane was not damaged by puncture or heat when subjected to the application of 275°F to 300°F bituminous mixes applied at a load of 200 pounds per square inch. The membrane displayed sufficient flexibility to resist cracking when bent around a 5-inch diameter mandril at -10°F; however, cracks occurred in the material when it was bent around mandrils of a smaller diameter. The membrane bridged cracks in cement mortar slabs when broken over a 3/16-inch anvil on 75 percent of the samples tested at 0°F.

RECOMMENDED APPLICATION PROCEDURE

1. Apply Protecto Wrap Number 80 primer by roller, brush or squeegee at a rate not exceeding 150 square feet per gallon. Allow the primer to dry to a tack free condition prior to applying the membrane. Reprime areas not covered within 24 hours.
2. Place the membrane wrinkle free with a minimum of 3-inch overlaps in a manner that will provide a shingling effect toward the low side of the deck. Apply a bead of mastic along the upper outside edge of the membrane along the curb to form a seal.
3. Remove the polyethylene release film from the surface of the membrane prior to placing the bituminous overlay. The temperature of the bituminous mix should not exceed 280°F at the time of application.

WORK LOCATION #1

Vt. Rte 9 westbound bridge over Vt. Rte 67-A at station 294+52.31 - 296+34.33 in Bennington, Vermont.

# DECK CONDITION AND PREPARATION PRIOR TO MEMBRANE APPLICATION

Surface Texture - Very smooth

Cracks - None visible

Laitance - None

Preparation - Deck was swept and blown clean prior to application. Crew scraped any protrusions from deck.

## OBSERVATIONS MADE DURING MEMBRANE APPLICATION

<u>Time</u>	<u>Air Temp.</u>	<u>% Humid.</u>	
7-15-74			
12:30	85°	50	Crew cleaning and preparing deck.
2:02	89°	48	Applying primer to half of deck length wise. Applying primer with paint brush to epoxy mortar.
2:45			Completed Priming. Approximately 150 s.f./gal.
3:00			Letting primer dry, went to Bennington to get supplies.
3:45	65°	58	Skies threatening, crew waiting to see if it will rain.
4:00		100	Raining
5:00			Ended work day.
7-16-74			
6:00	55°	74	Started placing one foot wide strip along northerly curb. Lapping approximately 1 1/2"-2" up.
7:00	60°	75	Place 2 1/2" wide rolls along northerly curb. Good overlap and no wrinkles.
7:55	60°	76	Completed length of deck.
8:00	60°	76	Moved truck on bridge, loading up with rolls.
8:05	60°	70	Started placing 5' wide rolls. Truck method seems to eliminate wrinkles. Using broom to work out any wrinkles in sheet.
8:30	65°	68	First length of 5' rolls complete
8:45			Truck tracked dirt on primer, blowing off with portable blower.
9:00	65°	64	3 Rows complete, no wrinkles and good overlap.
9:35	70°	58	Truck pulled up piece of membrane, pulled apart, where release paper had been stripped away. Contractor will patch.
10:00	75°	55	1/2 deck complete.
10:00	75°	55	Started Priming other half of deck.
10:25	80°	50	Completed Priming approximately 125-150 sf/gal.
11:20	80°	45	Started placing 1' wide strip at curb, getting good lap, complete one ft. strip.
11:30	80°	45	Started 2 1/2' wide roll length of deck.
12:00	80°	45	Completed 2 1/2' wide rolls.
12:05	80°	45	Started applying 5' wide rolls with truck.
1:15	85°	45	All rows completed but capping roll in center of the bridge.

<u>Time</u>	<u>Air Temp.</u>	<u>% Humid.</u>	
7-16-74			
2:00	90 <sup>0</sup>	47	Bridge is complete as far as sheet membrane is concerned.
2:05	89 <sup>0</sup>	47	Running over seams with truck to seal down.
4:15			Contractor removed release paper the night before in an attempt to avoid the picking and pulling of the membrane with the paver
5:00			Applying Mastic to curbs using stiff brush.
6:00	62 <sup>0</sup>	55	Completed application

#### COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment - 854 s.y. at \$5.00/s.y. = \$4270.00

Bituminous Concrete - 95 tons at \$14.80/ton = \$1406.00

#### DISCUSSION

The membrane was supplied in widths of 1, 2 1/2, and 5 feet. The 1 foot width sheet was placed at the curb, then the 2 1/2 foot width next. This greatly aided in the application at the most critical point, the curb.

After the two smaller widths of sheet membrane were completed by hand, the pickup truck was used in the application of the 5 foot wide rolls. This was done by stacking a supply of rolls in the back of the truck and using a steel bar to suspend the roll being applied. The truck was then driven into place and the roll was stretched out using the power of the truck. This adequately stretched the roll and aided it in going down completely wrinkle free.

The contractor elected to remove the protection paper the night before the paving in an attempt to reduce the tacky and sticky texture on the sheet. The next morning, the membrane was still very tacky. A dusting of cement was broadcast across the membrane to reduce the tacky texture. The paving temperature ranged from 240<sup>0</sup>F to 260<sup>0</sup>F. The 1 1/2 inch course of bituminous pavement went down without any problem.

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



## WORK LOCATION #2

Vermont Route 9 eastbound bridge over Vermont Route 67-A at station  
294+89.09 - 261+71.09, *Bennington, Vermont.*

### DECK CONDITION AND PREPARATION PRIOR TO MEMBRANE APPLICATION

Surface Texture - Rougher than WB bridge, pitted approximately 28% of deck.  
Slight to no laitance

Cracks - None detected

Preparation - The deck was scraped and blown clean, along with sweeping.

### OBSERVATIONS MADE DURING MEMBRANE APPLICATION

<u>Time</u>	<u>Air Temp.</u>	<u>% Humid.</u>	
7-16-74			
2:00	85°	47	Crew cleaning and preparing deck and blowing dry.
3:30	85°	47	Started priming all of deck lengthwise, using squeegee and brush.
4:30	85°	40	Completed Priming.
4:45	72°	37	Started placing 2 1/2' wide rolls at curb length of deck.
5:00	68°	47	Completed one length of 2 1/2' wide rolls.
5:05	68°	47	Went to work on WB structure.
6:15	62°	56	Started first full size roll.
6:30	61°	57	Rain (lightly) deck dried in 15 min.
8:00	58°	58	3 rows complete.
9:00	55°	60	Quit for day, 4 rows complete.
7-17-74			
7:45	65°	45	Started placing 2 1/2' wide strips
8:00	65°	45	First row complete
8:05	65°	45	Starting with full size rolls.
8:10	65°	45	Truck method stretches rolls enough so that all major wrinkles are removed when placing sheet.
8:30	69°	20	3 Rows complete with membrane, only wrinkles are that which were made in sheet.
10:00	80°	16	All rows of membrane complete except for capping row.
11:05	80°	20	Running over completed area with truck to seal joints.
11:10	80°	20	Workmanship not as polished on this bridge, feel the crew was hurrying too fast.
12:00	85°	21	Applying bead of mastic to curbs.
12:45	85°	21	Complete sealing of curbs.

### COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment -	972 s.y.	at \$5.00/s.y.	=	\$4860.00
Bituminous Concrete -	108 tons	at \$14.80/ton	=	\$1598.40

## DISCUSSION

The membrane was supplied in a variety of widths which greatly aided in the ease of application at the curb.

The pickup truck was again used as an application aid. The truck was also driven back and forth across the deck sealing all edges and aiding overall bond to the deck.

During the bituminous paving procedure, dusting of cement was used to help the paver in movement on the deck. The bituminous mix ranged from 245°F to 255°F. No difficulties were encountered during the paving operation nor was any damage to the membrane observed.

Electrical resistance readings on the completed system were recorded as infinity.

ROYSTON BRIDGE MEMBRANE #10DESCRIPTION

A 75-mil thick preformed sheet membrane composed of an impregnated fiber-glass 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.

LABORATORY TEST RESULTS

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

RECOMMENDED APPLICATION PROCEDURE

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

Vermont Route 9, eastbound bridge over Vermont Railroad at station 309+49.24 - 311+04.10 in Bennington, Vermont

### DECK CONDITION AND PREPARATION PRIOR TO MEMBRANE APPLICATION

Surface Texture - Very Smooth

Cracks - None visible

Laitance - Slight to none

Preparation - Bridge was scraped, swept and blown clean.

### OBSERVATIONS MADE DURING MEMBRANE APPLICATION

<u>Time</u>	<u>Air Temp.</u>	<u>% Humid.</u>	
8-19-74			
3:00	75°	20	Crew started scraping and blowing deck clean. Deck very clean.
4:30	75°	20	Started priming deck, using brush at the curb: (Royston Primer)
5:00	70°	20	Primer going down at approximately 10 s.y./gal. Roybond 713
8:00	65°	35	Priming complete 100 S.F./gal
8-20-74			
7:00	70°	25	Started placing sheets at southerly curb and working toward the center. Working out wrinkles with push broom.
9:15	70°	25	Two rows complete (48" rolls)
9:30	75°	30	4 rows complete very few wrinkles, only small wrinkles that appear in preformed sheet.
10:00	77°	35	After 5th roll, crew is starting on northerly end preceding to center of the bridge, there will be one capping roll on the bridge.
10:10	79°	30	Applying Royston Roskote Mastic at southerly curb line.
10:30	75°	35	Before mastic is applied at the curb, it is heat sealed with propane torch, care being taken not to over-heat.
10:35	80°	35	2 rows complete on northerly side of deck.
11:00	80°	35	Heating and mastic application complete on southerly curb.

<u>Time</u>	<u>Air Temp.</u>	<u>% Humid.</u>
-------------	----------------------	---------------------

8-20-74

11:05	80°	40	Heating and mastic application starting on northerly curb.
11:45	85°	40	Laying of sheets complete including capping roll. Very few wrinkles.
12:00	85°	35	Heat sealing end laps, using broom to push down ends.
12:15	85°	30	Mastic application complete, curbs also.
12:45	88°	30	Heat sealing complete.
12:45	90°	20	Heat sealing sheet lengthwise.
4:00	89°	20	Heat sealing complete deck.

#### COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment -	719 s y.	at \$5.00/s.y.	=	\$3595.00
Bituminous Concrete -	80 tons	at \$14.80/ton	=	\$1181.00

#### DISCUSSION

This system applied without problem, very few wrinkles as sheets were stretched sufficiently.

Before the mastic was applied at the curb, the sheets were heat sealed with a propane torch with care being taken not to overheat. All end laps were heat sealed and pushed down with a broom.

An inspection shortly after application revealed the sheets not to be sufficiently bonded at the curb at various locations. These areas were reheated to insure bond.

The Royston mastic was found not to be sealing the top edge of the sheets. Cracks were visible on the surface of the mastic coating.

The bituminous mix ranged from 320°F to 355°F and was placed at an average depth of 1 1/2 inches. No cracks appeared during the paving operation.

Electrical resistance readings on the completed system were all recorded as infinity.

NORDEL MEMBRANE

DESCRIPTION

A permanent non cured hydrocarbon rubber reinforced with Typar in form of sheets. The membrane is manufactured by the Carlisle Tire and Rubber Division, Carlisle Corporation, Carlisle, P.A., 17013.

LABORATORY TEST RESULTS

The Nordel membrane bridged cracks in cement mortar slabs when broken over a 3/16-inch rod at 0°F. The membrane was successfully bent over a 1-inch mandril at 0°F. Nordel showed a slight failure when bituminous concrete was applied at 250 psi at 300°F, this was evident by leakage.

RECOMMENDED APPLICATION PROCEDURE

1. Concrete surfaces should be dry and free from dust, dirt, grease or other contaminants.
2. Apply #9600 bonding adhesive to deck by roller, brush or squeegee at a rate of approximately 160 square feet per gallon.
3. Do not rush recommended drying time as entrapped solvents may cause blistering.
4. Sheets of membrane shall be unrolled onto the adhesive, discarding the release paper. As each sheet is laid, and before joints are sealed, air shall be expelled from under the sheet. Joints between sheets shall be lapped 2", and shall be sealed by application of adhesive to both mating surfaces.
5. Patched areas if required, shall be of the same membrane material; they shall be 2" larger than the damaged area and shall be sealed by brushing adhesive on both mating surfaces.

WORK LOCATION

Vermont Route 9 westbound over Vermont Railroad at station 309+09.24 - 310+64.10 in Bennington, Vermont.

DECK CONDITION AND PREPARATION PRIOR TO MEMBRANE APPLICATION

Surface Texture - Very Smooth

Cracks - None visible

## DECK CONDITION AND PREPARATION PRIOR TO MEMBRANE APPLICATION (Con't)

Laitance - Slight laitance on easterly half but limited.

Preparation - Deck was scraped and blown clean.

## OBSERVATIONS MADE DURING MEMBRANE APPLICATION

<u>Time</u>	<u>Air Temp.</u>	<u>% Humid.</u>	
9-11-74			
7:50	62°	64	Started primer application, using squeegees. Primer (bonding adhesive #9600 Gure Seal), using paint brush at the curb.
8:10	62°	64	Priming of 1/2 deck complete.
9:00	68°	60	Laying out chalk lines for sheet application.
9:15	68°	63	Laying sheets at southerly curb using chalk line for guide. Cutting sheets 20 feet to 30 feet in length for easier application at curb.
9:30	68°	65	Sheets are going down wrinkle free.
9:35	68°	65	Southerly curb complete.
10:00	70°	56	Laying full size sheets on southerly curb.
10:05	70°	57	Placed Copperfoil strips west end of bridge.
10:45	72°	52	Continue laying full length sheets working out wrinkles with push broom.
11:00	72°	52	Wrinkles appearing on deck from outgassing of concrete.
11:20	74°	48	Air bubbles becoming more evident as deck warms up.
11:45	75°	45	Starting fifth row, last row before capping row.
12:10	78°	40	Priming north 1/2 of deck, using squeegee and paint brush.
12:45	80°	38	Priming complete. Total used 35 gals on 719 s.y. 135 s.f./gal.
3:00	84°	30	Started laying sheets at northerly curb. Using chalkline and cutting sheets at lengths of 20 to 30' for easier applications.
3:30	84°	30	Going with full length sheets.
4:30	82°	25	3 rows complete, very few wrinkles.
5:00	81°	33	5 rows complete
5:10	80°	32	Laying out capping row
5:30	80°	32	Weep holes being cut out.
7:00	70°	32	Applying tar emulsion on approach slabs.

## COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment -	719 s.y.	at \$5.00/s.y.	=	\$3595.00
Bituminous Concrete -	80 tons	at \$14.80/ton	=	\$1181.00

## DISCUSSION

The primer was applied at a rate of 185 square feet per gallon. The representative recommended as light an application as possible. The primer was applied with paint brush at the curb and squeegee on the deck surface.

#### DISCUSSION (Con't)

Sheets were supplied in rolls 40 inches by 100 feet. They were applied in lengths of 20 to 30 feet at the curb for greater ease of application. A chalk line was also used to insure the proper 2 inch lap up the curb. The full size sheets went down wrinkle free with considerable ease. As the ambient temperature went up, many wrinkles appeared from the outgassing concrete.

The bituminous mix ranged from 300°F to 310°F. Blisters appeared during paving application and were punctured with a knife. The removal of compacted pavement from two areas disclosed complete lack of bond between pavement, membrane and no adhesion to the primed deck substrate.



HEAVY DUTY BITUTHENE

DESCRIPTION

A 65-mil thick preformed sheet membrane system composed of a woven polypropylene mesh coated on one side with a layer of rubberized asphalt. The material is manufactured by W. R. Grace & Company.

LABORATORY TEST RESULTS

The membrane was not damaged by puncture of heat when subjected to the application of 275°F to 300°F bituminous mixes applied at a load of 200 pounds per square inch. The material did not crack when bent around a 1-inch mandril at -10°F and satisfactorily bridged cracks in cement mortar slabs when broken over a 3/16-inch rod at 0°F.

RECOMMENDED APPLICATION PROCEDURE

1. Apply Bituthene primer by brush or roller at the rate of 200 to 400 square feet per gallon and allow the primer to dry tack free before applying the membrane.
2. Place 8 to 9-inch wide strips of the membrane along the base of the curb so that the material extends up the curb face to the height of the proposed bituminous overlay. On rough faces, place a bead of Bituthene Mastic on the vertical face before flashing strips are applied.
3. 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 2-1/2 inches.
4. All termination points at curbs, expansion joints or end of the deck should be sealed with a bead of Bituthene Mastic, applied after the membrane has been placed.
5. Repair any torn or cut areas by overlapping a minimum of 6 inches with a patch of the membrane.

## RECOMMENDED APPLICATION PROCEDURE (Con't)

6. The bituminous pavement should be between 275°F and 325°F at the time of application.

### WORK LOCATION #1

Vermont Route 9 eastbound bridge over existing U.S. Route 7 at station 311+87.99 - 313+76.93 in Bennington, Vermont.

### DECK CONDITION AND PREPARATION PRIOR TO MEMBRANE APPLICATION

Surface Texture - Very Smooth

Cracks - None visible

Laitance - Slight to none

Preparation - Deck was scraped and blown off three times.

### OBSERVATIONS MADE DURING MEMBRANE APPLICATION

<u>Time</u>	<u>Air Temp.</u>	<u>% Humid.</u>	
8-20-74			
1:00	90°	20	Deck scraped of any protrusions and blown clean for third time.
2:20	92°	20	Started applying bituthene primer using brush at curb.
3:00	92°	20	Started applying primer with squeegee.
4:00	92°	20	Priming complete, will allow to dry, 259 s.f./gal.
6:00	85°	20	Chalking deck with lines to insure exact placement of sheets. Chalkline excellent placement procedure.
6:15	80°	20	Started placement of first curb row. (southerly)
7:05	75°	20	First row complete no wrinkles, good lap at the curb.
7:10	70°	25	Starting 2nd row, by lining up sheet to chalkline approximately 20' roll out membrane on deck surface without picking up roll. One man checking line, one pulling release paper, sheet goes down wrinkle free and flawless.
7:40	68°	26	2nd row complete.
7:45	66°	27	Starting northerly curb, using chalkline. Curb row is only row you have to lift the sheet using bar.
9:00	60°	30	Curb row complete, quit for the day.
8-21-74			
<u>Sunny and Foggy</u>			
6:00	60°	60	Started laying sheets using chalkline as an aid.
7:00	62°	60	By doing work in early morning at cooler temps. sheets go down without wrinkle problems.

<u>Time</u>	<u>Air Temp.</u>	<u>% Humid.</u>	
8-21-74			
8:00	64 <sup>o</sup>	58	At cooler air temp. release paper comes off better. 6 rows complete, will move to northerly half and work toward capping row.
9:20	74 <sup>o</sup>	44	Release paper causing problems
10:10	80 <sup>o</sup>	45	9 Rows placed so far.
10:30	85 <sup>o</sup>	45	Jim Arrigo, Grace Chemical arrived on project.
10:45	84 <sup>o</sup>	45	Problems with release papers becoming more evident.
12:00			Crew breaking for lunch.
1:00	88 <sup>o</sup>	45	Crew continuing placing sheets.
2:00	90 <sup>o</sup>	20	Some outgasing from concrete causing bubbles under membrane.
2:45	90 <sup>o</sup>	25	Laying of full length sheets complete.
4:00	88 <sup>o</sup>	20	Sheets complete.
4:15	86 <sup>o</sup>	20	Cutting out weep holes.
4:30	80 <sup>o</sup>	20	Start tar emulsion application.
5:00	75 <sup>o</sup>	20	Start Mastic application.
5:45	75 <sup>o</sup>	20	Completed mastic application. Deck complete.

#### COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment -	893 s.y.	at \$ 5.00/s.y.	=	\$4465.00
Bituminous Concrete -	99 tons	at \$14.80/ton	=	\$1465.20

#### DISCUSSION

Many problems were encountered with the release paper during the membrane application. As sheets were placed and release paper pulled away, a thin film of paper remained with the sheet. The removal of this paper, and watching for the presence of it, greatly hindered the application. As usual, on a normal crown deck, the curbs were completed first to insure proper moisture flow. After a heavy rain, approximately 77 linear feet of sheet at the curb was found to be not bonded to the deck and contained water under the entire length. After careful inspection of the sheets, it was found that a plastic coating was present. In some cases, the film could not be seen but it could be felt. The total area of the deck that had to be repaired was 28 square yards.

The crew found that by keeping the rolls cool and applying sheets either early in the morning or later in the day, the problem with the release paper could be reduced slightly.

## DISCUSSION (Con't)

The bituminous mix temperatures ranged from 245°F to 300°F and the pavement went down at an average depth of 1 1/2 inches. During the paving, many cracks developed because of the shrinkage of the sheets. These cracks appeared on nearly all ends and edges of the sheets. Cracks ranged from hairline to as much as 2 1/2 inches. These cracks were filled just prior to rolling. The cracks greatly hindered the effectiveness of the bituminous mix in its part of the membrane system.

## WORK LOCATION #2

Vermont Route 9 westbound bridge over Vermont Railroad at station 309+09.24 - 310+64.10 in Bennington, Vermont

## DECK CONDITION AND PREPARATION PRIOR TO MEMBRANE APPLICATION

Surface Texture - Very Smooth

Cracks - None visible

Laitance - None

Preparation - Blown and scraped clean twice.

## OBSERVATIONS MADE DURING MEMBRANE APPLICATION

<u>Time</u>	<u>Air Temp.</u>	<u>% Humid.</u>	
9-9-74			
10:00	70°	40	Blowing and scraping deck clean.
12:15	75°	42	Priming deck using squeegee.
12:55	75°	42	1/2 of deck completed with primer.
1:00	75°	42	Marking out weep holes.
1:30	75°	42	Priming complete 229 s.f./gal.
1:35	80°	40	Placing sheet on southerly curb insuring a sufficient lap on the curb.
1:50	80°	40	Having problem with the release paper.
2:10	78°	40	Problems increasing with sheet release paper.
2:30	78°	40	First row complete, many release paper problems.
2:35	78°	39	Started second row.
4:00	77°	35	Started third row, good overlap and wrinkle free. have one man checking release paper at all times.
4:15	76°	35	Third row complete, crew working very well.
5:30	75°	27	4 rows complete.
8:00	72°	32	7 rows complete, quit for the day.

<u>Time</u>	<u>Air Temp.</u>	<u>% Humid.</u>	
9-10-74			
7:00	60°	56	Placing sheet at northerly curb, crew obtaining high lap at curb, still having some problems with release paper using broom to push into curb.
9:00	70°	54	2 rows complete - placed copperfoil strips, one on each side on westerly end of bridge.
10:05	74°	48	4 1/2 rows complete, workmanship excellent, good overlap, few wrinkles.
10:45	72°	52	5 1/2 rows complete
11:30	78°	45	All rows complete (full rows). Starting capping rows.
12:30	74°	44	Capping row Complete, excellent workmanship. Doing 3 ft. overlaps and applying mastic to the curbs.
1:05	80°	45	Cutting out weep holes.
2:35	80°	45	Working on mastic and patch work on EB structure.
5:30	79°	45	Mastic application complete and all three foot overlaps started.
6:00	75°	40	Started tar emulsion application.
7:00	70°	40	Project complete.

#### COST OF PROTECTIVE MEMBRANE AND BITUMINOUS CONCRETE WEARING SURFACE

Membrane Treatment -	893 s.y.	at \$ 5.00/sy.	= \$4465.00
Bituminous Concrete -	99 tons	at \$14.80/ton	= \$1465.20

#### DISCUSSION

Many problems were again encountered with the plastic film of the release paper.

Bituminous mix temperatures ranged from 255°F to 300°F. The pavement was placed at the approximate depth of 1 1/2 inches. Longitudinal and transverse cracks appeared in pavement over membrane sheets edges and ends. The cracks appeared in 30 seconds to 2 minutes. Larger cracks had to be refilled with bituminous mix before rolling. This weakens the effectiveness of the bituminous mix as a part of the membrane system.

Electrical resistance readings taken on the completed system were recorded as infinity.

## PROTECTO WRAP M-400

### Summary of Findings

The system requires that the concrete be dry but no extensive preparation is required. From the application viewpoint, this system is the easiest system to apply. The use of the pickup truck during application greatly adds to the ease of application. The use of the pickup truck allows the sheet to be more adequately stretched and placement becomes wrinkle free. The variety of membrane widths supplied by the manufacturer was an advantage during application, especially at the curb. After the protection paper is pulled off, the membrane is very tacky. Problems with the rubber tired paver developed as the membrane was pulled apart or from the deck completely. This condition was alleviated by broadcasting a dusting of portland cement across the deck. Electrical resistance on the membrane and completed pavement indicated the combined system was waterproof.

### Recommendation

Protecto Wrap M-400 is recommended for further use.

## ROYSTON #10 MEMBRANE

### Summary of Findings

The system requires no extensive preparation. The system is relatively easy to apply and it went down wrinkle free.

The Royston Roskote Mastic developed shrinkage cracks shortly after application and was found to be inadequate for sealing at the curb.

No problems were encountered during the paving operation. Electrical resistance readings on the membrane and completed pavement were recorded at infinity indicating that the combined system was initially impervious.

### Recommendation

The use of Royston Roskote Mastic should be discontinued, a substitute material should be used in place of the Roskote Mastic. Royston #10 membrane is recommended for further use.

## NORDEL

### Summary of Findings

Very little preparation is required for the application of Nordel other than having the deck dry and free of dirt. The membrane system is very easy to apply.

The bituminous mix was between 300°F and 310°F. Blisters appeared during paving application and a check revealed no bond between bituminous pavement, membrane and deck.

Electrical resistance readings were initially recorded as infinity.

### Recommendation

Further use of this membrane should be discontinued until an adequate bond can be shown between pavement, membrane and deck.

## HEAVY DUTY BITUTHENE

### Summary of Findings

Heavy Duty Bituthene did not require extensive surface preparation. The material displayed excellent bond and self-sealing characteristics. Many problems were encountered with the release paper during application. This was a problem in the manufacturing of the release paper. Regardless of the source, it resulted in the repairing of approximately 28 square yards of curb area. Many cracks occurred in the first course of pavement. These cracks were reflections of edges and ends of membrane sheets. These cracks were filled prior to rolling. Cracks of this nature reduce the effectiveness of the bituminous mix in its part of the waterproofing system. Electrical resistance readings on the membrane were recorded as infinity. From the application viewpoint, this product is the most difficult to apply of the sheet membranes.

### Recommendation

Heavy Duty Bituthene is recommended for further use, but recent problems should be weighed heavily in consideration between products.



## CONCLUSIONS

As a result of experiences encountered with the application of experimental membranes in the years 1971 through 1973, a specification was written which covers the use of the three standard preformed sheet systems; Heavy Duty Bituthene, Royston #10 and Protecto Wrap M-400. The specification, which has been on most non-experimental bridges, allows the contractor the option of selecting the preformed system. The experiences gained with the membrane systems covered in this report, combined with the latest results of continuous follow-up testing, do not indicate that any major shift should be made away from the preformed sheet systems. Characteristics such as flexibility and controlled membrane thickness, plus ease of application and the resulting low in-place cost, continue to make the standard preformed sheet systems more desirable than any other membrane type.

It is recognized that the preformed membranes do have several weak points or problem areas. These include the curb line seal, the formation of blisters during the pavement application and the question of whether a protective system should be placed over the materials. Although all three systems have the potential for waterproofing the gutter line and curb face, the end result depends to a great extent on the care and expertise of the workmen making the installation. For that reason, Vermont's specification now calls for the placement of a compatible liquid polyurethane seal along the membrane perimeter and the vertical curb face when Royston or Protecto Wrap are used. Bituthene mastic will continue to be used with the Bituthene system since the polyurethanes do not develop adhesion to the membrane. Problems with the formation of blisters in both the membrane and pavement during paving have been recorded on Protecto Wrap and a number of other experimental systems. The blisters are believed due to small concentrations of moisture which collect beneath the membrane due to outgassing of moisture vapor from the concrete. Such moisture consequently turns to a vapor or gas when exposed to the high temperatures of the bituminous overlay. Recommendations have been made to reduce the temperature



of the first course of the bituminous pavement. It is believed that such action would eliminate nearly all blistering and also lessen the potential for damaging thermo-plastic materials which have a relatively low melting point, such as Heavy Duty Bituthene.

The use of a protective course over individual membrane systems is a procedure which should be considered to protect against damage during the pavement application, as well as cold flow damage and/or creep under continuous traffic loading. Observations and field test results to date indicate that Royston and Protecto Wrap do not require a protective overlay if the full depth of pavement is placed shortly after the membrane application. Chemical analysis of cores taken from a structure treated with Heavy Duty Bituthene in 1972, have disclosed the penetration of chlorides in some wheelpath areas. Such findings suggest that the system may require a protective course. If such a need is confirmed by further test results, the use of Heavy Duty Bituthene would be discontinued since there is no reliable means of adhering a protective course to the membrane.

Agencies contemplating the use of the three standard sheet membranes are advised to consider the use of a protective course over the systems if coarse aggregates in their bridge pavements exceed 3/8-inch in size; if traffic volumes in excess of 10,000 vehicles per day are anticipated; or, if ambient temperatures often exceed 90°F.

Annual evaluations are being conducted on all bridges treated with experimental membranes after they have been subjected to two winters of deicing salt applications. The evaluations have included resistivity tests, steel potential readings, moisture strip readings, and the recovery of concrete samples for the determination of chloride content. Information recorded on Table 2 page 25 lists chloride concentrations recorded on bridge decks waterproofed between 1971 and 1973. The chloride levels can be compared with base chloride levels which ranged from 18 to 46 parts per

million in the newly constructed decks. The data also includes the chlorides detected in the paved but untreated approach slabs of the same structures. When compared with the approach slabs, the results show that most of the membrane systems have provided initial protection against leakage except for areas adjacent to the curb line. Although the findings may be considered tentative due to the relatively short evaluation period, the results indicate that simple, inexpensive, and less than impervious membrane materials may be adequate for protecting properly drained crack free structures, if curb line areas are treated with an impervious membrane material. Further research is required and will continue in this area.

Although the success of a membrane system is dependent upon a number of conditions which would vary in different localities, the observations and recommendations covered in this report should be of value to other agencies contemplating similar membrane usage.

PRODUCT EVALUATION SUMMARY

Field Observations	Royston Bridge Membrane #10	Heavy Duty Bituthene	Nordel Membrane	Protecto Wrap M-400
Surface Preparation Required	Wash & sweep	Wash & sweep	Wash & Sweep	Wash & sweep
Moisture Sensitive	Yes	Yes	Yes	Yes
Ease of Application	Easy	Average	Easy	Easy
Bond & Seal at Curb	Fair	Fair	Poor	Fair
Bubbles and/or pin- holes in Membrane	No	Yes/No	Yes/No	No
Electrical Resistance prior to Pavement in ohms/s.f.	Infinity	Infinity	Infinity	Infinity
Bond Between Pave- ment & Membrane	Fair to Good	Fair to Good	Poor	Good
Pavement Subject to Blistering and/or Cracking	No/No	No/Yes	Yes/No	Slight/No
Post Construction Problems with Pave- ment & Membrane	No	Shrinkage cracks First Course	No	No
Cost per s.y. not Including Pavement	\$ 5.00	\$ 5.00	\$5.00	\$5.00
Lab Observations				
Flexibility @ 0°F	Passed	Passed	Passed	Failed
Moisture Absorption	No Test	No Test	No Test	No Test
Elongation Over Cracks @ 0°F	Passed	Passed	Passed	Passed
Recommendations				
Recommended for Further Use	Yes	Yes	No	Yes
Await Follow-up Evaluations				

## CHLORIDE CONCENTRATIONS RECORDED IN

## BRIDGE DECKS PROTECTED WITH EXPERIMENTAL MEMBRANE SYSTEMS

BRIDGE NUMBER & PRODUCT	DATE APPLIED	WINTERS SALTED	CHLORIDE CONTENT IN PARTS PER MILLION OFFSET FROM CURB & SAMPLE DEPTH					
			1 Foot		5 or 10 Feet		15 Feet	
			0-1"	1-2"	0-1"	1-2"	0-1"	1-2"
1 Tar Emulsion	7-20-71	4	138	67	37	35	43	44
2 Uniroyal	8-18-71	4	52	56	82	50	63	51
3 Tar Emulsion	7-20-71	4	164	136	36	33	35	34
4 Uniroyal	8-18-71	4	60	51	35	32	46	37
6 Tar Emulsion & G.F.	7-14-72	3	86	67	42	35	46	35
7 Bonlastic	7-31-72	3	63	52	46	45	45	52
8 Tar Emulsion & G.F.	7-27-72	3	48	35	118	66	61	45
9 Duralkote 304	7-12-72	3	296	89	101	56		
10 Duralkote 306	7-29-72	3	117	64	82	84		
11 H. D. Bituthene	8-14-72	3	53	40	44	43	157	95
12 Tar Emulsion & G.F.	5-25-72	3	56	48	52	45	46	29
14 Tar Emulsion & G.F.	7-24-72	3	183	85	38	40	45	45
15 Polytok 165	5-13-72	3	53	40	32	37	31	38
16 Duralbond 102	7-20-72	2	50	31	55	36	22	41
17 Polytok 165	8-23-72	2	29	24	36	32	30	24
18 Hot Asphalt & G.F.	5-16-73	2	57	43	24	32	42	29
19 Rambond 620-S	4-20-73	2	78	58	45	39	43	29
20 Hot Asphalt & G.F.	5-23-73	2	26	31	21	27	32	33
21 Tar Emulsion & G.F.	5-7-73	2	42	44	37	43	41	45
22 Polyastics	5-7-73	2	127	69	38	34	55	39
23 Duralkote	4-21-73	2	30	29	40	35	39	32
24 Royston #10	5-2-73	2	37	39	40	46		
25 Protecto Wrap	4-16-73	2	32	46	44	21		
Approach Slabs (9)	No	3			88	58		
Approach Slabs (9)	Treatment	2			60	32		

Shading indicates areas with chloride concentrations over base levels of 18 to 46 PPM.  
Divide PPM by 250 to obtain chloride concentrations in lbs./c.y. of concrete.

#### REFERENCES

1. Frascoia , R. I. Experimental Bridge Deck Membrane Applications in Vermont, Report 75-2.

CONSTRUCTION AND MAINTENANCE DIVISION  
Experimental Construction and Applications Branch

ABBREVIATED INSTRUCTIONS FOR EXPERIMENTAL PROJECTS  
KEY WORD SELECTION - FORM 1461  
August 1978

MAJOR CATEGORIES

- |                         |                  |                      |
|-------------------------|------------------|----------------------|
| 1. BASESUBBASES         | 7. DRAINAGE      | 13. PAVEMENTASPHALT  |
| 2. BRIDGEDECKS          | 8. EARTHWORK     | 14. PAVEMENTCONCRETE |
| 3. BRIDGESUBSTRUCTURES  | 9. ENERGY        | 15. SAFETY           |
| 4. BRIDGESUPERSTRUCTURE | 10. ENVIRONMENT  | 16. SHOULDERS        |
| 5. CHANNELS             | *11. MATERIALS   | 17. SUBGRADE         |
| *6. CONSTRUCTION        | *12. MAINTENANCE | 18. TRAFFIC          |
|                         |                  | 19. TUNNELS          |

\*These categories are to be selected only when other categories cannot be utilized.

PROCEDURE

1. Assume that all experimental features fit into one of the 19 major categories above and that there is no need for cross referencing.
2. From the August 1978 key word list pick a major category word and enter it on card 05 (columns 12-31). These categories are numbered and underlined for emphasis in the list. Do not carry the number or underline to card 05. Then pick the best subword under the selected major category and enter it on card 05 (columns 32-51). A third and fourth selection is to be made in the same way if they are appropriate and available on the list. Enter the third word on card 05 (columns 52-79) and the fourth word on card 06 (columns 12-31).
3. All words from the list are to be entered exactly as shown and in the outline sequence of the list. This means no added hyphens or spaces and that spelling license is to be copied exactly except for use of capital letters which are for emphasis only in the list. ALL ENTRIES ARE TO BE IN CAPITAL LETTERS FOR CLARITY.
4. Before any new word is considered every effort is to be made to use only words from the key word list and to enter them in the outline sequence of the list as described above. New words may be additional descriptive words or proprietary names. Do not use overly general words, synonyms, abbreviations, or variations of words already used. There is no requirement that cards 05 and 06 are to be entirely full if two short words from the key word list are adequate.

5. Each new word (non-list) is to be heavily circled on the original Form 1461 to aid Headquarters in identification and evaluation. The intention is to completely utilize the August 1978 list, but new words will be carefully evaluated for incorporation in the list.

#### EXAMPLES

1. Brand XX fiber mats for erosion control of slopes.
  - a. From the key word list there are four words available.  
 EARTHWORK / SLOPES / ErosionControl / mats
  - b. Brand XX could be added plus one other to complete the six blanks.
  - c. Do NOT add synonyms or similar words such as:  
 excavation for EARTHWORK  
 backslopes for SLOPES
  - d. Do NOT add variations or parts such as:  
 Brand Double X for Brand XX  
 erosion for ErosionControl
2. An escape lane for trucks on steep grades.
  - a. From the key word list only two key words are available.  
 SAFETY / ESCAPELANES
  - b. Four more words could be added and may be appropriate. However, this subject is quite specific and additional words do not appear necessary for identification. In the future more sophistication in the subject may warrant more words.
3. Note that only one word in the list is intentionally misspelled in order to fit card 05 (columns 32-51).  
 It is "SUBSURFACEEXPLORATION."

#### NOTE:

Use of capital letters for key words above is parallel to the key word list for clarity in the examples. ALL LETTERS OF KEY WORDS ARE TO BE CAPITALS AS NOTED IN THE INSTRUCTIONS.

CONSTRUCTION AND MAINTENANCE DIVISION  
EXPERIMENTAL CONSTRUCTION AND APPLICATIONS BRANCH

KEY WORDS FOR EXPERIMENTAL PROJECTS  
August 1978

1. BASES  
SUBBASES

AGGREGATE

BITUMINOUS

Emulsion

Cutback

MEMBRANE ENCAPSULATED

PORTLAND CEMENT

SHELLS

TREATED

Asphalt

Cement

Chemical

Emulsion

Lime

Salts

WASTES

Chemical

Fly Ash

Glass

Incinerator

Mine

Rubber

Sawdust

Slag

2. BRIDGE DECKS

CONSTRUCTION

Cure

Finish

Forms

Mixing

Placing

CONCRETE

COVER

DESIGN

EVALUATION

GRIDS

HEATING

Electric

Heat pipes

Steam

JOINTS

Construction

Expansion

ORTHOTROPIC

OVERLAYS

Asphalt

Cement

Latex

Polymer

POLYMER IMPREGIATION

PRECAST

PRESTRESSED

REINFORCING

Cathodic Protection

Epoxy Coated

Galvanized

RESTORATION

WATERPROOFING

Epoxy Seals

Membranes

Wax Beads

WOOD

3. BRIDGE SUBSTRUCTURES

ABUTMENTS

APPROACHES

FOOTINGS

PIERS

PILES

Metal Sections

Metal Shells

Prestressed

Reinforced

Tests

4. BRIDGE SUPERSTRUCTURE

ALUMINUM

BEARING

Capacity

Methods

COATINGS

CONCRETE VARIATIONS

GIRDERS

LIFT SPANS

MODULAR SECTIONS

PAINTS

PARAPETS

Aluminum

Concrete

Precast

Shapes

Steel

PLASTICS

PRECAST

PRESTRESSED

TRUSSES

WOOD



5. <u>CHANNELS</u>	DITCHES Lined Paved Sodded	EXCAVATION Equipment Explosives Drilling Rock
DIKES		
GABIONS	FRENCHDRAINS	SLOPES Construction ErosionControl mats mulch sprays Presplit Serrated
RIPRAP	HEADWALLS	
PAVED	INLETS Curb Drop Grates	
SCOUR		
*6. <u>CONSTRUCTION</u>	MAINTENANCE	SUBSURFACEEXPLORATION
EQUIPMENT	MANHOLES	WALLS Cribbing Precast ReinforcedConcrete ReinforcedEarth
MANAGEMENT	SANDDRAINS	
QUALITYCONTROL RapidTests Specifications	PIPES Clay Concrete Fiberglass Inlets Joints Metal aluminum coated corrosion steel Outlets Plastic	9. <u>ENERGY</u>
WINTER		FUELS Gasohol Methanol
7. <u>DRAINAGE</u>		SAVINGS Commuting Planning Design
ARCHES Concrete Steel		SOLAR
BLANKETS Bituminous Filter	8. <u>EARTHWORK</u>	10. <u>ENVIRONMENT</u>
BOXES ReinforcedCIP Precast Prestressed	AERIALSURVEY	AIR Construction Dust Operations
CONSTRUCTION InducedTrench Jacking Placement	CLEARING	LANDSCAPING ArtificialCover Plants establishment maintenance RestAreas facilities maintenance sewage water Screening
CURBS Asphalt Concrete Granite Polymer Shapes	EMBANKMENT Controls Material highmoisture shale shells swampbase Tests	

NOISE Construction Highway barriers buildings vehicles	CEMENTS Colored Cutback Emulsion Synthetic Tars**	AGGREGATES Gradation Manufactured Natural Waste
SPILLS  WATER .. Fish Silt	CONSTRUCTION Compaction Placement Plants Sampling Testing	CEMENTS Expansive Pozzolan
*11. <u>MAINTENANCE</u>  BRIDGE  PAVEMENT  ROADSIDE	DESIGN  OVERLAYS. Design ReflectiveCracks asphalt concrete Reinforcement	CONSTRUCTION Curing Joints Finishing Placement Plants Pumping Sampling Testing
*12. <u>MATERIALS</u>  CONCRETE  SAMPLING  SOILS  TESTING	PERFORMANCE Roughness Serviceability	DESIGN Composite Continuous Plain Prestressed Reinforced
13. <u>PAVEMENTASPHALT</u>  ADMIXTURES Antistrip Asbestos Color Chemicals Fillers Rubber Silicone Slag Sulfur	RECYCLING Cold Hot Surface Testing  TREATMENTS Milling OpengradedOGFC Prime Rejuvenators Seals chip slurry	JOINTS Contraction Dowels Drainage Expansion Inserted LoadTransfer Longitudinal Pressure Spacing Terminal
AGGREGATES Gradation Manufactured Natural Waste	14. <u>PAVEMENTCONCRETE</u>  ADMIXTURES Accelerators Air Color Coolants Latex Polymer Pozzolan Retardant WaterReducer	OVERLAYS Continuous Plain Prestressed Reinforced Thin

PERFORMANCE	GUARDRAILS	RUMBLESTRIPS
Composite	Coatings	TREATMENTS
Continuous	Design	
DCracking	Ends	
Plain	Material	17. <u>SUBGRADE</u>
Rehabilitation	aluminum	CONTROL
Reinforced	steel	INSULATION
Roughness	wood	ORGANIC
Serviceability		STABILIZATION
	RAILCROSSING	Cement
RECYCLING	Materials	Chemical
Criteria	asphaltic	FlyAsh
Plain	precastConcrete	Lime
Reinforced	polyethylene	
Sampling	rubber	SWELLING
Testing	timber	
	Signals	
REINFORCEMENT	Signs	
Continuous		
Fiberglass	RIGHTOFWAYCONTROL	18. <u>TRAFFIC</u>
Fibers	Bicycles	CONTROL
Mesh	Domestic	Computers
Noncontinuous	Fences	LaneLines
Prestressed	Pedestrians	grooves
	Wildlife	inserts
15. <u>SAFETY</u>		paint
BARRIERS	SKIDRESISTANCE	plastic
Concrete	Evaluation	RaisedMarkers
castinplace	equipment	RecessedMarkers
slipform	tests	Lighting
precast	Grooving	delineation
Delineation	Milling	hazard
Planting	StuddedTires	highmast
Temporary	Treatments	lowlevel
		luminaires
BICYCLES	SNOWICECONTROL	signs
	Detection	towers
CUSHIONS	Heating	RadioAdvisory
Barrels	Insulation	Ramps
Modular	Removal	ReverseLanes
Nets	SnowFence	Signals
Sand		Signs
Water	16. <u>SHOULDERS</u>	commercial
	ASPHALT	supports
ESCAPELANES	CONCRETE	surfaces
		messages
FOG	COLOR	
GLARESCREENS	JOINTS	
Criteria		
Construction		
Material		

SURVEILLANCE  
Detectors  
Helicopters  
RadioAid  
Television

19. TUNNELS

LIGHTING

PORTALS

VENTILATION

NOTES: \*These categories are to be selected only when other categories cannot be utilized.

\*\*Include all tar pavement here.