INVESTIGATION OF PROTECTIVE MEMBRANES USED ON
FOUR VERMONT BRIDGE DECKS

Report 72-3

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VERMONT DEPARTMENT OF HIGHWAYS

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  I Summary of field inspections, permeability tests, and steel corrosion readings
  II Summary of salt applications, core locations, membrane condition, and chloride readings

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ABSTRACT

An investigation was made to determine the effectiveness of four different bridge deck protective membranes: asphalt emulsion, tar emulsion, polyester resin, and epoxy resin. The membranes had been exposed to either two or three winters of deicing salt applications.

Membrane performance evaluations were based primarily on whether or not the treatment had protected the bridge deck from the penetration of chlorides. Although visual observations did not reveal significant information on membrane performances, analysis of the concrete cores indicated that only the deck treated with asphalt emulsion appeared to be free of chlorides.
INVESTIGATION OF PROTECTIVE MEMBRANES USED ON
FOUR VERMONT BRIDGE DECKS

INTRODUCTION

The accelerated deterioration of concrete bridge decks caused by the increased use of deicing chemicals has prompted the Vermont Department of Highways to enter into active participation in the National Experimental & Evaluation Program - Bridge Deck Protective Systems. The purpose of the program is to apply and evaluate various protective treatments recommended for use on concrete bridge decks to determine which material is most effective in prohibiting the deterioration caused by intrusion of deicing chemicals and moisture. In conjunction with participation in the National Program, it was also suggested that an investigation be made of several special membrane treatments used in the past. The following information is the result of that investigation.
INSPECTION PROCEDURE

All bridges were visually inspected for leakage or efflorescence on the underside of the decks. In addition, two deck cores were taken from each membrane system for visual inspection and testing. This included noting the bond between the membrane and concrete, inspecting the membrane surface for pinholes, cracks or other failures, and testing the bituminous portion of the cores for water permeability and air void content. The top inch of concrete was analyzed for chloride content using ASTM Designation D512-67, Method B. The inspection also included the use of a Steel Corrosion Detection Device, as developed by the California Division of Highways, on selected areas of two of the decks.
DATA

Test Location

Interstate 89 Southbound over Vt Rte 132 in Sharon
Project - Hartford-Sharon I 89-1 (7) C/4 & I 89-1 (25) Stage II

Protective Treatment

Product
Date Applied
Weather Log
Construction Cost
Test Results
Viscosity @ 77°F
Construction Operation
Wearing Surface

- Asphalt Emulsion RS-1
- September 13, 1968
- Clear 75°F
- $3.00 per gallon Total Cost $ 780.00
- Residue % - 61.0 Sieve Test % - .005
- Meets all requirements for RS-1
- 260 gallons applied in one coat for an application of 0.25 gallons per square yard
- 2" bituminous concrete

Deck Construction Data

Type of Structure
Span Lengths
Curb to Curb Width
Skew
Horizontal curvature
Grade
Banking or superelevation
Date Deck Poured
Concrete Cover Over Top Reinforcement
Deck thickness
Surface texture

- 3 span WF Beam (composite & non composite)
- 44 - 84 - 44 Overall length 172'-0
- 37'-5
- 40°
- 3°-35
- + 0.614%
- 15/16"/foot
- August, 1967
- 1 ½"
- burlap drag

Traffic Data

Average Daily Traffic
Percent Trucks

- 1970 - 1930 vehicles
- 1971 - 2600 vehicles
- 1970 - 10%
- 1971 - 10%

Climatic Conditions

Approximate number of freeze-thaw cycles

- 1968-1969 - 125 cycles
- 1970-1971 - 106 cycles

Annual Application of Deicing Chemicals in tons per two lane mile

- 1968-1969 not open to traffic
- 1969-1970 25 tons (estimated)
- 1970-1971 22.5 tons

cont'd
DATA

Precipitation and Temperatures as recorded at Chelsea, Vermont

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DATA

Test Location

I 89 Northbound over Vt Rte 132 in Sharon
Project - Hartford-Sharon I 89-1 (7) C/4 & I 89-1 (25) Stage II

Protective Treatment

Product - Cybond 2501 Polyester Resin
Date Applied - August 29 & 30, 1968
Weather Log - August 29 Clear 70°F August 30 Clear 75°F
Test Results - None
Construction Operation -
The deck was washed first with water, then with acetone and then washed a third time using water. The first coat of the treatment consisted of Cybond part I which was applied with street brooms. Upon completion of curing, which took less than one hour, an application of Cybond part II was applied with squeegees. A total of 385 gallons of the material was placed on the 1035 square yard deck for an application of 0.372 gallons per square yard. 5250 pounds of washed sand was spread on the top coat prior to its curing, for an application rate of five pounds per sq. yd.
Construction Cost - No information available
Wearing Surface - 2" bituminous concrete

Deck Construction Data

Type of Structure - 3 span WF Beam (composite & non-composite)
Span Lengths - 44 - 84 - 44 Overall Length - 172'-0
Curb to Curb Width - 37'-5 Skew - 38° Horizontal Curvature - 3°25
Grade - +0.614% Banking or Superelevation - 15/16"/foot
Date Deck Poured - August 1967 Deck Thickness - 7½"
Concrete Cover Over Top Reinforcement - 1½" Surface Texture - Burlap Drag

Traffic Data

Average Daily Traffic
  1970 - 1930 vehicles
  1971 - 2600 vehicles

Percent Trucks
  1970 - 10%
  1971 - 10%

Climatic Conditions

Approximate Number of Freeze-Thaw Cycles
  1968-1969 - 125 cycles
  1969-1970 - 107 cycles
  1970-1971 - 106 cycles

Annual Application of Deicing Chemicals in tons per two lane mile.
  1968-1969 - not open to traffic
  1969-1970 - 25 tons (estimated)
  1970-1971 - 22.5 tons

Precipitation and Temperatures - see page 5
Test Location

I 89 Northbound over State Aid Hwy #3 & Central Vermont Railroad in Sharon
Project - Sharon-Royalton I 89-1 (37) & I 89-1 (26) Stage II

Protective Treatment

Product - Tar Emulsion
Date Applied - April 28 & 29, 1969
Weather Log - April 28 Cloudy - Humid 70°F April 29 Cloudy 52°F
Test Results - Water % - 50.5 Non-volatile % - 47.8
Solubility of Non-volatile % - 47.8
Meets all requirements for Item 318 Tar Emulsion
Construction Operation - 280 gallons applied in two coats on a 990 square yard
area for an application of 0.283 gallons per square yard
Construction Cost - $3.00 per gallon Total cost - $840.00
Wearing Surface - 1½'' Bituminous Concrete

Deck Construction Data

Type of Structure - 4 span composite WF Beams
Span Lengths - 49-59-59-59 Overall length - 236'-0"
Curb to Curb Width - 30'-0" Skew - 44° Horizontal Curvature - 2°-0"
Grade - -1.000% Banking or Superelevation - 5/8' /foot
Date Deck Poured - May 10 & 16, 1968 Deck thickness - 8"
Concrete Cover Over Top Reinforcement - 2" Surface Texture - light broom finish

Traffic Data

Average Daily Traffic
1970 - 1930 vehicles
1971 - 2600 vehicles
Percent Trucks
1970 - 10%
1971 - 10%

Climatic Conditions

Approximate Number of Freeze-Thaw Cycles
1969-1970 - 107 cycles
1970-1971 - 106 cycles

Annual Application of Deicing Chemicals in tons per two lane mile
1968-1969 - not open to traffic
1969-1970 - 35 tons (estimated)
1970-1971 - 32.3 tons

Precipitation and temperatures - see page 5
Test Location

I-89 Northbound over Vt Rte 104 In Fairfax
Project - Georgia-Fairfax-St. Albans I-89-3 (35) C/2 & I-89-3 (41) Stage II

Protective Treatments

Product - Tar Emulsion (Used on End Spans Only)
Date Applied - May 15, 1968
Weather Log - Fair 65°F
Test Results - Water % - 45.8 Non-volatile % - 51.7
Solubility of Non-volatile % - 48.7
Specific Gravity - 1.20
Meets all requirements for Tar Emulsion, Vt. Spec. 318
Construction Operation - 240 gallons applied in two coats on a 675 square yard
area for an application of 0.36 gallons per square yard
Construction Cost - $3.00/gal Total Cost - $720.00
Wearing Surface - 1½" Bituminous Concrete

Product - Rambond 223 Epoxy (Used on Center Span Only)
Date Applied - August 8, 1967
Weather Log - Clear 55°- 75°
Test Results - None
Construction Operation - The treatment consisted of a single coat of trowel
spread 100% solids epoxy topped with an application of stone grits. Application rate unknown.
Construction Cost - Cost of treatment borne by bridge contractor.
Wearing Surface - Added protection considered necessary due to low
air in center span deck concrete.

Wearing Surface - 1½" Bituminous Concrete

Deck Construction Data

Type of Structure - 3 span composite WF Beam
Span Lengths - 44 - 74 - 59 Overall Length - 177'-0
Curb to Curb Width - 37'-3 Skew - 7° Horizontal Curvature - 0°-48'-08"
Grade - +1.850% Banking or Superelevation - ¼"/foot
Date Deck Poured - May 25 & 31, 1967 Deck Thickness - 7½"
Concrete Cover Over Top Reinforcement - 1½" Surface Texture - broomed

Traffic Data

Average Daily Traffic 1969 - 2295
1970 - 2560
1971 - 2760

Percent Trucks
1969 - 8%
1970 - 10%
1971 - 10%

(cont'd)
Climatic Conditions

Approximate Number of Freeze-Thaw Cycles
- 1968-1969: 76 cycles
- 1969-1970: 75 cycles

Annual Application of Deicing Chemicals in tons per two lane mile
- 1968-1969: 45 tons (estimated)
- 1969-1970: 45 tons (estimated)
- 1970-1971: 43.6 tons

Precipitation and Temperatures as Recorded at Burlington, Vermont

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DISCUSSION

ASPHALT EMULSION

I 89 southbound over Vt Rte 132 Membrane applied September 1968

Visual inspection of the bridge deck treated with asphalt emulsion disclosed that the underside of the deck was free of all but a very few minor temperature or shrinkage cracks, and there were no signs of leakage or efflorescence.

Two-4 inch cores were taken from the northerly and middle spans adjacent to the expansion dams on the low side of the deck. The bond between the bituminous pavement, membrane and concrete was such that a hammer and wedge were required to loosen the core prior to removal from the deck. Inspection of the core upon separation revealed that most of the asphalt emulsion was retained on the bituminous portion of the core with only a light coating remaining on the concrete. There was no indication of any cracks or holes in the membrane surface.

A permeability test performed on the bituminous portion of one core using a twenty-four inch head of water (0.865 lbs/in² pressure) demonstrated that water was able to penetrate through the core in three hours and fifty minutes. (See Table I) The penetration time could be considered quite lengthy when compared against the readings of from one to twenty-two minutes recorded on six other cores tested in the same manner. The 9.4% air void content of the core would not appear to be the reason for the resistance to water penetration since it was higher than the 8.9% average air void content of the other cores checked. (The air void content of all the initial bridge deck cores averaged 6.8%). The presence of asphalt emulsion on the bottom of the core could have been partially responsible for the extended penetration time.

A chloride analysis made on the top inch of concrete indicated that there were no chlorides present in the cores. (See Table II) Although only two cores were taken, the absence of chlorides is a good indication of the membrane's effectiveness since the cores were taken adjacent to the expansion dams in an area where ponding would increase the likelihood of chloride intrusion. For deicing chemical applications, see data on page 4.
Cybond 2501  Polyester Resin

I 89 northbound over Vt Rte 132        Membrane applied August 1968

Visual inspection of the bridge deck treated with a polyester resin system disclosed efflorescence on the underside of the deck in two small areas at opposite ends of the deck. Temperature or shrinkage cracks of similar magnitude at other locations in adjacent areas were free of any leakage.

Cores taken adjacent to the expansion dams on the center and northerly spans displayed very little bond between the bituminous pavement and the polyester resin. However, the bond between the polyester membrane and concrete appeared to be satisfactory on both cores. The membrane surface on the core taken from the center span appeared to be free of any cracks or holes, while the core taken from the northerly span revealed a thin membrane coating with several holes visible when viewed under a thirty power microscope.

Permeability tests performed on the bituminous portion of the cores demonstrated that water could pass through the samples in one minute. The air void contents of the two samples were 8.6% and 8.9%.

An analysis of the top inch of concrete taken from the center span revealed an average sodium chloride content of 33 parts per million, while the core taken from the northerly span contained 45 parts per million of sodium chloride.

Readings were taken with a steel corrosion detection device which is used to measure voltage produced by the active corrosion of reinforcing steel. The readings, taken within 15 foot by 70 foot section of the right hand lane, center span, on the high side of the deck, revealed two areas of active corrosion registering 0.35 and 0.40 volts. Potential readings over 0.30 volts indicate active corrosion.
Tar Emulsion

I 89 northbound over State Aid Hwy #3 & Central Vermont Railroad in Sharon
Membrane applied April 1969

I 89 northbound over Vt Rte 104 in Fairfax (end spans)
Membrane applied May 1968

Visual inspection of areas treated with tar emulsion revealed no wet areas or
signs of leakage on the underside of the decks.

There were no cracks or openings detected on the membrane coatings recovered on
cores taken from the deck in Sharon and the southerly span in Fairfax. Inspection of
the core taken from the northerly span in Fairfax disclosed numerous long fine cracks.
The application of hydrochloric acid on the membrane produced effervescence confirm-
ing that the cracks were open to the concrete surface.

Permeability tests performed on the two bituminous cores taken in Sharon dis-
closed that the water was able to pass through one sample in two and one-half minutes,
and a second one in nine minutes. Air void contents were recorded at 9.8% and 10.3%
with the latter reading from the core which took the longer penetration time. Air
void contents of the cores taken in Fairfax were 6.4% and 7.8%, with water permeation
reading of 22 minutes on the latter.

An analysis of the concrete cores taken in Sharon showed average sodium chloride
contents of 46 parts per million. The readings were much higher than the average
count of 19 parts per million detected in cores taken from Fairfax where the deck has
been exposed to greater applications of deicing chemicals over a longer period of time.
Refer to pages 7 and 9 for deicing chemical applications.

Readings taken with a steel corrosion detection device in Fairfax on a 20 foot
by 45 foot section of the right hand lane, southerly span, revealed no active corro-
sion. Electrical resistance readings taken over the same area also indicated there
were no openings in the tar emulsion membrane.
I 89 northbound over Vt Rte 104 in Fairfax (center span)

Membrane applied August 1967

Visual inspection of the span treated with epoxy resin disclosed no signs of leakage or wet areas on the underside of the deck.

Inspection of the cores revealed that the epoxy membrane surface was free of pinholes or other types of distress. The bond between the epoxy resin and the concrete appeared to be very strong; although cracks or separations were detected between the two materials with the aid of a microscope. The existence of the cracks could be due to stresses caused by the higher coefficient of thermal expansion of the epoxy, in comparison to that of the concrete; or it may have been due, at least in part, to handling during core recovery and testing.

A permeability test performed on the bituminous portion of one core disclosed that water could penetrate through the sample in six and one-half minutes. The air void content of the sample was 10.2%.

An analysis of the concrete core taken four feet north of the expansion dam revealed an average sodium chloride content of 66 parts per million. The second core, which was taken 32 feet north of the expansion dam, contained sodium chloride at the rate of five parts per million. The difference in chloride content may have been due to the core locations, since the second core was taken from an area which was less susceptible to ponding and subsequent leakage.

An August 1971 report issued by the Federal Highway Administration, Eastern Highway Projects Office, Region 15, stated that steel corrosion readings taken on the deck revealed no active corrosion of the reinforcing steel. High electrical resistance readings taken in the same area indicated that the membrane system was impermeable. The information was incorrect with regard to the membrane system since the area tested was on the southerly span of the bridge deck which had been treated with tar emulsion rather than epoxy resin as stated in the report.
<table>
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<tr>
<th>Water Penetration Time</th>
<th>Voltage</th>
<th>Reading 1</th>
<th>Reading 2</th>
<th>Reading 3</th>
<th>Comments</th>
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<td>6.4%</td>
<td>9.1%</td>
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<tr>
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<td>8.6%</td>
<td>9.3%</td>
<td>8.8%</td>
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</tbody>
</table>

**Notes:**
- Water penetration is measured in cm.
- Voltage readings are in percent.
- No active corrosion detected.
SUMMARY & CONCLUSIONS

Results of the investigation of the protective membranes are as follows:

(1) Field inspection of the deck treated with the polyester resin system revealed two areas of leakage on the underside of the deck. There were no wet areas or other signs of leakage detected on the other decks. The overall absence of leakage is due in part to the fact that the simple span structures were free of all but minor temperature or shrinkage cracks.

(2) Permeability tests indicated that water was able to flow through all of the bituminous concrete cores when tested under a 24 inch head.

(3) Visual inspection of the cores disclosed that one out of four areas treated with tar emulsion and one out of two areas treated with polyester resin had cracks or holes in the membrane surface. The epoxy resin membrane surface was free of distress, but cracks or separations were detected between the concrete and the epoxy membrane with the aid of a microscope.

(4) Chlorides were found in concrete cores taken from the bridge decks treated with tar emulsion, polyester resin, and epoxy resin, but chlorides were not detected in cores taken from the deck treated with asphalt emulsion.

The results of the investigation suggest that the polyester resin and tar emulsion systems placed in Sharon were not satisfactory and do not warrant further evaluation. Because epoxy membrane systems are currently being used, yearly evaluations will be continued on the epoxy membrane placed in Fairfax, with special emphasis placed on attempting to determine how the chlorides have penetrated through the membrane. The study of the bridge deck treated with asphalt emulsion will also be continued and expanded to include at least one more deck treated with the same material.

This report is not meant to be a blanket endorsement or condemnation of any of the membrane systems due to the limited number of decks surveyed. An investigation covering a larger number of bridge decks with complete monitoring of the membrane applications would be required for that purpose.