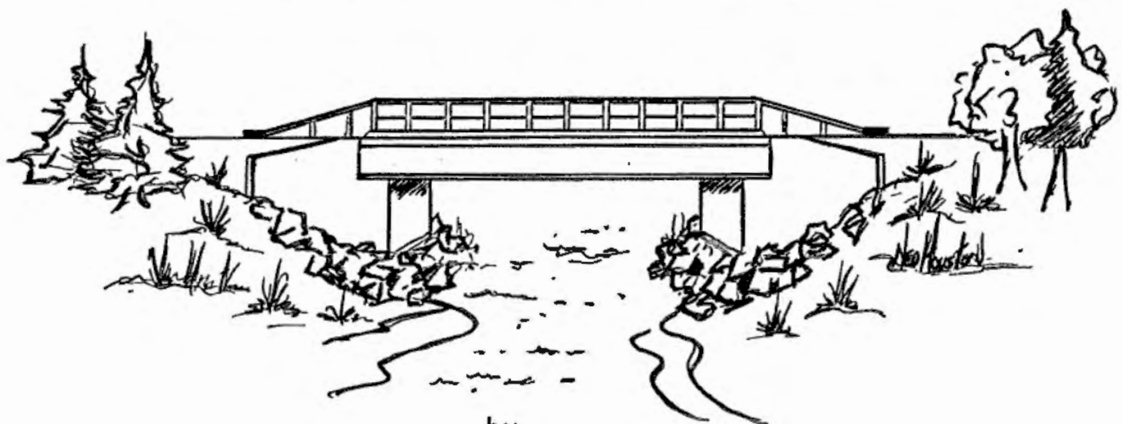
10 YEAR FIELD PERFOMANCE OF EXPERIMENTAL BRIDGE DECK MEMBRANE SYSTEMS IN VERMONT



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ABSTRACT

This paper reviews the Vermont Agency of Transportation Bridge Deck Membrane Evaluation Program begun in 1971 and discusses the field performance of 33 membrane systems over a period of up to 11 years. Applications of deicing chemicals (sodium chloride) during the evaluation period have averaged 29.5 tons per 2 lane mile per year with accumulations totaling up to 123 pounds of chloride per linear foot of structure. Performance results are based upon the presence or absence of chloride above base levels as determined by chemical analysis of recovered concrete samples. The results show that almost without exception, the experimental systems have outperformed the Agency's original standard treatment, tar emulsion. When grouped by general type or class, the best performance has been provided by the thermoplastic systems and the standard preformed sheet membranes. Although less succesful, a reasonable level of performance has been provided by the polyurethanes, miscellaneous preformed materials, and the systems classified most promising in the NCHRP Project 12-11. In general, the epoxy and tar emulsion systems were not successful although they have allowed only an average of 0.35 pounds of chloride per cubic yard of concrete (#/CY) above base levels in the top inch of concrete as compared to an average of 6.34 #/CY on exposed bridge decks over a similar evaluation period.

10 YEAR
FIELD PERFORMANCE OF EXPERIMENTAL
BRIDGE DECK MEMBRANE SYSTEMS
IN VERMONT

By

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Introduction

Vermont's membrane evaluation program began in 1971 with the application of two experimental systems on four new bridge decks. From that point to the present, 33 different systems were field applied on 69 new concrete bridge decks. The products included 15 preformed systems; 7 epoxies, 5 thermoplastic materials, 4 polyurethanes, and 2 tar emulsion systems. Because the membrane systems were considered experimental, the applications were closely monitored and reported under the National Experimental and Evaluation Program #12, Bridge Deck Protective Systems. The information included background data on deck construction, concrete test results, condition of the decks, membrane product data, laboratory test results, observations made during the membrane applications, cost information, preliminary field test results and discussions on the applications. Summaries of each membrane system were concluded with recommendations on further use.

Field Evaluation Procedure

Follow-up field evaluations of the membrane systems began in 1975 on products which were exposed to a minimum of two winters of deicing chemical applications. Field testing in 1976, 1977 and 1978 included 37, 34 and 47 structures respectively. Through the present date, field performance results have been obtained on all 33 experimental systems.

Field testing the first two years included electrical resistivity readings, electrical half cell potential readings, and the recovery of concrete samples for the determination of chloride content by wet chemical analysis. Comparisons were made between the resistivity readings and the chloride levels detected at specific resistivity test locations. When correlation between the two test methods was found to be less than 60 percent, resistivity testing was deleted from the evaluation program in the following years.

Steel potential readings obtained at the same grid points as the resistivity tests were all below the -0.35 volt level considered to be the corrosion threshold. Such readings were in agreement with the sample results which indicated chloride levels were insufficient to cause corrosion of the reinforcing steel.

For the past six years (1977-1982), the performance of the various membrane systems has been considered only in relation to the presence or absence of chloride above base levels as determined by chemical analysis of recovered concrete samples. Such samples were taken at points 1, 5 & 15 feet off the curb line. The 1 foot offset was selected because of the potential for leakage at the critical curb line area while the 15 foot offset establishes membrane performance in the wheel path area which is subject to aggregate puncture under continuous traffic. The 5 foot offset is located in the breakdown lane where satisfactory performance would be expected if the membrane was not damaged during paving or lateral leakage did not occur. In most cases, the test areas were located on the low end of the decks where chloride concentrations would be heaviest. Where super-elevations resulted in drainage away from the breakdown lane, concrete samples were obtained from the opposite curb line. The pulverized concrete samples were procured from 0-1 inch and 1-2 inch depth with the aid of a rotary hammer and 3/4 inch carbide tipped twist drill. The overlying bituminous pavement was removed by the same procedure followed by cleaning with compressed air. A depth gauge attached to the drill was used to obtain the proper depth. Core holes were patched with a quick-set cement.

Prior to 1982, total chloride content in the recovered concrete samples were analyzed following California Test Method No. 404-C (1972). This method involved an indirect Volhard titration. In 1982 total chloride content was analyzed using a colorimetric procedure based on Standard Methods for the Examination of Water and Wastewater Method No. 602 (1975). The colorimetric method was employed because it enabled a rapid analysis (10 fold increase) without sacrificing accuracy or sensitivity.

Field Conditions

Approximately 80 percent of the experimental membrane systems are located on Interstate 91 in the east central to northern portion of the State where the freezing index averages 1400, 80 to 115 freeze-thaw cycles occur and snowfall ranges up to 140 inches. With the exception of one installation in central Vermont, the remaining systems are located in southwestern areas where the freezing index ranges from 950 to 1100, 75 to 115 freeze-thaw cycles occur and snowfall ranges from 70 to 100 inches.

Through the present time, the test sites have been exposed to an average of 8 winters of deicing chemical applications. The applications of road salt have been monitored and the records show yearly applications ranged from 8.5 to 38.3 tons per 2 lane mile with an average of 29.5 tons. Over the evaluation period, the applications have totaled up to 123 pounds of chloride per linear foot of structure.

Average daily traffic volumes on the experimental systems have ranged from 370 to 1990 vehicles while total vehicle passes average 3,336,000 per structure. The average total passes are equivalent to approximately 3000 18 kip equivalent axle loads (EAL).

MEMBRANE PERFORMANCE SUMMARY

The test results show a wide range in the performance of the various systems under evaluation. As shown in Table 1, when grouped by general type or class, all of the experimental systems have outperformed the original standard treatment, tar emulsion.

TABLE 1 SUMMARY OF MEMBRANE PERFORMANCE BY TYPE

TYPE SYSTEM	NO. OF BRIDGES	AVERAGE WINTERS SALTED	% SAMPLES CONTAMINATED 0-1"	1"-2"	AVG.CONTAMINATION LEVEL PPM / #/CY 0-1"	1"-2"
THERMOPLASTIC	7	10.3	17	8	131/.52	57/.23
STANDARD PREFORMED	3	7.3	19	7	110/.44	60/.24
POLYURETHANE	5	8.6	26	14	48/.19	42/.17
MISC. PREFORMED	10	4.9	28	10	114/.46	52/.21
PROJ. 12-11 PREFORMED	5	8.0	29	15	128/.51	110/.44
EPOXY	8	8.9	48	14	116/.46	65/.26
TAR EMULSION	7	10.1	59	34	144/.58	98/.35
EXPOSED BRIDGE DECKS	6	9.0	100	98	1585/6.34	716/2.86

The best performance has been provided by the thermoplastic and standard preformed sheet membrane. Test results identifying the performance of individual systems in Tables 2 and 3 suggest that at least one thermoplastic system be considered for further use in addition to the standard preformed materials currently specified. However, it should be noted that the rubberized asphalt is not recommended for superelevated structures or on grades in excess of 3 percent due to the potential for stability problems related to the bituminous overlay. The majority of the contaminated samples detected on the standard preformed systems were located along the curblines. Modification of the treatment or greater care in application may be required along such areas.

TABLE 2 FIELD PERFORMANCE OF STANDARD PREFORMED SYSTEMS

SYSTEM	NO. OF BRIDGES	AVERAGE WINTERS SALTED	% SAMPLES CONTAMINATED		AVG. CONTAMINATION LEVEL PPM / #/CY	
			0-1"	1"-2"	0-1"	1"-2"
70 Mil Preformed Sheet	7	8.1	14%	5%	111/.44	80/.32
65 Mil Preformed Sheet	5	8.4	19%	12%	111/.44	79/.32
75 Mil Preformed Sheet	9	6.1	27%	5%	136/.54	103/.41
*SYSTEM AVERAGES		7.3	19%	7%	110/.44	60/.24

TABLE 3 FIELD PERFORMANCE OF THERMOPLASTIC SYSTEMS

Rubberized Asphalt	2	11	9%	0%	73/.29	0
Polyproplene Fabric & AC	1	6	11%	0%	70/.28	0
Hot Asphalt & Glass Fabric	2	9	28%	14%	208/.83	131/.52
PVC Polymer	2	7	33%	33%	393/1.57	128/.51
SYSTEM AVERAGES		10.3	17%	8%	131/.52	57/.23

*The system averages for Tables 2 through 8 are determined by using all of the individual sample values for each system.

The polyurethanes, miscellaneous preformed materials and the NCHRP Project 12-11 systems have provided a reasonable level of performance. Two of the individual polyurethane systems and two of the miscellaneous preformed materials have remained free of detectable chloride contamination for up to 8 years of exposure. The miscellaneous preformed systems included two products manufactured with 1/16 inch pre-punched vent holes. The holes were designed to prevent initial and post construction blistering by allowing vapors to escape from beneath the membrane following the installation. Both products were basically successful in reducing the amount of air entrapped beneath the materials but contamination found in 27 to 40 percent of the field samples suggests that some of the holes did not reseal upon application of heat and pressure during the paving operation. The five preformed sheet systems selected as most promising in the NCHRP Project 12-11 were well designed and displayed excellent physical characteristics. However, their applications were difficult thus making it appear doubtful that the systems could be placed properly under typical field conditions.

TABLE 4 FIELD PERFORMANCE OF POLYURETHANE SYSTEMS

SYSTEM	NO. OF BRIDGES	AVERAGE WINTERS SALTED	% SAMPLES CONTAMINATED		AVG. CONTAMINATION LEVEL PPM / #/CY	
			0-1"	1"-2"	0-1"	1"-2"
100% solids (69 Mils)	1	8	0%	0%	0	0
Asp. Modified (100 Mils)	1	6	0%	0%	0	0
Asp. Modified (38 Mils)	2	9.5	31%	19%	88/.35	71/.28
Tar Modified (39 Mils)	1	10	50%	22%	77/.31	74/.30
SYSTEM AVERAGES		8.6	26%	14%	48/.19	42/.17

TABLE 5 FIELD PERFORMANCE OF MISCELLANEOUS PREFORMED SYSTEMS

SYSTEM	NO. OF BRIDGES	AVERAGE WINTERS SALTED	% SAMPLES CONTAMINATED 0-1"	1"-2"	AVG. CONTAMINATION LEVEL PPM / #/CY 0-1"	1"-2"
165 Mil 4'x8' Panel	1	4	0%	0%	0	0
60 Mil Tar Resin	1	4	0%	0%	0	0
PVC-Butyl Rubber	1	6	11%	0%	68/.27	0
Hydrocarbon Rubber	1	8	27%	7%	88/.35	78/.31
75 Mil Vented	2	4.5	27%	20%	120/.48	82/.33
60 Mil Vented	2	4.5	40%	13%	108/.43	98/.39
Butyl-Neoprene	2	4.5	47%	13%	193/.77	142/.57
SYSTEM AVERAGES		4.9	28%	10%	114/.46	52/.21

TABLE 6 FIELD PERFORMANCE OF NCHRP PROJECT 12-11 PREFORMED SYSTEMS

Pitch & PVC Polymer	1	8	7%	7%	298/1.19	150/.60
Neoprene Rubber	1	8	27%	13%	180/.72	109/.44
EPDM Rubber	1	8	33%	7%	82/.33	72/.29
Butyl Rubber	1	8	33%	27%	99/.40	89/.36
Butyl Rubber & Felt	1	8	47%	20%	90/.36	150/.60
SYSTEM AVERAGES		8	29%	15%	128/.51	110/.44

With the exception of 1 product, the epoxy systems have not performed satisfactorily allowing chloride intrusion on 48 percent of the samples taken. The tar emulsion systems also performed poorly with contamination found on 59 percent of the samples. Although less than satisfactory, the epoxy and tar emulsion systems have only allowed an average of 0.35 pounds of chloride per cubic yard of concrete (#/CY) above base levels when all samples are included. Such contamination levels may be considered low when compared to the average of 6.34 #/CY recorded on 6 untreated concrete decks exposed to similar deicing salt applications over the same evaluation period (Table 9). The highest levels of chloride contamination were recorded on the two 11 year old structures treated with 2 coats of tar emulsion. Half-cell potential measurements taken on the 2 structures indicate the presence of active corrosion on 1 percent of the deck areas.

TABLE 7 FIELD PERFORMANCE OF EPOXY SYSTEMS

SYSTEM	NO. OF BRIDGES	AVERAGE WINTERS SALTED	% SAMPLES CONTAMINATED 0-1"	% SAMPLES CONTAMINATED 1"-2"	AVG. CONTAMINATION LEVEL PPM / #/CY 0-1"	AVG. CONTAMINATION LEVEL PPM / #/CY 1"-2"
90 Mil 100% Solids	1	8	0%	0%	0	0
13 Mil Polyamide	1	8	44%	6%	70/.28	62/.25
Coal Tar Modified	2	9.5	44%	17%	103/.41	91/.36
48 Mil 100% Solids	1	9	50%	17%	156/.62	68/.27
12 Mil Polyamide	1	8	60%	13%	108/.43	67/.27
52 Mil 100% Solids	1	9	67%	0%	100/.40	0
12 Mil Solvent Cut	1	10	89%	67%	202/.81	69/.28
SYSTEM AVERAGES		8.9	48%	14%	116/.46	65/.26

TABLE 8 FIELD PERFORMANCE OF TAR EMULSION SYSTEMS

SYSTEM	NO. OF BRIDGES	AVERAGE WINTERS SALTED	% SAMPLES CONTAMINATED 0-1"	1"-2"	AVG. CONTAMINATION LEVEL PPM / #/CY 0-1"	1"-2"
Tar Emulsion & Glass Fabric 7 Layer System	5	9.8	57%	30%	112/.45	85/.34
Tar Emulsion 2 Coats	2	11	64%	44%	228/.91	182/.73
SYSTEM AVERAGES		10.1	59%	34%	144/.58	98/.35

TABLE 9 CHLORIDE PENETRATION RATES ON EXPOSED PCC BRIDGE DECKS

Linseed Oil & Mineral Spirits	3	11.7	100%	98%	1942/7.77	992/3.97
No Treatment	3	7.3	100%	100%	1477/5.91	535/2.14
SYSTEM AVERAGES		9.0	100%	99%	1585/6.34	716/2.86

CONCLUSIONS

1. Almost without exception, the experimental bridge deck membrane systems have outperformed the Agency's former standard treatment, tar emulsion.

2. Long term field performance results indicate that a variety of membrane systems can be made to work if adequate time and effort is spent in selection, design, and installation. However, the potential for improper placement and other related problems with individual applications should be sufficient to discourage membrane usage in areas where a lack of sufficient care and attention might be anticipated.

The findings in this paper were made possible through funding of an HPR Part II Research Project. The Agency is committed to the continuation of this evaluation program for a minimum of 5 additional years through Fiscal 1987.

MEMBRANE EVALUATION SUMMARY

Membrane Type	Ease of Application	Flexibility	Bond & Seal at Curb	Blisters or Pinholes	Bond Between Concrete Membrane & Pavement	Problems with Pavement Application	Cost per sy (1971-1978)	Overall Performance	Recommendation
Standard Preformed	easy	good	fair	yes/ no	fair/ good	occ.	$ 4.50	good	Continue Use
Miscellaneous Preformed	easy	good	poor	yes/ no	poor/ fair	yes	$ 5.00	fair/ good	Consider Selective Use
Project 12-11 Preformed	hard	exc.	fair	yes/ no	good/ good with prot. boards	yes	$10.65	fair to good	Not recommended - application too difficult
Polyurethane	easy	good	exc.	no/ yes	good/ poor	occ.	$ 5.25	fair to good	Consider Selective Use
Thermoplastic	hard	poor to good	fair	no/ yes	good/ good	occ.	$ 4.00	good	Consider Selective Use
Epoxy	easy	poor	fair	no/ yes	good/ poor	no	$ 9.50	poor	Not recommended for use
Emulsion	very easy	poor	poor	no/ no	good/ good	no	$ 1.35/ 3.50	poor	Not recommended for use

BRIDGE DECK MEMBRANE EVALUATION PROGRAM

LIST OF SYSTEMS APPLIED

15 Preformed Systems on 38 Bridges

Heavy Duty Bituthene - 65 mil reinforced rubberized asphalt
Protecto Wrap M 400 - 70 mil reinforced tar and synthetic resin modified
Royston No. 10 - 75 mil reinforced bituminous
Royston No. 10 P.V. - 75 mil pre-vented reinforced bituminous
Royston No. 15 - 60 mil pre-vented reinforced bituminous
Nordel - 65 mil reinforced non-cured hydrocarbon rubber
Hyload 125 - 125 mil pitch and poly vinyl chloride polymer
Gacoflex N-35 - 1/16 inch cured and buffed neoprene rubber
Sure-Seal Butyl - 65 mil vulcanized butyl rubber
Sure-Seal EPDM - 65 mil cured EPDM rubber
Butylfelt - 60 mil butyl rubber and felt laminate
Hydro-Ban RVN-45 - 45 mil reinforced PVC and butyl rubber
Tri-Ply - 62 mil butyl neoprene rubber
Polyguard 860 - 60 mil reinforced tar resin
Melnar 8 - 165 mil reinforced rubberized asphalt in 4'x8' panels

5 Thermoplastic Systems on 9 Bridges

Uniroyal 6125 - 195 mil hot applied rubberized asphalt
Hot Asphalt & Glass Fabric - 5 layer built up system
NEA 4000 - 90 mil single component PVC Polymer
Petromat - non-woven polyproplene fabric and asphalt cement
*Gussasphalt - 2 inch mastic type paving mixture

4 Polyurethane Systems on 7 Bridges

Polytak 165 - asphalt modified polyurethane, 38 mil application
Bon-Lastic Membrane - tar modified polyurethane, 39 mil application
Duralseal 3100 - 100 percent solids polyurethane, 69 mil application
Chevron Bridge Membrane - asphalt modified polyurethane, 100 mil application

7 Epoxy Systems on 8 Bridges

Duralkote 304 - solvent cut epoxy, 12 mil application
Duralkote 306 - coal tar modified, 46 and 65 mil applications
Duralbond 102 - 100 percent solids, 48 mil application
Rambond 620-S - 100 percent solids, 52 mil application
Rambond 223 - 100 percent solids, 90 mil application
Ramcoat Epoxy Paint - polyamide, 12 mil application
Polyastics - polyamide epoxy, 13 mil application

2 Tar Emulsion Systems on 7 Bridges

Tar Emulsion - 2 coats at 0.1 - 0.2 gal. per coat
Tar Emulsion & Glass Fabric - 7 layer built up system

*Development of full depth cracks necessitated removal of the system.