BRIDGE DECK MEMBRANE SYSTEMS

A Review of Current Usage, Evaluation Methods and Field Performance

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For Presentation At The Bridge Deck
Rehabilitation Seminar

Transportation Systems Center
Cambridge, Massachusetts
October 25, 1977

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CURRENT STATUS OF MEMBRANE USAGE

States Now Specifying Membranes				*Primary Method Being Used - Other Than Membranes		
New Construction		Rehabilitation		Latex Modified or Low Slump Concrete	Epoxy Coated Reinforcing Steel	Linseed Oil
Yes	No	Yes	No	24 States	21 States	6 States
*23	25	28	20			
**28	20	35	13			

* Results from AASHTO-AGC-ARBA poll - January, 1977
** Results from ASTM poll - April, 1977

CURRENT STATUS OF MEMBRANE USAGE

*Membranes Currently Specified

System	# States Specified In
H. D. Bituthene	20
Protecto Wrap	19
Superseal, NEA, or Wabo 4000	15
Royston No. 10	14
Multi-Layer Systems	5
Uniroyal 125	3
Nordel	2
9 Miscellaneous Systems	1 each

**Membrane Performance Rating by States

Excellent	2
Good	15
Fair	19
Poor	11

* Results from AASHTO-AGC-ARBA poll - January, 1977
** Results from ASTM poll - April, 1977

The following information was gathered during field tests conducted in 1975 and 1976 on 37 new bridges which were treated with 24 experimental membrane systems prior to being opened to traffic.[1]

FIELD PERFORMANCE OF EXPERIMENTAL MEMBRANES IN VERMONT

The 24 different membrane systems under evaluation were exposed to an average of 2.3 winters of deicing salt applications when field tests were conducted in 1975 and 3.3 winters in 1976. Chloride applications during the winters of 1971-1972 through 1975-1976 averaged 32.2 tons per two lane mile. Although field testing included a significant number of bridges, only 8 of 24 membrane systems were evaluated on more than a single structure. For this reason, the performance of the membrane systems will be discussed in relation to the class of material rather than by individual products. The systems were broken down into seven classes as follows:

1. Standard Preformed Membranes - Three preformed sheet membranes no longer considered experimental under FHWA NEEP #12.

2. Miscellaneous Preformed Membranes - One experimental preformed sheet membrane system.

3. Project 12-11 Preformed Membranes - Five vulcanized, cured or cross-linked elastomer systems selected as the most promising membrane materials under phase one of the NCHRP Project 12-11.

4. Polyurethanes - Three asphalt modified, tar modified, or 100 percent solids polyurethane systems.

5. Thermoplastic or Thermosetting - Three hot applied rubberized-asphalt, mopped asphalt and glass fabric or PVC polymer systems.

6. Epoxies - Seven solvent cut, coal tar modified or 100 percent solids epoxy systems.

7. Emulsions - Two systems consisting of two coats of tar emulsion or five coats of tar emulsion and two layers of glass fabric.

1. Frascoia, R. I., "Evaluation of Bridge Deck Membrane Systems and Membrane Evaluation Procedures", Report 77-2, Vermont Department of Highways, March, 1977.

The standard preformed sheet membranes provided the best performance with 84 percent of the concrete samples free of chloride contamination. Four of the five samples with contamination were located one foot from the curb line. The results point out the difficulty of obtaining a complete seal along the deck-curb joint and lower portion of the curb section which consists of a rough granite face on most Vermont bridges. Curb line leakage on later installations will hopefully be prevented with the use of compatible liquid polyurethane sealants applied along the membrane perimeter and vertical curb face on two of the three systems. The occasional formation of blisters which occured prior to, during, or after the pavement installations has not resulted in leakage to date, based upon the field test results obtained.

The single miscellaneous preformed membrane was not recommended for further use based upon observations made during the installation. Chloride contamination found at all sample locations after two winters further supports the initial recommendations.

The National Cooperative Highway Research Program Project 12-11 preformed sheet membranes have prevented chloride intrusion on 67 percent of the cores recovered after two winters of deicing salt applications. Leakage detected on three of the five systems may have been due in part to blisters which occurred during and after the installation of the first one inch course of pavement.

Three polyurethane membrane systems have prevented chloride contamination on 57 percent of the samples obtained from four decks exposed for an average of three winters. Chloride levels in the top inch of contaminated cores were limited to 32 parts per million (ppm) over base chloride levels or 0.13 pounds

per cubic yard of concrete. The low chloride levels and random occurance may have been due to the pinholing and bubbling which occurred during the application of the liquid applied materials.

Hot applied materials and epoxy systems had 50 and 43 percent of the samples respectively free of chloride contamination. Once again, chloride levels ranging from 0.16 to 0.22 pounds per cubic yard of concrete suggest that the leakage relates to pinholing or blistering which occurred with most of the systems.

Contamination was found on 61 percent of the samples obtained from six bridges treated with two emulsion systems. Leakage along curb line areas where surface drainage is normally poor accounted for 46 percent of the contaminated samples.

A summary of membrane performance by class is shown on Table 1, page 7 The table reveals that chloride contamination was present at 44 percent of all locations tested. It should be noted that the concrete samples were obtained from areas where low resistivity readings were obtained whenever possible, rather than by random sampling. The amount of chloride above the base level averaged 50 ppm or 0.20 pounds of chloride per cubic yard of concrete in the top inch of the contaminated samples. Seven of the 131 test locations exhibited chloride levels over one-half pound in the top inch of concrete with the highest reading recorded at 1.03 pounds. Contamination in the second inch of concrete was found on 32 percent of the cores with chloride levels averaging 36 ppm above base levels or 0.14 pounds per cubic yard of concrete. Chloride levels slightly over one-half pound were recorded on two samples. The difficulty of obtaining a satisfactory seal along the curb lines was evidenced by the detection of contamination in 66 percent of the cores taken at the one foot offset. Such cores made up 48 percent of all the contaminated samples while 30 percent were located at the 5 foot offset and the remaining 22 percent were at the 15 foot offset.

In general, the test results indicate that few of the membrane systems under evaluation were able to seal off all areas of the bridge deck surfaces. Such results were not surprising considering that 17 of the 24 systems were not recommended for further use based upon initial observations and test results. The remaining seven systems recommended for use with or without limitations have generally performed well with chloride contamination limited to 18 percent of the areas tested. Where leakage did occur, chloride levels averaged 0.14 pounds in the top inch of concrete. Such chloride concentrations are not significant when compared with the one to two pound concentrations required at the rebar level in order to create active corrosion of the steel. The results indicate the most effective membrane systems have prevented or reduced the level of chloride penetration to the extent that they may be considered an acceptable bridge deck protective system until other more effective methods or systems become available.

SUMMARY OF MEMBRANE PERFORMANCE BY CLASS
BASED UPON CHEMICAL ANALYSIS OF CORES

Membrane Type	Average Winters Cl^- Applied	% Cores Contaminated	Ave. Cl^- above base level in top inch of contaminated cores ppm	#/cy
Standard Preformed	2.5	16	37	0.15
Project 12-11 Preformed	2	33	58	0.23
Polyurethane	3	43	32	0.13
Thermoplastic or Thermosetting	3.3	50	40	0.16
Epoxy	2.7	57	55	0.22
Emulsion	3.8	61	75	0.30
Weighted Ave. of All Systems	2.8	44	50	0.20

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	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	poor	Not recommended for use
Project 12-11 Preformed	hard	exc.	fair	yes/ no	good/ good with prot. boards	yes	$10.65	fair to good	Not recommended unless other systems prove to be unsat.
Polyurethane	easy	good	exc.	no/ yes	good/ poor	occ.	$ 5.19	fair	Restrict Use
Thermoplastic or Thermosetting	hard	poor to good	fair	no/ yes	fair/ fair	occ.	$ 4.00	fair	Restrict Use
Epoxy	easy	poor	fair	no/ yes	good/ poor	no	$ 9.42	poor	Not recommended for use
Emulsion	very easy	poor	poor	no/ no	good/ good	no	$1.32/ $3.50	poor	Restrict Use

CHLORIDE PENETRATION THROUGH LIQUID APPLIED

MEMBRANES AS COMPARED TO UNTREATED CONCRETE

MEMBRANE TREATMENT	NO. OF TEST SLABS	HOLES OR BUBBLES PER FOOT	TEST PERIOD IN DAYS	CHLORIDE CONTENT IN POUNDS			
				0-1/2"	1/2"-1"	1"-1 1/2"	1 1/2"-2"
No Treatment	4		440	22.7	18.5	13.5	11.2
No Treatment	4		730	21.5	22.2	21.0	18.7
Polyurethane (1 coat)	5	232	730	3.5			
Polyurethane (2 coat)	5	47	730	1.2			
Polyurethane (3 coat)	5	31	730	2.0			
Polyurethane (4 coat)	1	5	730	0.6			
Epoxy (1 coat)	3	132	730	2.8			
Epoxy (2 coat)	3	33	730	3.7			
Epoxy (3 coat)	3	8	730	0.9			
Epoxy (4 coat)	2	1	730	2.4			

RELIABILITY OF FIELD ELECTRICAL RESISTIVITY TEST RESULTS

The method used to establish the validity of electrical resistivity readings was to compare the readings with the presence or absence of chloride in concrete samples taken from selected resistivity test locations.

The pulverized concrete core samples were recovered from 35 locations on 16 bridges in 1975 and from 96 locations on 35 bridges in 1976. Of the total, 74 of the resistance readings were in agreement with the chloride levels when 500,000 ohms was used as the minimum acceptable reading which would indicate an impervious pavement membrane system. Based upon such results the resistivity test would have a reliability factor of 57 percent.

35 of the 57 resistance tests which did not correlate indicated acceptable or infinite resistance at locations where chlorides were found to be above base levels. With the possible exception of lateral chloride migration occurring beneath membranes not completely adhered to the deck surface, such resistivity readings would be considered incorrect.

The remaining 22 readings which did not correlate were low indicating leakage but the chloride results were unchanged from base levels. Due to several factors, it is possible that the results of both tests are accurate even though the results do not agree. The most likely reason for the lack of correlation may relate to the difference in the physical areas involved with each test procedure. The resistivity test covers an area at least the size of the sponges used and in all likelihood an even larger area due to the migration of the wetting agent in the pavement and/or at the pavement-membrane interface. Accordingly, a low resistivity reading could be due to holidays in the membrane throughout the test area or simply due to a porous condition at a single small location. If the latter occurred and the concrete sample was not recovered from the immediate area of leakage, chloride contamination would not be found and the resistivity

and core results would not support one another. Low resistivity readings could also occur without evidence of contamination in cases where membrane failures result just prior to resistivity testing, but when chlorides have not had sufficient time to penetrate through the membrane at the failure points. A low resistivity-no chloride condition would also exist if the low reading was due to a false electrical circuit caused by moisture in the pavement or at the pavement-membrane interface. Every attempt was made to avoid the latter condition since moisture was recognized as a potential problem prior to initiating the study.

If the 22 low resistivity-no chloride test results were not included in the 131 field tests, the reliability factor of the remaining 109 resistance tests would improve from 57 percent to 68 percent. The reliability of the resistivity test varied between 1975 and 1976 with factors of 69 percent and 52 percent obtained in consecutive years. Varying the acceptable resistance level above or below 500,000 ohms did not improve the reliability factor. The use of one million ohms as the minimum acceptable level resulted in 66 percent correlation with the core results while a 100,000 ohm level resulted in a factor of 55 percent.

In general, the number of satisfactory resistivity readings has decreased with time as evidenced by 81 percent satisfactory readings in 1975 as compared to 71 percent satisfactory readings in 1976.

CORRELATION BETWEEN RESISTIVITY TEST RESULTS
AND CHLORIDE LEVELS ON MEMBRANE CLASSES

Membrane Type	Average Winters Cl^- Applied	% Cores OK	% Resistivity Tests Passing
Standard Preformed	2.5	84	67
Miscellaneous Preformed	2	0	100
Project 12-11 Preformed	2	67	54
Polyurethane	3	57	62
Thermoplastic or Thermosetting	3.3	50	85
Epoxy	2.7	43	88
Emulsion	3.8	39	85
Weighted Average of All Systems	2.8	56	75

RELATIONSHIP BETWEEN RESISTIVITY RESULTS AND CHLORIDE

PENETRATION THROUGH LIQUID APPLIED MEMBRANES

MEMBRANE TREATMENT	NO. OF TEST SLABS	HOLES OR BUBBLES PER FOOT^2	LBS CL AT 0-1/2" DEPTH AFTER 730 DAYS	OHMS RESISTANCE		
				HIGH	LOW	AVERAGE
Polyurethane (1 coat)	5	232	3.5	30,000	550	9,800
Polyurethane (2 coat)	5	47	1.2	380,000	2,800	98,300
Polyurethane (3 coat)	5	31	2.0	5,000,000	37,000	802,000
Polyurethane (4 coat)	1	5	0.6	7,000,000	95,000	3,365,000
Epoxy (1 coat)	3	132	2.8	10,000	1,000	6,000
Epoxy (2 coat)	3	33	3.7	28,000	1,200	11,700
Epoxy (3 coat)	3	8	0.9	400,000	1,400	82,500
Epoxy (4 coat)	2	1	2.4	160,000	5,000	45,000

SECTION 519 - SHEET MEMBRANE WATERPROOFING

519.01, DESCRIPTION. Sheet Membrane Waterproofing shall consist of the application of a reinforced asphalt, synthetic resin or coal tar based preformed sheet membrane to bridge decks to serve as a waterproof barrier between the concrete deck and the bituminous concrete surface pavement. The system shall include the use of a prime coat over the horizontal deck surface and a sealing mastic or acceptable polyurethane liquid membrane on the lower portion of the curb face and adjacent deck area.

519.02, MATERIALS. Following is a list of acceptable materials. The material selected shall meet the approval of the Engineer prior to installation.

(a) Heavy Duty Bituthene as manufactured by Construction Products Division, W. R. Grace and Co., Cambridge, Massachusetts. The membrane sheet consists of a bottom layer of rubberized asphalt with adhesive qualities, a polypropylene barrier sheet, and a top layer of rubberized asphalt/wax which will bond to the wearing course. The membrane system shall include the use of Bituthene primer and mastic.

(b) Protecto Wrap M-400 as manufactured by Protecto Wrap Company, Denver, Colorado. The membrane sheet consists of a non-woven fibrous mat between 2 layers of synthetic resin reinforced coal tar. The membrane system shall include the use of Protecto Wrap Primer and a polyurethane membrane sealant along the curb line.

Materials suitable for sealing the curb line include the following products:

1. Witmer T-830 as manufactured by Witco Chemical Corporation, 100 Convery Boulevard, Perth Amboy, New Jersey 08862. Tel. 201-826-6600

2. Sonaborn HLM 2000 as manufactured by the Sonaborn Company, 5825 Queens Boulevard, Woodside, New York 11377. Tel. 212-335-6200

3. Bon-Lastic Membrane as manufactured by the Robson Corporation, Box 67, Oxford, Maryland 21654. Tel. 301-226-5468

4. Duralseal 3100 Deck Coating as manufactured by Dural International Corp., Deer Park, New York 11729. Tel. 516-586-1655

5. Gacoflex UWM-28 Liquid Membrane as manufactured by Gates Engineering Company, Inc., Box 1711, Wilmington, Delaware 19899. Tel. 302-656-9951

(c) Royston Bridge Membrane No. 10 as manufactured by Royston Laboratories, Inc., Pittsburgh, Pennsylvania. The membrane sheet consists of an impregnated fiberglass mesh sandwiched between layers of a bituminous mastic. The membrane system shall include the use of Royston primer and a polyurethane membrane sealant along the curb line.

Materials suitable for sealing the curb line include the following products:

1. Polytok Membrane 165 as manufactured by the Carboline Company, 328 Hanley Industrial Court, St. Louis, Missouri 63144. Tel. 314-644-1000 or Southborough, Mass. Tel. 617-481-7755

2. Chevron Industrial Membrane System as manufactured by The Asphalt Division, Chevron USA, 1200 State Street, Perth Amboy, New Jersey 08862. Tel. 201-738-2141

3. Duralseal 3100 Deck Coating as manufactured by Dural International Corp., Deer Park, New York 11729. Tel. 516-586-1655

4. Gacoflex UWM-28 Liquid Membrane as manufactured by Gates Engineering Company, Inc., Box 1711, Wilmington, Delaware 19899. Tel. 302-656-9951

CONSTRUCTION REQUIREMENTS

519.03, WEATHER LIMITATIONS. Waterproofing shall not be done in wet weather or when the temperature is below 40° F, without the authorization of the Engineer.

519.04, SURFACE PREPARATION. The concrete surfaces which are to be waterproofed shall be reasonably smooth and free from projections or holes and shall be cleaned of dust and loose material. The surfaces shall be visibly dry prior to and during application of the membrane system. The area of the bridge decks three feet from the face of the curbs and for the full length of the curbs shall be blast cleaned.

519.05, CONSTRUCTION DETAIL.

(a) Primer Application. The primer shall be mixed thoroughly before use. It shall be applied by roller or squeegee over the horizontal deck surface to a point approximately 6 inches from each curb face. The primer shall be applied at the manufacturer's recommended application rate. Heavy applications shall be avoided with any build up eliminated by brushing out the excess material. The primer shall be allowed to dry to a tack free condition prior to applying the membrane. The surface shall be reprimed if it has become contaminated with dust or dirt or if the membrane has not been applied within 24 hours. When system (a), Heavy Duty Bituthene, is selected for use, the primer application shall be made over the entire horizontal deck surface and approximately 3 inches up each curb face.

(b) Treatment Adjacent to Curb Face. When system (a), Heavy Duty Bituthene, is selected for use, Bituthene mastic shall be applied at the junction between the mortar fillet and the deck and along the edge of the membrane sheet at the joint between the mortar and the granite curb. On rough curb and fillet faces, the mastic shall be applied by brush or other approved method over the entire area to be sealed by the membrane. Immediately upon installation of the first roll of material, an additional seal of mastic shall be applied along the edge of the membrane.

When system (b), Protecto-Wrap M-400, or (c), Royston Bridge Membrane No. 10, are selected for use, the treatment adjacent to the curb line shall be as follows:

1. A 2-component polyurethane shall be mixed and applied on the unprimed 6 inch wide area adjacent to each curb face. The application shall be made at the rate of 10 square feet per gallon (20 lineal feet per gallon). A narrow squeegee or paint brush shall be used to apply a coating of the material approximately 3 inches up the curb face. To insure a build up of material on the vertical face, the squeegee or paint brush shall be used to re-work material up the curb face immediately prior to the installation of the first strip of preformed sheet membrane.

2. The first strip of membrane material shall be placed into the polyurethane membrane while it is still liquid (5 to 20 minutes after application). The sheet membrane shall overlay the polyurethane membrane by approximately 4 inches. Pressure shall be applied along the edge of the sheet membrane in order to force any excessive amounts of the polyurethane sealant from beneath the membrane.

3. Before the polyurethane membrane has cured to a tack free condition a second coat of the material shall be applied over the edge of the sheet membrane and on the curb face at the rate of 40 lineal feet per gallon. The application shall be made in a manner that will insure a 3-inch overlap onto the membrane sheet.

(c) Sheet Membrane Installation. Additional rolls of the membrane shall be installed in a shingled pattern so that water is permitted to drain to the low areas of the deck without accumulating against seams. A chalk line shall be used to insure proper alignment of each roll. The membrane shall be pressed or rolled into place as the installation progresses to assure bond with the primed surface and to avoid entrapment of air between the membrane and the deck. Rolling shall be accomplished with a light duty vehicle such as a pickup truck or with a heavy duty segmented linoleum roller.

The membrane sheet shall be overlapped a minimum of 2 inches laterally and 6 inches on end laps and the perimeter of the membrane placed in a given days operation shall receive a seal of mastic along the edges.

If any large air bubbles have developed, they shall be eliminated prior to paving by slitting the membrane at a nearly horizontal angle and forcing the air out. These punctures and any damaged areas found shall be repaired by applying a bead of mastic completely around the area and applying a patch of the membrane over the mastic.

If blisters develop in the pavement during application, they shall be eliminated by puncturing the pavement and membrane with an ice pick or other sharp instrument at a nearly horizontal angle.

In all cases, the application of the membrane system shall be in accordance with the manufacturer's recommendations.

519.06, PROTECTION OF MEMBRANE. No traffic shall be permitted on an exposed membrane surface. Care shall be exercised to prevent damage to the completed membrane, especially during paving operations. Any areas which are damaged shall be cleaned and patched to the satisfaction of the Engineer.

The specified bituminous overlay shall be placed on the membrane within 3 days after application unless otherwise permitted.

A rubber tired or rubber tracked paver shall be used to place the bottom course of bituminous mix. Asbestos fibers shall not be utilized in the first course of pavement. The thickness of the first course of pavement shall be 1½ inches compacted.

The temperature of the bituminous concrete pavement to be placed on sheet membrane waterproofing shall be as follows:

Sheet Membrane Waterproofing	
1. Heavy Duty Bituthene	260 F ± 20° F
2. Protecto Wrap M-400	260 F ± 20° F
3. Royston No. 10	300 F – 325° F

The contractor shall maintain a small supply of Portland Cement on the project during the time of paving. In the event that the paver or truck tires stick or pull the membrane during periods of hot weather, cement dust shall be sparingly cast over the membrane surface to reduce tackiness.

The paver operator shall be advised not to ride the curb lines while paving such areas since the screed shoe may damage the polyurethane sealant or mastic seal on the vertical curb face.

519.07, PROTECTION OF EXPOSED SURFACES. The Contractor shall exercise care in the application of the waterproofing materials to prevent surfaces not receiving treatment from being spattered or marred. Particular reference is made to the face of curbs, copings, finished surfaces, substructure exposed surface and outside faces of the bridge. Any material that spatters on these surfaces shall be removed and the surfaces cleaned to the satisfaction of the Engineer.

519.08, METHOD OF MEASUREMENT. The quantity to be measured for payment will be the number of square yards of the specified type of membrane waterproofing complete in place in the accepted work.

519.09, BASIS OF PAYMENT. The accepted quantity will be paid for at the contract unit price per square yard for the sheet membrane waterproofing system, including primer, mastic, polyurethane membrane sealant, and surface preparation, which price shall be full compensation for furnishing, transporting, handling and placing the material specified and the furnishing of all labor, tooks, equipment and incidentals necessary to complete the work.

Payment will be made under:

	Pay Item	Pay Unit
519.20	Sheet Membrane Waterproofing	Square Yard

CORRELATION BETWEEN ELECTRICAL RESISTIVITY
TEST RESULTS AND CHLORIDE LEVELS AT 131 FIELD
TEST LOCATIONS

Results	Comments
56% of the resistivity tests correlated with the core results.	Resistivity readings correct
27% of the resistivity readings indicated no leakage while core results disclosed chloride contamination.	Resistivity readings incorrect
17% of the resistivity readings indicated leakage while core results disclosed no chloride contamination.	Lack of correlation may relate to the size of the test area, where membrane failure has occurred but chlorides have not yet penetrated, or low resistivity readings may be due to moisture in the pavement overlay.

SUMMARY OF MEMBRANE PERFORMANCE BY CLASS
BASED UPON CHEMICAL ANALYSIS OF CORES

Membrane Type	Average Winters Cl^- Applied	Average Base Cl^- in ppm	% Cores OK	% Cores Contaminated	*Ave. Cl^- above base level in contaminated cores	
					ppm	#/cy
Standard Preformed	2.5	42	84	16	37	0.15
Miscellaneous Preformed	2	55	0	100	39	0.22
Project 12-11 Preformed	2	66	67	33	58	0.23
Polyurethane	3	48	57	43	32	0.13
Thermoplastic or Thermosetting	3.3	37	50	50	40	0.16
Epoxy	2.7	36	43	57	55	0.22
Emulsion	3.8	30	39	61	75	0.30
Weighted Average of All Systems	2.8	42	56	44	50	0.20

* Results based on samples taken from the top inch of concrete.

CORRELATION BETWEEN FIELD RESISTIVITY TESTS RESULTS
AND CHLORIDE LEVELS

Membrane Type	% Cores OK	% Resistivity Tests Passing
Standard Preformed	84	67
Polyurethane	57	62
Thermoplastic or Thermosetting	50	85
Epoxy	43	88
Emulsion	39	85
Weighted Average of All Systems	56	75

TABLE

CORRELATION BETWEEN RESISTIVITY TEST RESULTS
AND CHLORIDE LEVELS ON MEMBRANE CLASSES

Membrane Type	Average Winters Cl^- Applied	% Cores OK	% Cores Contaminated	% Resistivity Tests Passing	% Resistivity Tests Failing
Standard Preformed	2.5	84	16	67	33
Miscellaneous Preformed	2	0	100	100	0
Project 12-11 Preformed	2	67	33	54	46
Polyurethane	3	57	43	62	38
Thermoplastic or Thermosetting	3.3	50	50	85	15
Epoxy	2.7	43	57	88	12
Emulsion	3.8	39	61	85	15
Weighted Average of All Systems	2.8	56	44	75	25