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FINAL REPORT

POLYMER CONCRETE OVERLAY ON THE BIG SWAN CREEK BRIDGE

-- Condition of Overlay After Two Years in Service --

by

Michael M. Sprinkel
Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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TO DARRELL E. MARET, FORMER SENIOR PROJECT MANAGER, DEMONSTRATION PROJECTS DIVISION, FEDERAL HIGHWAY ADMINISTRATION. Darrell was responsible for the application and evaluation of the polymer concrete overlay on the bridge over Big Swan Creek, and reviewed a draft of this report just before his death on June 25. We remember Darrell for his enthusiastic efforts to demonstrate the use of polymer concretes in structural applications.

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SUMMARY

The multiple-layer polymer concrete overlay on the Big Swan Creek Bridge was soundly bonded to the base concrete and providing excellent protection against the infiltration of chloride ions after 2 years in service.

Evaluations of this and PC overlays in Virginia have resulted in the state-of-the-art materials, installation techniques, and test methods presented in this report and believed to be necessary for the construction of polymer overlays that can provide a useful service life of 10 or more years.

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INTRODUCTION

This is the second and final report resulting from an agreement between the Federal Highway Administration (FHWA) Demonstration Projects Division and the Virginia Department of Highways and Transportation to construct and evaluate a multiple-layer polymer concrete (PC) overlay on a six-span bridge located on the Natchez Trace Parkway and spanning Big Swan Creek near Hohenwald, Tennessee.(1) The project was conducted under FHWA Demonstration Project No. 51, Bridge Deck Repair and Maintenance, which is directed to extending the service life of bridge decks.

The purposes of this report are to describe the condition of the PC overlay after 2 years of service life, to compare the condition of the overlay with that of the PC overlays constructed in Virginia, and to extend the knowledge concerning the potential of multiple-layer PC overlays for extending the service life of bridge decks. Data obtained from deck evaluations in Virginia and at Swan Creek are shown in Appendix A. The Virginia Department of Highways & Transportation state-of-the-art special provision for PC overlays is shown in Appendix B. Application equipment for multiple-layer PC overlays is shown in Appendices C, D, E, and F.

The PC overlay on the Big Swan Creek Bridge was installed on June 6, 7, 8, and 9, 1983, to restore grade, to provide a skid resistant wearing surface, and to provide a waterproof membrane, as well as to provide an opportunity to evaluate the installation and performance of a PC overlay constructed with a moderately high elongation polyester resin; namely, 317. The overlay differs from other PC overlays being evaluated by the author (2,3,4,5) in that the resin was supplied by a different distributor; the overlay was placed on portland cement concrete that was relatively new, less than 2 months old; and the geometry of the bridge was extreme in that the maximum slope exceeded 10%. The details of the installation and initial condition of the overlay can be found in the first report.(6) Tables A-1 and A-2 of Appendix A show general information and installation data for PC overlays that have been constructed in Virginia.

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CONDITION OF OVERLAY AFTER TWO YEARS

Delaminations

No delaminations in the deck were found by the FHWA prior to placing the PC overlay, with the exception of small areas in the vicinity of the expansion joints over piers 1 and 5 that had been blocked out by the contractor to facilitate installation of the expansion devices. These delaminations were removed when the expansion joints were installed. Although no delaminations were noted one week after the PC overlay was installed, small areas of delamination of the PC overlay were noted in the vicinity of the joint over pier 5 (the southernmost pier) when the deck was sounded with a chain drag in 1984 and 1985. Two other small areas of delamination were also found in the 1985 survey. Both were located in the left wheel path of the northbound lane (NBL), one in span 1 and one in span 3. The total area of delamination after 2 years in service was only approximately 1% of the overlay.

Experience indicates that delaminations caused by improper deck preparation or overlay installation will usually occur within the first year. Delaminations caused by thermal stresses and fatigue usually occur after the first year, and the time to delamination is a function of the properties of the resin and the initial condition of the overlay.(5) For example, overlays constructed with the brittle resins MMA and LB183 near Williamsburg, Virginia, in 1981 began to show significant delamination at an age of 4 1/2 years (bridge 1 -- 20%, 2 -- 5%, 3 -- 5%, 8 -- 60%, and 9 -- 0%). It is anticipated that the overlay on the Big Swan Creek Bridge will not show significant delamination for 10 years, since it was constructed with the flexible 317 resin.

Half-Cell Potentials

Copper sulfate half-cell potentials (ASTM C 876-77) were measured by the FHWA over the entire deck surface on May 14, 1983, prior to the installation of the PC overlay, and on June 12, 1985, two years after the installation. The results are shown in Table 1. The half-cell data imply that there was greater than a 90% probability that no corrosion was occurring in 99% of the reinforcing steel, which is reasonable since no deicing salts had been applied to the bridge. Table A-3 shows half-cell potential data collected for decks in Virginia with PC overlays. These data are reported for future reference.

TABLE 1

Electrical Half-Cell Potentials, Percentage of Total Number of Readings

		Range (-Volts CSE)		
Date	Overlay Age, wk	<0.20	0.20 to 0.35	>0.35
5/14/83	- 3	99	1	0
6/12/85	104	99	1	0

Electrical Resistivity

Electrical resistivity measurements (ASTM D 3633-77) were made by the FHWA over the entire deck surface in 1983 and 1984, and the results are reported in Table 2. All of the low readings recorded on June 13, 1983, were measured along the curbs and may have resulted from the water used in the test coming into direct contact with the unprotected concrete curb. If the readings along the curb are eliminated, the resistivity of the overlay within 1 week after the installation would appear to have been excellent, indicating that no shrinkage nor reflective cracks had formed. However, only 35% of the readings taken in 1984 were in the good range. In 1985 readings were taken only on spans 5 and 6, and the results indicated that after 2 years the PC overlay had cracked sufficiently to cause poor readings over 100% of the area tested. As can be seen from the data in Table A-4, the time to cracking for the 317 resin was between the 1 year found for the brittle LB183 resin and the 3 years found for the more flexible 90-570 resin.

TABLE 2

Electrical Resistivity, Percentage of Total Number of Readings

		Range of Electrical Resistivity, Ohms/ft^2			
Date	Age, wk	Poor $<10^4$	Fair 10^4 to $<10^6$	Good 10^6 to 10^8	Excellent $>10^8$
5/14/83	-3	100	0	0	0
6/13/83	1	0	41	1	58
5/01/84	46	31	34	35	0
6/12/85	104	100	0	0	0

Permeability

A rapid permeability test (AASHTO T 277) was used to determine the permeability to chloride ions of 4-in-diameter cores removed from the bridge. From the results shown in Table 3 it can be seen that the permeability of the PC overlay was increasing with age and after 2 years it was providing protection similar to that provided by a latex modified concrete overlay.(7) As can be seen from Table A-5, the performance of the 317 resin was better than that of the LB183 resin but worse than that of the 90-570.

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TABLE 3

Permeability to Chloride Ions of 4-in-Diameter Cores

Year	Coulombs
1983 (before overlay)	2,787
1983 (after overlay)	0
1984	513
1985	794

Shear Strength

To obtain an indication of the shear strength of the portland cement concrete and PC overlay composites, cores were subjected to two tests. In the first test, the shear force was directed through the bond interface; for the second, it was directed through the concrete approximately 1.0 in below the bond interface to gain an indication of the shear strength of the portland cement concrete base. The load was applied at 10,000 lb/min.

The results of tests conducted on six or more 2.75-in-diameter cores in 1983, 1984, and 1985 are shown in Table 4. It was obvious from the data in Table 4 that the overlay was soundly bonded after 2 years. In fact, data for other PC overlays shown in Table A-6 indicate that the in-service bond strength of the 317 resin was as good as that of the 90-570.

TABLE 4

Shear Strength of Cores from Swan Creek

Year	Location	Average Shear Strength, lb/in^2	Standard Deviation
1983	Base concrete	1,386	199
1983	Bond interface	1,186	232
1984	Bond interface	769	146
1985	Base concrete	1,392	204
1985	Bond interface	910	266

Comparative Performance of Resins

Table 5 shows data which can be used to compare the condition of the PC overlay on the Big Swan Creek Bridge through 2 years of service with that of PC overlays constructed with LB183 and 90-570 resins through 3 years of service. Some deterioration of the former occurred during the first 2 years due to shrinkage and thermal stress, but the performance was as would be expected for a polyester resin with a tensile elongation at yield of 23% (see Table A-7). The overlay had deteriorated less than the overlays constructed with resin LB183, which elongates 8%, and more than the overlay constructed with resin 90-570, which elongates 49%. For example, after 1 year in service the percentages of the electrical resistivity readings in the good-to-excellent range were 35%, 12%, and 89%, respectively, for overlays constructed with resins 317, LB183, and 90-570. Also, after 1 year in service the permeabilities to chloride ions were 513, 772, and 1 coulombs, respectively, for overlays constructed with the three resins. Finally, the strengths of the bonds at the interfaces after 1 year in service were 769, 436, and 730 lb/in^2, respectively. The ratios of the shear strengths of the bond interfaces after 1 year to the strengths immediately after the overlays were installed were 65%, 44%, and 75%, respectively.

TABLE 5

Comparative Performance of Resins

	1 Year			2 Years		3 Years	
Criteria	317	LB183	90-570	317	90-570	LB183	90-570
Resistivity readings = good to excellent, %	35	12	89	0	85	0	5
Permeability, coulombs	513	772	1	794	187	1809	412
Bond strength, lb/in^2	769	436	730	910	602	244	734
Bond strength at indicated year/bond strength new, %	65	44	75	77	62	32	76

Based on the data in Table 5, it appears that the majority of the deterioration of the overlay with the 317 resin occurred during the first year. For example, only the overlay constructed with the most flexible resin, 90-570, exhibited a high percentage of electrical resistivity readings in the good-to-excellent range after 1 year. In addition, the average bond strength of the overlay constructed with the 317 resin was 65% of the initial bond strength after 1 year and 77% after 2 years. Also, the permeability to chloride ions was 0 in 1983, 513 coulombs in 1984, and 794 coulombs in 1985. Although after 2 years the overlay with the 317 resin had a higher permeability than that with the 90-570 resin, it also had a higher bond strength. By comparison, after 3 years the overlays with the more brittle LB183 resin had a much higher permeability and a much lower bond strength than the overlay with the 90-570 resin. Based on the data in Table 5, it can concluded that after 2 years the Big Swan Creek overlay was soundly bonded and providing excellent protection against the infiltration of chloride ions, the overlay was performing as would be expected, a service life of 10 years seemed likely, and future overlays should be constructed with a resin with an elongation of from 20% to 50%, but preferably on the higher end of the range.

LABORATORY TEST METHODS FOR PREDICTING PERFORMANCE

The data collected indicate that the following tests provide the best indication of the performance to be expected from a PC overlay.

Tensile Elongation (ASTM D 638)

The data collected with ASTM D 638 are shown in Table A-7. Based on these data, the greater the elongation of the resin at break, the longer the time until electrical resistivity readings and shear bond strengths are low and permeabilities are high. The author has no experience with resins with elongations >50%.

Rapid Permeability Test (AASHTO T 277)

Data collected with the equipment shown in Figure 1 are presented in Table A-5. The data indicate that as an overlay ages and cracks the permeability increases. However, the test quantifies the cracking and shows that even a badly cracked overlay provides some protection against the infiltration of chloride ions and water.

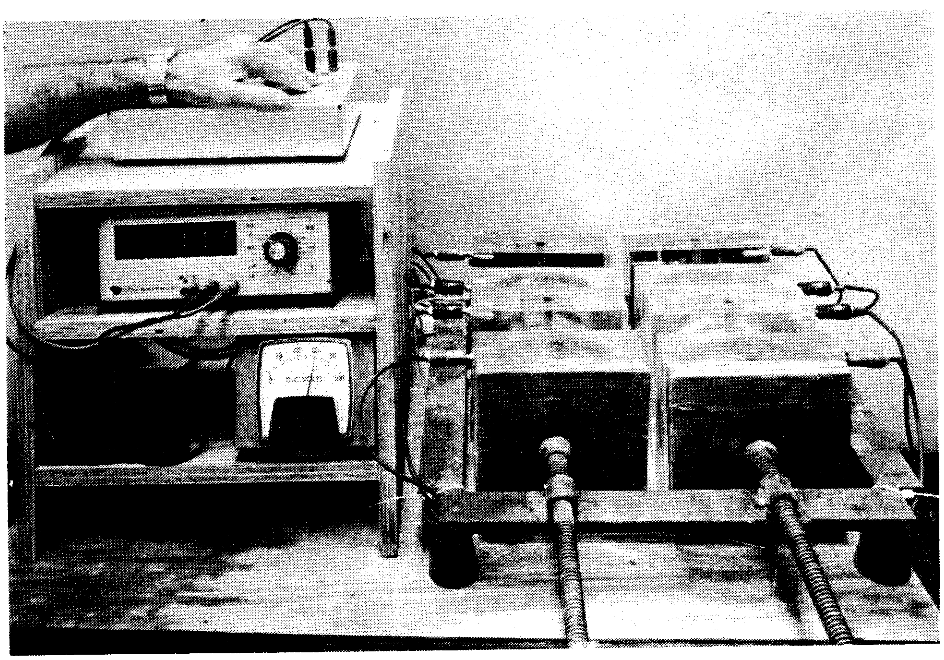


Figure 1. Apparatus used to test specimens for permeability to chloride ions.

Shear Bond Test

The shear bond test is being studied by AASHTO and is likely to be adopted soon. The test rig used is shown in Figure 2 and the data collected are shown in Table A-6. A typical standard deviation for the average of three tests of 2.75-in-diameter cores is 180 lb/in^2 for the bond interface and 130 lb/in^2 for the base. The data indicate that the bond between a high modulus PC overlay and the base concrete decreases as the overlay ages. On the other hand, the bond between a low modulus PC overlay and the base concrete decreases during the first year and then seems to reach an equilibrium.

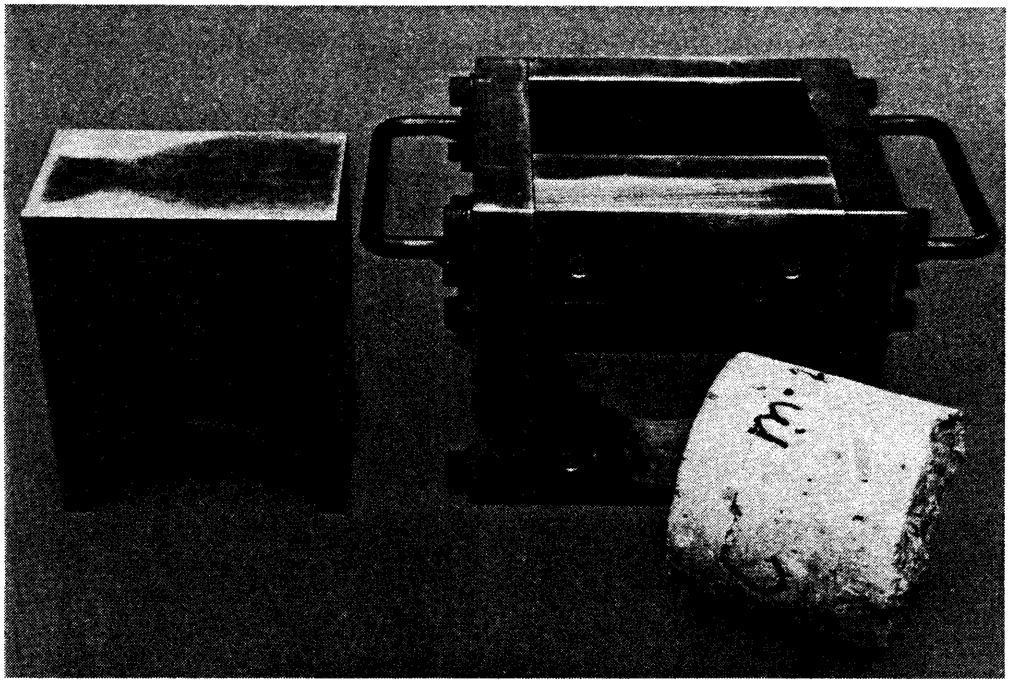
Tensile Bond Test (ACI 503R)

The apparatus used for the ACI 503R surface adhesion test is shown in Figure 3, and the data collected with it are shown in Table A-8 (excluding the data for HRW and HRE). Although no data were obtained for resin 317 by this method, it is believed that the test provides one of the best indications of the adequacy of surface preparation prior to the application of a first layer. This test is required by the Virginia Department of Highways and Transportation "Special Provision for Polymer Concrete Overlays" shown in Appendix B.

A modified version of the test can be conducted in the laboratory using a universal testing machine and the apparatus shown in Figure 4. A plate with a 3-in-diameter hole in the center is placed around the pipe cap to apply a tensile force to the concrete surface that is opposite to that provided by the pipe cap. Data collected with the modified version are shown in Tables A-8 (HRW, HRE), A-9, and A-10. A typical standard deviation for the average of three tests was 40 lb/in^2. The modified version of the test is useful for evaluating the surface of cores removed from a structure under consideration for an overlay. As shown by the data in Table A-9, an indication of the degree of cleaning needed to obtain a tensile bond strength greater than 250 lb/in^2 can be obtained by applying different degrees of cleaning to the surface of the cores prior to conducting the test. Also, it is obvious from the data in Table A-10 that acceptable bond strengths were obtained for all conditions except that in which the penetrating sealer was applied 24 hours prior to the application of the overlay. It's obvious that the strength of the base concrete affected the tensile bond strength, and, as would be expected, lower strength concretes caused lower tensile bond strengths. It is obvious that acceptable bond strengths can be obtained without the aid of additives or primers.

Thermal Cycling Test

The thermal cycling test involves subjecting cores or specimens having a diameter of up to 4 in to cycles of temperature change in air. The air temperature in the test chamber is fluctuated from 0°F to 100°F at the rate of 3 cycles per day for up to 100 days. Specimens are removed at different times throughout the test period and destructively tested for permeability and bond strength.



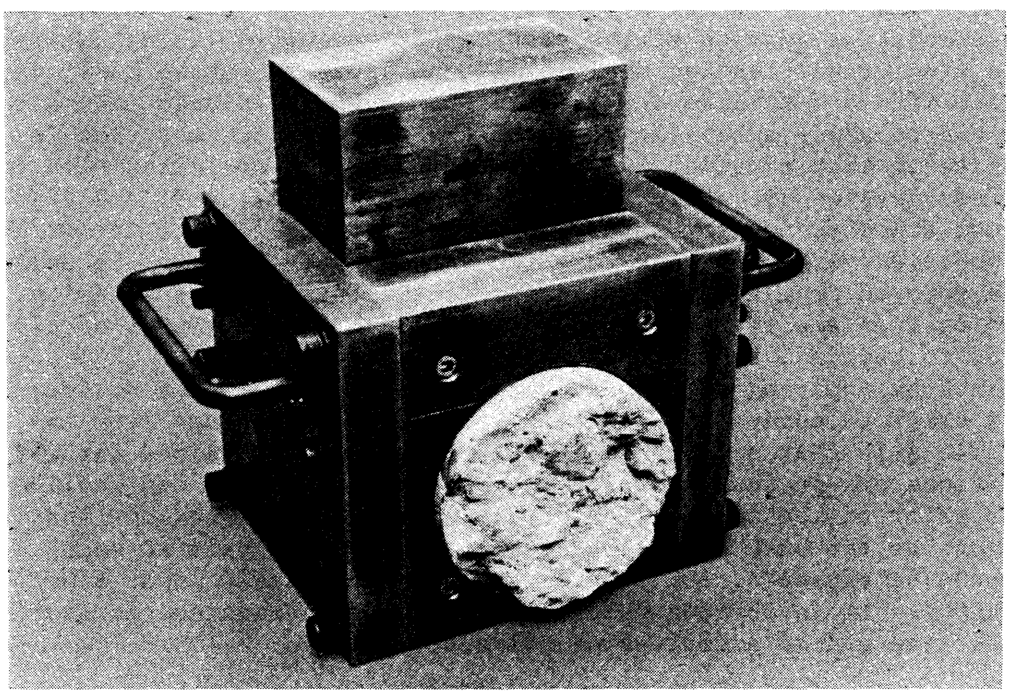


Figure 2. Apparatus used to subject cores to shear.

Figure 3. Apparatus used for ACI 503R surface adhesion test.

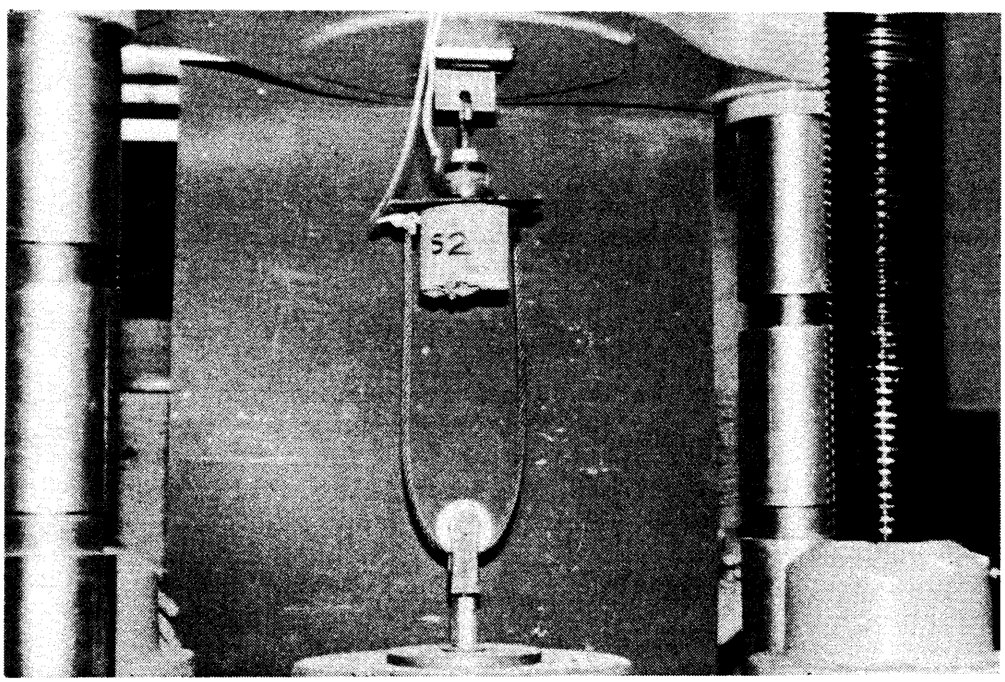


Figure 4. Apparatus used for measuring surface adhesion in the laboratory.

Experience indicates that tests of specimens subjected to cycles of temperature change can be used to model the service life of a PC overlay and possibly any composite that deteriorates due to thermal stress. For example, Figures 5 and 6 show the deterioration in the shear bond strength and the increase in the permeability, respectively, for specimens subjected to the thermal cycling test (dashed lines) and to natural thermal cycles that occur in service (solid lines). Note how the in-service performance of cores taken from the overlays constructed with resins 317, 90-570, and LB183, as shown in Figures 5 and 6, compares with the performance of cores taken from the structures when the overlays were new and subjected to the thermal cycles. The thermal cycle data in Figure 5 for the overlays constructed with the LB183 resin are based on tests of specimens for which the overlays were placed on the sandblasted surfaces of the cores in the laboratory. Based on the trends shown in Figures 5 and 6, it appears that 25 thermal cycles approximate 1 year of in-service deterioration in shear bond strength and that 75 thermal cycles approximate 1 year of in-service increase in permeability. Although one can argue that the test needs to be refined and that the correlation between cycles and years in service will likely vary with climatic conditions, the test has the potential to provide a model of the performance to be expected from a PC overlay and should be used to evaluate the relative performance of new PC overlay materials.

Table A-11 shows the results of tests conducted for shear bond strength and permeability to chloride ions on cores subjected to 200 thermal cycles. The cores were taken within weeks after the installation of the overlays. It is obvious from the data in the table that with the exception of resin XU40047, the more flexible resins provided the best performance when subjected to the test.

OTHER TESTS

Tables A-12 through A-17 show the results of other tests that have been conducted on PC overlays and the materials used in the overlays.

Skid Resistance

Skid numbers for tests at 40 mph are reported in Table A-12. Numbers in excess of 37 for the treaded tire and 20 for the bald tire are considered satisfactory. It is obvious from the data that the polymer overlays have continued to provide high skid numbers.

Rutting in the Wheel Paths

Data collected on rutting in the wheel paths are reported in Table A-13. It is obvious from the data that rutting was not a problem.

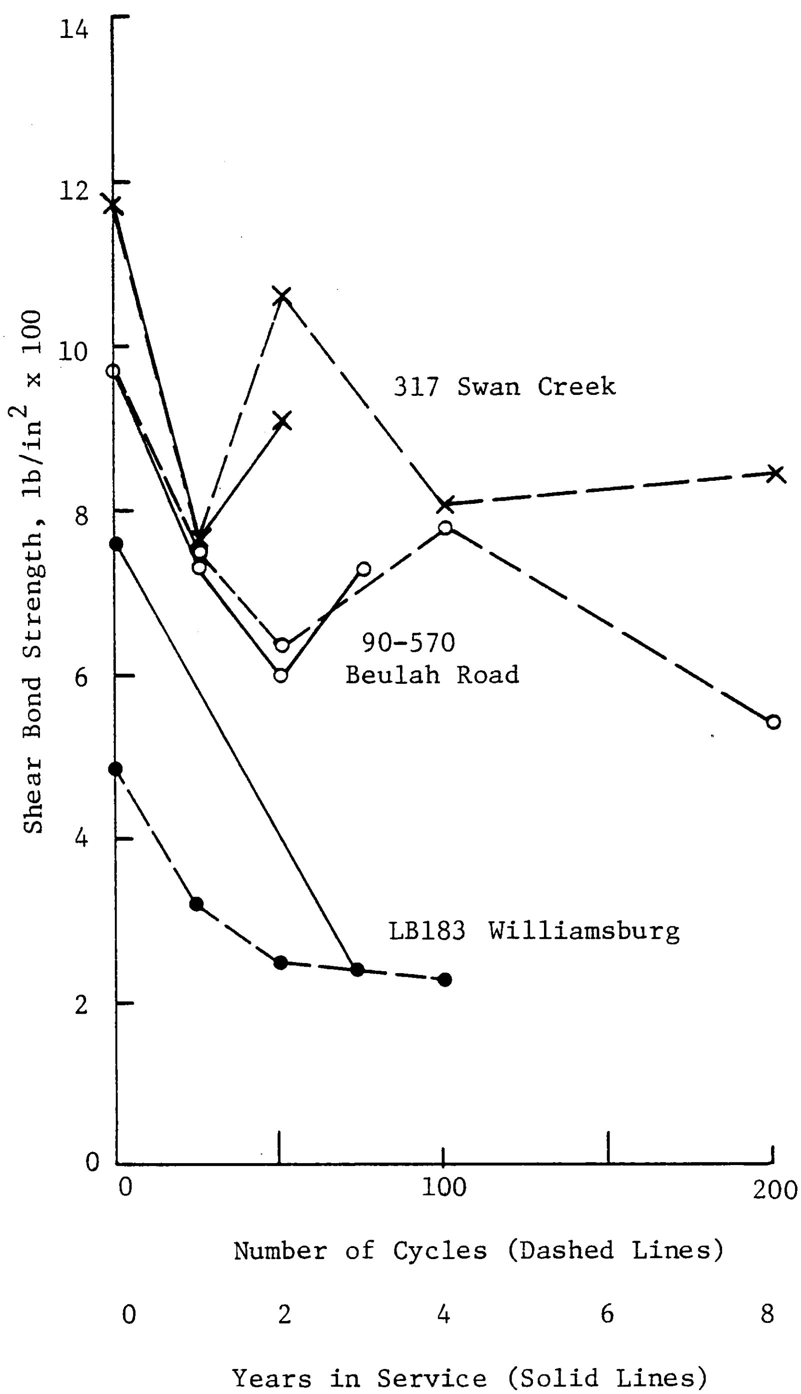


Figure 5. Shear strength as a function of number of thermal cycles and years in service (25 cycles = 1 year).

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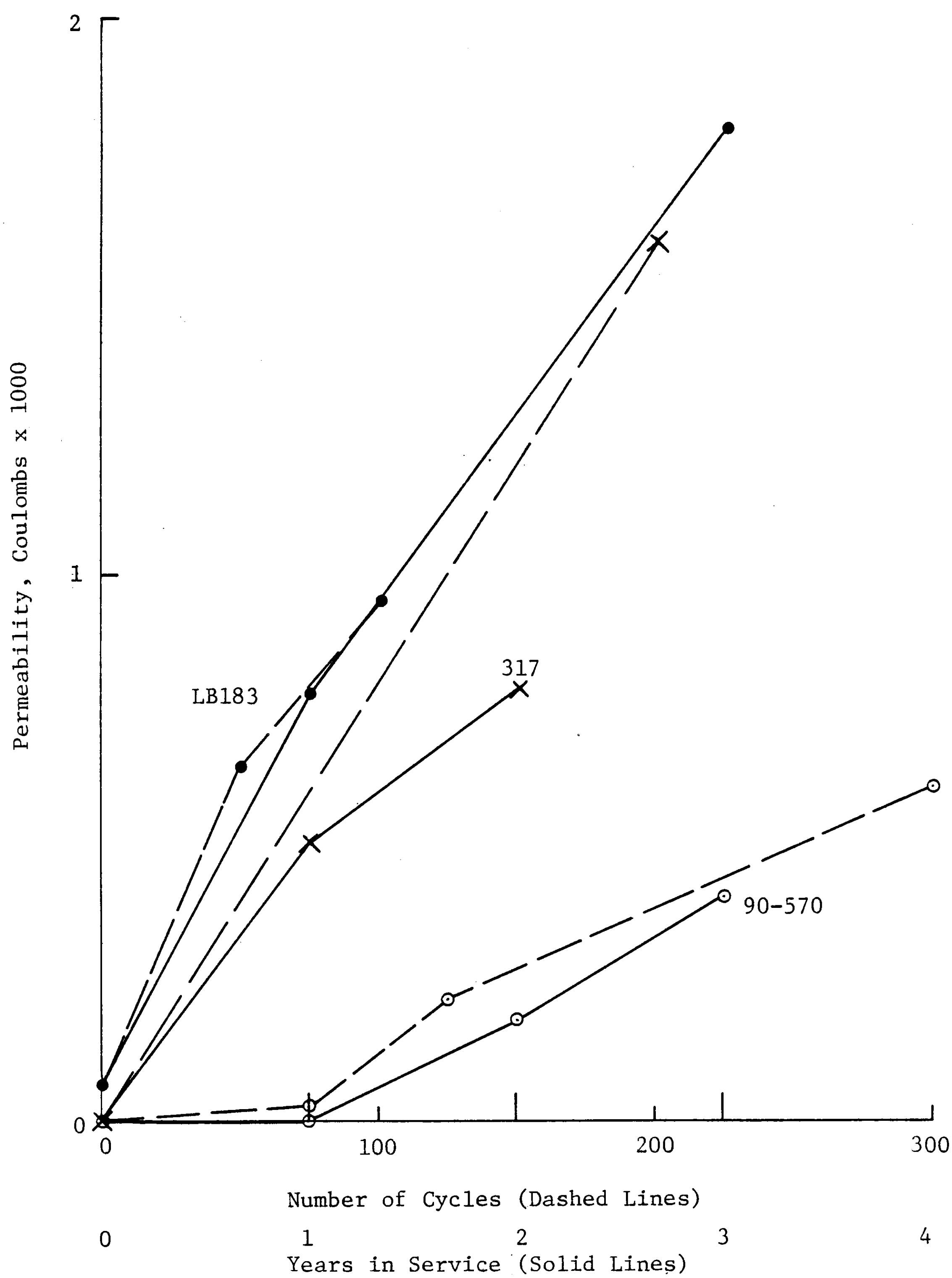

Figure 6. Permeability to chloride ions as a function of number of thermal cycles and years in service (75 cycles = 1 year).

Viscosity of Resins

The viscosity of the resin affects the penetration of the resin into the surface and the packing of the aggregate into the resin. Table A-14 shows values for viscosity for the resins used on the I-64 bridges over the Rivanna River and the SBL of the Beulah Road Bridge. The 92-339 resin has a higher viscosity than the 90-570 resin.

Properties of Overlay Based on Compression Tests

Seven cylindrical specimens were cast using 92-339 resin and the silica sand that is used for the first layer of a multiple-layer polymer overlay. The resin and sand mixture was mixed in the laboratory, placed in plastic cylinder molds, and consolidated on a vibrating table.

Compressive Strength

Four 4-in-by-8-in cylinders were tested in compression at 24 hours of age and found to have an average strength of 7,220 lb/in^2, with a standard deviation of 390 lb/in^2.

Compressive Modulus of Elasticity

At 28 days of age, tests were started to measure the relationship between the compressive modulus of elasticity and temperature.

Three 6-in-by-12-in specimens were stored overnight at the desired test temperature prior to testing. The specimens were tested in the following sequence: 73°F, 0°F, 122°F, 73°F, 35°F, and 100°F.

The data in Table A-15 show that the compressive modulus of elasticity increased as the temperature decreased. Also, the stress strain relationship for each loading condition is best described as two somewhat linear relationships. The first relationship is referred to as Young's Modulus and the second as the tangent modulus after the first break in the curve.

Poisson's Ratio

After the compressive modulus measurements were made, 4 specimens 2 in by 2 in by 4 in were cut from one of the 3 cylinders so that the Poisson's ratio could be measured at 73°F. Two of the specimens were saw cut so that the long axis was parallel to the axis of the 6-in-by-12-in cylinders and two were saw cut so that the long axis was perpendicular to the axis of the cylinder. The specimens were loaded parallel to their long axis and a clamp instrumented with strain gages was attached to the specimens to allow the measurement of strain in the longitudinal and transverse directions. The average values for Poisson's ratio were found to be -0.298 for the first pair of specimens (long axis of prism parallel to axis of cylinder) and -0.254 for the second pair. The average values for Young's Modulus, which were determined at the same time, were found to be 1.57 x 10^6 lb/in^2 (long axis of prism parallel to axis of cylinder) and 1.25 x 10^6 lb/in^2. These values are similar to those reported in Table A-15 for the cylinders after the break in the stress strain curve.

Freeze-Thaw Performance of Polymer Concrete

Tables A-16 and A-17 show the results of rapid freezing and thawing tests conducted on two groups of specimens using the Research Council's ASTM C 666 Procedure A method. The test deviates from ASTM C 666 in that the test water contains 2% NaCl. For the first group of specimens, overlays were cast on Class A4 portland cement concrete beams using the two resins that were placed on I-64 near Williamsburg. The specimens were different in that the quantity of sand broadcast into the resin was varied from 0 to 56 lb/yd^2. During the test the specimens were visually inspected periodically for cracks or delaminations in the bond between the overlay and the concrete. It is obvious from the data in Table A-16 that the LB183 resin must be sanded to excess to prevent complete delamination prior to 300 cycles. The MMA overlays did not delaminate completely after 300 cycles, but cracked extensively through the thickness of the overlay after a few cycles of freezing and thawing.

A second group of specimens (3 in by 4 in by 16 in) were fabricated using the 317 resin and different aggregates. Two specimens were cast with no aggregate, and the others were cast with as much aggregate as could be mixed with the resin, which was approximately 80% by weight of the specimen. Two were cast with the silica sand that is used in the first layer of a multiple-layer polymer overlay and two were cast with equal parts of 1 in maximum size gravel and silica sand, two were cast with a gneiss sand, and one was cast with equal parts of gneiss sand and a 1 in maximum size gneiss coarse aggregate. It is obvious from the data in Table A-17 that all of the polymer concretes exhibited excellent durability. In fact, the data in Table A-17 reflect the condition of the specimens after 300 cycles. The specimens were tested for a total of 750 cycles without a significant change in their condition.

CONCLUSIONS

1. The thin PC overlay on the Big Swan Creek Bridge provides further evidence that an overlay of low permeability can be soundly bonded to a concrete deck by maintenance forces with a minimal disruption to traffic.(6)

2. The overlay on the Big Swan Creek Bridge was soundly bonded to the base concrete and was providing excellent protection against the infiltration of chloride ions and water after 2 years in service.

3. Laboratory tests indicated that the 317 resin used on the Big Swan Creek Bridge had a high elongation as determined by ASTM D 638-80 but was not as flexible as the 90-570 resin used on one lane of the Beulah Road Bridge in Virginia. Because of the high elongation, overlays constructed with these resins are less likely to crack and show less deterioration in bond strength than overlays constructed with the brittle polyester resin LB183 and the brittle methyl methacrylate resin MMA.

4. When the cores from the overlay constructed with 317 were subjected to cycles of temperature change, the bond strength decreased and the permeability increased. Although a useful service life of 10 years seems reasonable, it will be necessary to monitor the performance of the Swan Creek Bridge overlay, as well as that of the overlays in Virginia, to obtain a more accurate projection of the useful service life.

5. A good indication of the performance to be expected from a PC overlay can be obtained by measuring the tensile elongation of the neat resin (ASTM D 638) and by testing specimens with PC overlays for permeability to chloride ions (AASHTO T 277) and bond strength in shear and direct tension after subjecting the specimens to a thermal cycling test. The tensile pull-off test prescribed by ACI 503R provides a good indication of surface adhesion and should be used prior to placing an overlay.

6. To develop the full potential of PC overlays, industry, government and academia must continue to work together to refine the materials, installation techniques, and test methods.

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The study was conducted under the direction of Howard Newlon, Jr., and with administrative guidance and support from Harry Brown.

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SI CONVERSION FACTORS

To Convert From	To	Multiply By
Length:		
in	cm	2.54
in	m	0.025 4
ft	m	0.304 8
yd	m	0.914 4
mi	km	1 . 609 344
Area:		
in^2	cm^2	6.451 600 E+00
ft^2	m^2	9.290 304 E-02
yd^2	m^2	8.361 274 E-01
mi^2	Hectares	2.589 988 E+02
acre (a)	Hectares	4.046 856 E-01
Volume:		
oz	m^3	2.957 353 E-05
pt	m^3	4.731 765 E-04
qt	m^3	9.463 529 E-04
gal	m^3	3.785 412 E-03
in^3	m^3	1.638 706 E-05
ft^3	m^3	2.831 685 E-02
yd^3	m^3	7.645 549 E-01
Volume per Unit Time:	NOTE: $1m^3$ = 1,000 L	
ft^3/min	m^3/sec	4.719 474 E-04
ft^3/s	m^3/sec	2.831 685 E-02
in^3/min	m^3/sec	2.731 177 E-07
yd^3/min	m^3/sec	1.274 258 E-02
gal/min	m^3/sec	6.309 020 E-05
Mass:		
oz	kg	2.834 952 E-02
dwt	kg	1.555 174 E-03
lb	kg	4.535 924 E-01
ton (2000 lb)	kg	9.071 847 E+02
Mass per Unit Volume:		
lb/yd^2	kg/m^2	4.394 185 E+01
lb/in^3	kg/m^3	2.767 990 E+04
lb/ft^3	kg/m^3	1.601 846 E+01
lb/yd^3	kg/m^3	5.932 764 E-01
Velocity: (Includes Speed)		
ft/s	m/s	3.048 000 E-01
mi/h	m/s	4.470 400 E-01
knot	m/s	5.144 444 E-01
mi/h	km/h	1.609 344 E+00
Force Per Unit Area:		
lbf/in^2 or psi	Pa	6.894 757 E+03
lbf/ft^2	Pa	4.788 026 E+01
Viscosity:		
cS_t	m^2/s	1.000 000 E-06
P	Pa·s	1.000 000 E-01
Other:		
ohm/ft^2	ohm/m^2	1.080 000 E+01
lb/min	kg/min	4.356 000 E-01

Temperature: (°F-32)^5/9 = °C

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APPENDIX A

Data on Multiple-layer PC Overlays Constructed in Virginia and at Swan Creek, Tennessee

Source: Progress Report on HPR study 2160 "Evaluation of the Construction and Performance of Polymer Concrete Overlays on Five Bridges," May 5, 1986.

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TABLE A-1

General Information

Bridge No.	Location	Str. No.	Resin	Resin Supplier	Contractor	Date of Inst.	Contract Quantity, yd^2	Cost, $\$/yd^2$
-	Rte. 629 over Cowpasture River	6030	LB183	USS Chem.	Charles W. Barger	10/80	250±	-
W-8	I-64 over Rte. 143, WBL	2807	LB183	USS Chem.	Luke Const./ Con.Repair Specialists	6/81	1,508	41.00
W-3	EBL	2806	LB183	"	"	6/81	1,508	41.00
W-9	I-64 over C&O, WBL	2001	LB183	"	"	8/81	1,074	41.00
W-2	I-64 EBL	2000	LB183	"	"	8/81	1,156	41.00
W-1	I-64 over 143, EBL	2002	MMA	DuPont	"	9/81	1,088	54.00
BRN	Rte. 675 over Dulles Airport Road, NBL	6232	LB183	USS Chem.	VDHT, FHWA, FAA	5/82	600	12.00 (Matls.only)
BRS	SBL	6232	90-570	Reichhold Chem.	"	5/82	600	12.00 (Matls.only)
RRET	I-64 over Rivanna River, TL EBL	2047	92-339	Reichhold Chem.	Marvin V. Templeton & Sons, Inc./Polymer Systems	4,5, 6/85	2,359	25.50
RREP	PL EBL	2047	XU40047	Dow Chem.	"	4,5/85	2,358	25.50
RRW	I-64 WBL	2048	92-339	Reichhold Chem.	"	4,5,6/85	4,944	25.50
HRW	I-64 over Hampton Roads, WBL	2900	92-339	"	"	7,8/85	5,500	28.75
HRE	EBL	2866	92-339	"	"	7,8,9/ 85	13,334	28.75
-	I-95 SBL Ramp over I-495	2025	92-339	"	Marboro Const.Co./ Polymer Sys.	9,10/85 85	741	57.00
-	Rte. 123 over I-95, NBL	1072	92-339	"	Jewell Painting, Inc.	10/85	1,005	34.00
-	SBL	1071	92-339	"	"	10/85	714	34.00
-	Rte. 620 over 495, WBL	6212	92-339	"	"	10/85	1,425	36.00
-	Rte. 7 over Rte. 50, EBL	1035	92-339	"	Dural Int.	10,11/85	587	34.00
-	WBL	1043	92-339	"	"	10,11/85	493	34.00
-	Frontage Rd over Rte. 50	1042	92-339	"	"	10,11/85	195	34.00

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TABLE A-2

Installation Data for PC Overlays

Bridge No	Average Surface Temp., °F	Average Resin App. Rate, lb/yd²	Average MEKP Dosage, %	Average Gel Time, min.
W-8	97 (86)*	10.7 (1.7)	3.2 (3.3)**	13 (16)
W-3	90 (80)	10.0 (1.9)	3.6 (4.0)**	15 (18)
W-9	85 (74)	10.7 (2.2)	4.5 (4.2)**	11 (16)
W-2	80 (75)	10.5 (2.2)	5.2 (4.8)**	11 (15)
W-1	66 (61)	10.1 (2.1)	3.0 (3.8)**	12 (13)
BRN	77 (74)	11.5 (2.6)	1.2 (1.2)	16 (15)
BRS	81 (81)	10.7 (2.3)	1.2 (1.2)	18 (18)
RRET	97 (85)	10.5 (2.2)	2.3 (2.9)	12 (19)
RREP	88 (93)	9.9 (1.9)	2.4 (2.9)	8 (6)
RRW (TL)	99 (103)	10.3 (2.2)	2.3 (2.6)	12 (12)
RRW (PL)	103 (100)	10.1 (2.4)	2.1 (2.2)	14 (11)
HRW	78 (80)	9.6 (1.9)	2.2 (2.2)	10 (11)
HRE	77 (76)	9.8 (1.8)	2.3 (2.4)	10 (11)
Rte. 123 NBL	71 (71)	10.1 (1.7)	2.1 (2.0)	15 (14)
Rte. 123 SBL	70 (72)	10.4 (1.7)	2.2 (2.0)	13 (15)
Rte. 620	59 (65)	10.5 (2.0)	2.5 (2.5)	20 (14)
I-95 RAMP	55 (68)	11.2 (2.0)	-- --	14 (11)
Front Road over Rte. 50	62 (52)	-- (1.8)	-- --	17 (18)

* Numbers in parentheses are data for first layer

** BPO-40

TABLE A-3

Electrical Half-Cell Potentials, Percentage of Total Number of Readings, 1981-85

		Range (-Volts CSE)														
	Deck	<0.20					0.20 to 0.35					>0.35				
Bridge	Surface	81	82	83	84	85	81	82	83	84	85	81	82	83	84	85
W-1	MMA	94	79	-	92	-	6	20	-	8	-	0	1	-	0	-
W-2	LB183	98	96	-	97	-	1	4	-	3	-	1	0	-	0	-
W-3	LB183	98	86	-	98	-	2	14	-	2	-	0	0	-	0	-
W-4	Concrete	98	94	-	97	-	1	6	-	3	-	1	0	-	0	-
W-5	Bituminous	96	77	-	71	-	3	13	-	27	-	1	10	-	2	-
W-6	Bituminous	99	-	-	97	-	0	-	-	3	-	1	-	-	0	-
W-7	Concrete	100	-	-	100	-	0	-	-	0	-	0	-	-	0	-
W-8	LB183	95	93	-	95	-	5	7	-	5	-	0	0	-	0	-
W-9	LB183	94	100	-	99	-	6	0	-	1	-	0	0	-	0	-
BR	90-570	-	100	100	-	93	-	0	0	-	7	-	0	0	-	0
BR	LB183	-	100	99	-	-	-	0	1	-	-	-	0	0	-	-
SC	317	-	-	99	-	99	-	-	1	-	1	-	-	0	-	0
RR	92-339	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RR	XU40047	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE A-4

Electrical Resistivity, Percentage of Total Number of Readings

Bridge	Deck Surface	Poor $<10^4$					Fair 10^4 to $<10^6$					Good 10^6 to 10^8					Excellent $>10^8$				
		81	82	83	84	85	81	82	83	84	85	81	82	83	84	85	81	82	83	84	85
1	MMA	0	100	-	99	-	23	0	-	1	-	11	0	-	0	-	66	0	-	0	-
2	LB183	0	24	-	100	-	4	73	-	0	-	1	3	-	0	-	95	0	-	0	-
3	LB183	0	38	-	85	-	12	55	-	15	-	16	7	-	0	-	72	0	-	0	-
4	Concrete	91	100	-	100	-	9	0	-	0	-	0	0	-	0	-	0	0	-	0	-
5	Bituminous	4	24	-	2	-	36	34	-	73	-	13	9	-	14	-	47	33	-	11	-
6	Bituminous	1	0	-	0	-	29	0	-	58	-	25	0	-	26	-	45	0	-	16	-
7	Concrete	100	0	-	90	-	0	0	-	10	-	0	0	-	0	-	0	0	-	0	-
8	LB183	0	44	-	78	-	9	26	-	22	-	53	30	-	0	-	38	0	-	0	-
9	LB183	0	46	-	97	-	5	52	-	3	-	9	2	-	0	-	86	0	-	0	-
Avg.	LB183	0	38	-	90	-	7	52	-	10	-	20	10	-	0	-	73	0	-	0	-
BR	90-570	-	1	0	0	0	-	2	11	15	95	-	13	78	84	5	-	84	11	1	0
BR	LB183	-	0	2	-	-	-	6	80	-	-	-	15	17	-	-	-	79	1	-	-
SC	317	-	-	0	31	100	-	-	41	34	0	-	-	1	35	0	-	-	58	0	0
RR	92-339	-	-	-	-	0	-	-	-	-	2	-	-	-	-	4	-	-	-	-	94
RR	XU40047	-	-	-	-	0	-	-	-	-	0	-	-	-	-	6	-	-	-	-	94

Range of Electrical Resistivity, ohm/ft²

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TABLE A-5

Permeability, Coulombs

idge	Deck Surface	1981	1982	1983	1984	1985
·1	Concrete[a]	6974	-	-	-	-
·2	Concrete[a]	6109	-	-	-	-
·1	MMA	216	1331	-	1339	-
·2	LB183	12	384	-	-	-
·3	LB183	167	3607	-	3252	-
·4	Concrete	3100	-	-	-	-
·5	Bituminous[b]	69	-	-	-	-
·6	Bituminous[c]	6349	-	-	-	-
·7	Concrete	2494	-	-	-	-
·8	LB183	200	747	-	1892	-
·9	LB183	37	370	-	962	-
·Avg.	LB183	62	787	-	1809	-
·Avg.	Concrete 1,2,6	6467	-	-	-	-
	90-570	-	1	1	187	412
	LB183	-	3	713	-	-
-90-570	Concrete	-	2124	-	-	4303
-LB183	Concrete	-	2308	-	-	-
	317	-	-	0	513	794
	Concrete	-	-	2787	-	-
-92-339		-	-	-	-	29
-XU40047		-	-	-	-	92
-92-339	Concrete	-	-	-	-	7378
-XU40047	Concrete	-		-	-	6986

Base concrete prior to overlay.

Concrete after removing bituminous overlay.

Concrete after removing bituminous overlay and rubberized asphalt membrane.

TABLE A-6

Shear Bond Strength, lb/in^2

Bridge No.	Deck Surface	1981 Concrete New[a]	1981 Concrete Old	1981 Bond Interface New and Old	1982 Concrete Old	1982 Bond Interface Old	1983 Concrete New	1983 Concrete Old	1983 Bond Interface New	1983 Bond Interface Old	1984 Concrete New	1984 Concrete Old	1984 Bond Interface New	1984 Bond Interface Old	1985 Concrete New	1985 Concrete Old	1985 Bond Interface New	1985 Bond Interface Old
W-1	MMA	1404	921	–	–	–	–	–	–	–	838	774	335	271	–	–	–	–
W-2	LB183	838	774	1125	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W-3	LB183	1124	730	469	–	–	–	–	–	–	470	573	222	187	–	–	–	–
W-4	Concrete	–	597	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W-5	Bituminous	660	565	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W-6	Bituminous	774	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W-7	Concrete	–	884	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
W-8	LB183	832	541	776	–	–	–	–	–	–	1046	808	678	137	–	–	–	–
W-9	LB183	860	541	681	–	–	–	–	–	–	1245	794	84	282	–	–	–	–
W-Avg.	LB183	923	690	763	–	–	–	–	–	–	920	725	328	202	–	–	–	–
BR	90-570	–	–	–	812	972	–	823	–	730	–	763	–	602	–	950	–	734
BR	LB183	–	–	–	804	1001	–	838	–	436	–	–	–	–	–	–	–	–
SC	317	–	–	–	–	–	1386	–	1168	–	–	–	769	–	1392	–	910	–
RREB	92-339	–	–	–	–	–	–	–	–	–	–	–	–	–	–	980	–	793
RREB	XU40047	–	–	–	–	–	–	–	–	–	–	–	–	–	–	771	–	582
HRW	92-339	–	–	–	–	–	–	–	–	–	–	–	–	–	–	794	–	519
HRE	92-339	–	–	–	–	–	–	–	–	–	–	–	–	–	–	695	–	750

[a] Concrete was placed the same year the overlay was placed.

TABLE A-7

Tensile Properties of Resins (ASTM D 638)

Resin	Age	Tensile Strength, lb/in²		Elongation at Break, %		Young's Modulus, lb/in²x10⁴	
		x	s	x	s	x	s
LB183	1 wk	5089	1928	8.0	3.8	7.81	0.91
"	1 yr	4270	972	5.9	1.9	7.45	0.72
90-570	1 wk	2836	373	49.2	11.4	3.52	0.21
"	1 yr	2586	157	41.3	7.0	3.04	0.91
MMA	1 wk	1427	525	2.3	0.4	6.29	1.39
"	1 yr	1410	267	2.3	0.2	6.04	0.94
317	1 wk	2858	301	23.3	8.1	4.69	0.99
EP5LV	1 wk	4797	626	12.5	1.2	6.60	1.56
"	1 yr	760	29	52.2	5.1	0.87	0.04
Flexogrid	1 wk	1489	179	89.9	13.9	0.57	0.01
"	1 yr	1406	-	49.0	-	1.42	-
92-339	1 wk	3728	156	23.4	4.7	4.86	0.76
XU40047	1 wk	2570	67	28.8	5.5	3.47	0.22

Source: Data supplied by Richard Steele, Physical Lab Engineer, Virginia Department of Highways & Transportation.

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TABLE A-8

Tensile Bond Strength, lb/in^2

Bridge	Deck Surface	81	82	83	84	85
W-Avg.	LB183	175	156	--	--	--
BRN	LB183	--	337	241	--	--
BRS	90-570	--	268	266	--	134
RRET	92-339	--	--	--	--	353
TS-1	92-339	--	--	--	--	241
TS-2	92-339	--	--	--	--	287
TS-2	XU-40047	--	--	--	--	218
RREP	XU40047	--	--	--	--	90
HRW	92-339	--	--	--	--	175
HRE	92-339	--	--	--	--	220

TABLE A-9

Effect of Surface Preparation of Cores on Tensile Bond Strength

	Tensile Bond Strength, lb/in^2, for Indicated Bridge		
Surface Preparation	HRW	Rte. 360/Dan River	Rte. 7/Shenandoah River
Air blasted	78 (98)*	54 (100)	320 (34)
Sandblasted	237 (1)	352 (48)	319 (0)
Saw cut at 3/8-in depth	278 (5)	318 (7)	279 (5)

* Numbers in parentheses are the percentages of the failed areas at the bond line.

TABLE A-10

Effect of Additives, Primers, and Surface Condition on Tensile Bond Strength and Failure Condition

			Base Concrete 28-Day Compressive Strength, lb/in^2								
			7350			5450			2200		
Test Condition	No. Spec.	Average Strength, lb/in^2	Strength, lb/in^2	Failure, % base	Failure, % bond	Strength, lb/in^2	Failure, % base	Failure, % bond	Strength, lb/in^2	Failure, % base	Failure, % bond
No A174 No S440	4,7,4	308	369	32	30	315	6	24	239	68	25
Control	3,6,4	310	355	37	19	330	40	18	244	76	18
E-bond sealer	3,6,3	159	179	11	87	149	12	88	149	8	90
Saturated at test	3,3,3	241	258	18	50	265	33	25	200	92	5
Damp at overlay	0,3,0	--	--	--	--	291	23	53	--	--	--
PCM 200 primer	4,4,4	306	321	29	16	388	45	7	210	47	8
PCM 1100 primer	4,4,4	302	327	30	10	328	69	12	252	96	3
PCM 200 primer No A174 No S440	4,4,4	345	364	2	14	422	35	12	248	84	15
PCM 1100 primer No A174 No S440	3,3,3	335	353	0	0	329	7	3	322	100	0

NOTE: These data were developed by George Kelsey to partially satisfy his requirements for Materials Science Laboratory Course MS-692. Tests were conducted on one-layer overlays placed on the saw cut surfaces of slices of 4-in-x-8-in cylinders of concrete having three different 28-day compressive strengths. The overlays were constructed with silica sand and 317 resin with 1% S440 and 1% A174 unless noted otherwise.

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TABLE A-11

Performance of Cores from Bridges After 200 Thermal Cycles

Bridge	Deck Surface	Shear Bond Strength, lb/in^2	Permeability, coulombs
W-Avg.	LB183	--	950[(a)]
BRN	LB183	609	1846[(b)]
BRS	90-570	544	609[(b)]
SC	317	854	1596
RRET	92-339	620	996
RREP	XU40047	85	2426
W-1	MMA	--	2100[(a)]

(a) 100 cycles

(b) 300 cycles

TABLE A-12

Skid Numbers for Tests at 40 MPH, 1980-1985

		Treaded Tire												Bald Tire											
		Travel Lane						Passing Lane						Travel Lane						Passing Lane					
Bridge	Deck Surface	80	81	82	83	84	85	80	81	82	83	84	85	80	81	82	83	84	85	80	81	82	83	84	85
W-1	MMA	46	59	53	--	45	--	49	60	54	--	49	--	26	56	38	--	42	--	22	54	43	--	48	--
W-2	LB183	46	64	58	--	45	--	51	63	57	--	52	--	24	63	46	--	43	--	22	62	46	--	50	--
W-3	LB183	45	63	57	--	46	--	53	58	61	--	54	--	25	62	43	--	41	--	33	60	50	--	52	--
W-4	Concrete	46	43	48	--	63[a]	45	50	46	51	--	65[a]	--	27	27	24	--	52[a]	28	24	24	23	--	60[a]	--
W-5	Bituminous	45	43	42	--	39	--	44	43	44	--	45	--	41	27	23	--	28	--	41	25	20	--	32	--
W-6	Bituminous	46	49	45	--	41	--	44	47	49	--	47	--	41	25	20	--	24	--	44	30	20	--	36	--
W-7	Concrete	47	47	51	--	58[a]	46	50	48	52	--	66[a]	--	30	27	28	--	46[a]	30	24	28	26	--	58[a]	--
W-8	LB183	46	59	55	--	48	--	48	64	55	--	54	--	25	58	42	--	44	--	23	64	45	--	52	--
W-9	LB183	47	62	56	--	47	--	52	61	59	--	55	--	23	60	44	--	41	--	24	60	50	--	53	--
W-Avg.	LB183	46	62	56	--	46	--	51	62	58	--	54	--	24	61	44	--	42	--	26	61	48	--	52	--
BR	90-570	--	--	55	56	--	49	--	--	--	--	--	--	--	--	49	45	--	38	--	--	--	--	--	--
BR	LB183	--	--	53	58	--	--	--	--	--	--	--	--	--	--	47	49	--	--	--	--	--	--	--	--
RR	92-339	--	--	--	--	--	62	--	--	--	--	--	--	--	--	--	--	--	56	--	--	--	--	--	--
RR	XU40047	--	--	--	--	--	--	--	--	--	--	--	64	--	--	--	--	--	--	--	--	--	--	--	59
HRW	92-339	--	--	--	--	--	43	--	--	--	--	--	42	--	--	--	--	--	42	--	--	--	--	--	40
HRE	92-339	--	--	--	--	--	47	--	--	--	--	--	48	--	--	--	--	--	45	--	--	--	--	--	45

[a] EP5-LV epoxy overlay installed in 1984.

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TABLE A-13

Rutting in Wheel Paths, 1/32 in

Bridge	Deck Surface	Year	Passing Lane Left	Passing Lane Right	Traffic Lane Left	Traffic Lane Right	Average
W-1	MMA	1982	0.0	0.4	0.1	0.2	0.2
		1984	(0.4)[a]	0.4	0.0	0.1	0.0
W-2	LB183	1982	1.8	0.1	0.6	0.3	0.7
		1984	1.8	0.1	(0.1)	0.5	0.6
W-3	LB183	1982	0.8	0.0	(0.9)	0.8	0.2
		1984	0.8	0.6	(0.2)	0.7	0.5
W-4	Concrete	1982	0.1	0.0	0.7	0.5	0.3
		1984	0.0	(0.1)	1.4	0.6	0.5
W-5	Bituminous	1982	0.8	0.6	0.6	1.1	0.8
		1984	0.6	0.4	0.8	1.3	0.8
W-6	Bituminous	1982	---	---	---	---	---
		1984	0.7	0.3	0.7	1.2	0.7
W-7	Concrete	1982	---	---	---	---	--
		1984	(0.9)	1.1	(0.8)	(0.8)	(0.4)
W-8	LB183	1982	0.3	1.1	0.2	0.0	0.4
		1984	0.6	2.7	(1.2)	1.2	0.8
W-9	LB183	1982	0.3	1.7	0.9	0.5	0.9
		1984	0.3	0.1	0.8	1.4	0.7
W-Avg.	LB183	1982	0.8	0.7	0.2	0.4	0.5
		1984	0.9	0.9	(0.2)	1.0	0.7
BRS	90-570	1982	---	---	(2.4)	1.5	(0.5)
		1983	---	---	(2.5)	1.3	(0.6)
		1985	---	---	(2.4)	1.1	(0.6)
BRN	LB183	1982	---	---	(0.5)	1.0	0.3
		1983	---	---	(0.7)	0.8	0.1
RRET	92-339	1985	---	---	(0.6)	2.4	0.9
RREP	XU40047	1985	(1.6)	(0.1)	---	---	(0.9)

[a] Relatively higher in wheel path.

TABLE A-14

Viscosity of Resins (ASTM 2393)

Resin	Brookfield Viscosity at 77°F, cP
90-570	143
92-339	205
XU40047	145

TABLE A-15

Compressive Modulus of Elasticity at Several Temperatures

Test Temp., °F	Young's Modulus, lb/in² x 10^6		Modulus after Break, lb/in² x 10^6	
	x	s	x	s
0	3.03	0.38	2.62	0.05
35	2.29	0.51	1.93	0.23
73	1.92	0.71	1.29	0.23
73	1.92	0.22	1.50	0.10
100	0.49	0.12	0.42	0.11
122	0.27	0.08	0.20	0.07

TABLE A-16

Freeze-Thaw Performance of Portland Cement Concrete Beams with Multiple-Layer Polymer Overlays

Resin	Aggregate, lb/yd^2	Cycles to First Crack in Bond Line	Cycles to Complete Delamination
LB183	0	52	145
"	14	83	208
"	28	>300	>300
"	56	>300	>300
MMA	0	52	>300
"	14	>300	>300
"	28	>300	>300
"	56	>300	>300

TABLE A-17

Freeze-Thaw Performance of Polymer Concrete Beams Cast with 317 Resin

Mixture	Weight Loss, %	Surface Rating	Durability Factor, %
Neat	0.08	0	106
Silica fine agg.	.00	0	92
Silica fine and coarse agg.	.14	0	97
Gneiss fine agg.	.11	0	88
Gneiss fine and coarse agg.	0.00	0	90

APPENDIX B

Virginia Department of Highways & Transportation Special Provision for PC Overlays

2492

VIRGINIA DEPARTMENT OF HIGHWAYS AND TRANSPORTATION
SPECIAL PROVISION FOR
POLYMER CONCRETE OVERLAY

March 26, 1986

I. DESCRIPTION -

This work shall consist of furnishing and applying thin polymer concrete overlays on designated bridge structures in accordance with this specification and in reasonably close conformity with the lines, grades and details shown on the plans or established by the Engineer.

II. DEFINITION OF TERMS -

A. Monomer as used herein is a low viscosity, liquid organic material from which a polymer is made.

B. Polymers are hard glassy solids commonly called plastics.

C. Polymerization is a chemical process by which a monomer is converted to a polymer.

D. Inhibitors are materials that are added to monomers to prevent polymerization from occurring during shipping and storage.

E. Initiators are chemical materials that are required to start the polymerization process.

F. Promoters are chemicals used to accelerate the polymerization process.

III. MATERIALS -

A. Polymer Materials:

1. Monomers Polyester Resin -

A clear, low viscosity, highly resilient, general purpose, unsaturated polyester resin designed for applications requiring toughness and high impact and shall have a viscosity of 100 to 200 cP at 77°F (25°C) using Spindle 1 at 60 RPM on a Brookfield Model LVT viscometer, a tensile elongation of 20-40% (ASTM D638) and, equal to Reichhold Chemicals, Inc. blend Polylite 90-570. The first course shall contain 1% of Union Carbide A-174 coupling agent and 1% of Surfynol S440 wetting agent to enhance bond strength and to reduce surface tension. The second and third courses shall contain a minimum of 0.5% of Union Carbide A-174 coupling agent and a minimum of 0.5% of Surfynol S440 wetting agent.

2. Initiators -

a. Methyl Ethyl Ketone Peroxide (MEKP) $C_4H_8O_2$ and BPO-40 shall consist of a 60% MEKP in dimethyl phthalate with approximately 9% active oxygen and with a Specific Gravity of 1.15 at 64°F (18°C), shall be in a liquid state with a water white color, with a flash point (Cleveland Open Cup) of above 180°F (82°C) and with a mildly thermal decomposition point (rapid rise) at 302°F (150°C).

b. 40% Benzoyl Peroxide Dispersion (BPO-40) shall be either Reichhold Chemicals, Inc. formulation 46-742, or Witco Chemical's formulation BZQ-40.

(Continued)

3. Promoters -

(a) N,N, Dimethyl Aniline (DMA) $C_6H_4N(CH_3)_2$ shall have a technical grade freezing point of 35.8°F (2.1°C), a percentage purity of 98.9 mole, a maximum monomethyl aniline content of 0.5%, a density of 8 lb./gal. (0.96 g/cc), a refractive index of 1.5581.

(b) Cobalt Naphthenate (CoN) shall contain approximately 6% active cobalt in naphtha, shall be in a liquid state with a bluish red color, with a flash point at or above 121°F (49°C), and with a density of 7.5 lb./gal. (0.90 g/cc).

B. Aggregate Materials shall consist of clean, dry with less than 1% moisture, angular grained silica sand and shall be free from dirt, clay, asphalt and other organic materials. Except as otherwise approved by the Engineer, silica sand shall conform to the following gradation for the grading specified:

Grading	No.8 Sieve	No.12 Sieve	No.16 Sieve	No.20 Sieve	No.30 Sieve	No.100 Sieve
A	95 - 100	----	Max. 15	Max. 5	Max. 2	Max. 1
D	-----	95 - 100	30 - 70	Max. 10	Max. 3	Max. 1

Note: Numbers indicate percent passing U.S. Standard Sieve Series.

IV. INITIATOR-PROMOTER FORMULATIONS -

A. Polymers:

1. Polyester Resin

Property	Mix No.1	Mix No.2	Mix No.3
Temperature range, °F	65 - 75	75 - 90	65 - 90
**Initiator Concentration, percent of monomer by weight	1.2% MEKP	0.6% MEKP	2.5% BPO-40
Promoter Concentration, percent of monomer by weight	0.5% CoN	0.25% CoN	0.3% DMA

** The quantity of initiator is affected by mixing efficiency and temperature, and may vary from day to day. The quantity of initiator shall be determined at the beginning of each day. Gel time should be between 10 and 20 minutes when tested using a container which will produce a depth of approximately 1 to 1½ inches when filled with 50 ml of resin.

Ungelled portion of overlay course represented by a test Gel which has not gelled within 30 minutes shall be removed immediately and replaced at no additional cost to the Department.

V. CONSTRUCTION METHODS -

A. Safety Provisions:

Personnel shall be thoroughly trained in the safe handling of materials in accordance with the Manufacturer's recommendations.

B. Storage of Materials:

Information pertaining to the safe practices for the storage, handling and disposal of the materials and to their explosive and flammability characteristics, health hazards and the recommended fire fighting equipment shall be obtained from the manufactures and posted at storage areas. All required fire fighting equipment shall be kept readily accessible at storage areas. A copy of such information shall be provided to the Engineer.

In addition:

1. Monomers -

   Monomers shall be stored in an area separate from the areas in which the initiator is stored. Sufficient ventilation shall be maintained in the storage area to prevent the hazardous buildup of monomer vapor concentration in the storage air space.

2. Initiators -

   The MEKP and BPO-40 initiators shall be stored in a cool place away from the monomer and promoter storage area.

3. Promoters -

   Storage of the promoters DMA and CoN shall be in a cool place away from the initiator storage area.

C. Surface Preparation:

Before placement of the polymer concrete overlay, the entire deck surface shall be cleaned by shotblasting and other means to remove asphaltic material, oils, dirt, rubber, curing compounds, paint, carbonation, laitance, weak surface mortar and other potentially detrimental materials, which may interfere with the bonding or curing of the overlay. Acceptable cleaning is usually achieved by significantly changing the color of concrete and mortar and beginning to expose coarse aggregate particles. Mortar which is sound and soundly bonded to the coarse aggregate must have open pores due to cleaning to be considered adequate for bond. Areas of asphalt larger than one inch in diameter, or smaller areas spaced less than six inches apart, shall be removed. Traffic paint lines shall be considered clean when the concrete has exposed aggregate showing through the paint stripe. A vacuum cleaner shall be used to remove all dust and other loose material.

Prior to placing the first course on a lane span, the contractor shall use the test method prescribed in ACI 503R - Appendix A of the ACI Manual of Concrete Practice to demonstrate that the surface is sufficiently clean to provide a tensile bond strength greater than or equal to 250 psi or a failure area, at a depth of ¼ in. or more into the base concrete, greater than 50% of the test area. The engineer will designate the test area(s) on each lane span. If a test fails, the contractor may conduct a second test without additional cleaning. If the second test fails, the contractor shall reclean and retest the failed lane span until a satisfactory test result is obtained. If prior to placing the first course, traffic must be placed on a lane span that has a passing test result, the lane span must be cleaned again. If the first course is not placed within seven days of the passing test result, the span shall be cleaned and tested again to demonstrate that the surface is sufficiently clean.

All patching and cleaning operations shall be inspected and approved prior to placing each layer of the overlay. Any contamination of the deck or to intermediate courses, after initial cleaning, shall be removed. Subjecting any overlay course to traffic for more than seven days, without other evidence of contamination, shall be considered as having contaminated the surface. The first course shall be applied following the cleaning and prior to opening the area to traffic. Subsequent courses shall be placed as soon as practicable.

There shall be no visible moisture present on the surface of the concrete at the time of application of the polymer concrete overlay. Compressed air may be used to dry the surface of the deck.

D. Equipment and Demonstration Test:

The Contractor's equipment shall consist of no less than a polymer distribution system, fine aggregate spreader, broom and sweeper broom or vacuum truck, and a source of lighting if work will be performed at night. The distribution system or distributor shall accurately blend the monomer and initiator/promoter, and shall uniformly and accurately apply the polymer materials at the specified rate to the bridge deck in such a manner as to cover approximately 100% of the work area. The fine aggregate spreader shall be propelled in such a manner as to uniformly and accurately apply the dry silica sand to cover 100% of the polymer material. The sweeper broom or vacuum truck shall be self-propelled.

Prior to beginning the polymer concrete overlay operation, the Contractor shall conduct a demonstration test on a strip of pavement provided by the Department to duplicate and fine-tune the procedures for placing the polymer concrete overlay. The demonstration test strip shall be at least 10 feet wide by 50 feet long, and shall be a minimum of 2 layers thick. The first layer shall be a course 1 application and the second layer shall be a course 3 application. The Contractor shall demonstrate to the satisfaction of the Engineer that the proposed equipment and personnel have the reliability and experience to perform the work in a uniform and consistent manner. In the event the Contractor does not complete the demonstration test or fails to show that the proposed equipment and personnel have the required reliability and experience to perform the work, the Contractor shall make such necessary changes in equipment and personnel and shall repeat the demonstration test until the aforementioned requirements have been met, at no additional cost to the Department.

E. Application of Polymer Concrete Overlays:

The handling, mixing and addition of promoters, initiators and monomers shall be performed in a safe manner to achieve the desired results in accordance with the manufacturer's recommendations as approved or directed by the Engineer. Polymer concrete overlay materials shall not be placed when weather or surface conditions are such that the material cannot be properly handled, placed and cured within the specified requirements of traffic control.

The polymer concrete overlay shall be applied in 3 separate courses in accordance with the following rate of application; the total of the 3 applications shall not be less than 6.25 lbs. per square yard.

Course	Polymer Rate (Lb./S.Y.)	Silica Sand (Lb./S.Y.)*
1	1.75 ± 0.25	Grading D; 17 ±
2	2.25 ± 0.25	Grading A; 17 ±
3	2.75 ± 0.25	Grading A; 17 ±

* Application of sand shall be of sufficient quantity to completely cover the polymer.

After the polymer mixture has been prepared for the polymer concrete overlay, it shall be immediately and uniformly applied to the surface of the bridge deck. The first course polymer mixture shall be broomed into the deck surface immediately following application. The temperature of the bridge deck surface shall be above 40°F. The dry silica sand shall be applied in such a manner as to cover the polymer mixture completely within 5 minutes. First course applications which do not receive enough sand prior to gel shall be removed and replaced. Second and third courses insufficiently sanded may be left in place, but will require additional applications before opening to traffic. The polymer concrete overlay shall be cured at least one hour, or until brooming or vacuuming can be performed without tearing or otherwise damaging the surface and no traffic or equipment shall be permitted on the overlay surface during the curing period. After the curing period, all loose silica sand shall be removed by brooming or vacuuming and the next overlay course applied to completion.

Unless otherwise specified the polymer concrete overlay courses shall be applied over the expansion joints of the bridge deck. The expansion joints shall be provided with a bond breaker. Prior to opening any application to traffic, the overlay shall be removed over each joint by removal of tape, bond breakers, or by scoring the overlay prior to gelling, or by saw cutting after cure.

The Contractor shall plan and prosecute the work so as to provide a minimum of 3 hours cure prior to opening that section to public or construction traffic, unless otherwise permitted. Night operations, or other times of slow curing, the minimum time shall be increased to 4 hours cure prior to opening to traffic.

In the event the Contractor's operation damages or mars the polymer concrete overlay course(s), the Contractor shall remove the damaged area(s) by saw-cutting in rectangular sections to the top of the concrete deck surface and shall replace the various courses in accordance with the Specifications in a manner acceptable to the Engineer at no additional cost to the Department.

In the event the Contractors method of operation or polymer mixture is outside the limitations provided herein, the overlay as placed will be removed to the satisfaction of the Engineer. The Contractor shall demonstrate the reliability of his revisions at the Demonstration Site at no additional cost to the Department before proceeding.

VI. METHOD OF MEASUREMENT -

Polymer concrete overlay will be measured in square yards of bridge deck surface for the type specified, complete-in-place.

Polymer concrete overlay demonstration test will be paid for on a lump sum basis, wherein no measurement will be made.

Repairing of the deck and removing bituminous overlay will be measured and paid for in accordance with Section 416 of the Specifications.

VII. BASIS OF PAYMENT -

Polymer concrete overlay will be paid for at the contract unit price per square yard, which price shall be full compensation for deck preparation and testing for furnishing and applying polymer concrete overlay courses, for all safety precautions, for any necessary repairs, for saw-cutting expansion joints, and for all materials, labor, tools, equipment and incidentals necessary to complete the work.

Polymer concrete overlay demonstration test will be paid for at the contract lump sum price, which price shall be full compensation for the successful completion of the demonstration test, and for all materials, labor, tools, equipment and incidentals necessary to complete the work.

Payment will be made under:

PAY ITEM	PAY UNIT
Polymer Concrete Overlay	Square Yard
Polymer Concrete Overlay Demonstration Test	Lump Sum

-2497

APPENDIX C

SHOTBLAST EQUIPMENT AND SUPPLIERS

2498

Shotblast Equipment Suppliers

Company	Address	Telephone Number
Blastrac	Rte. 130 Yardville, New Jersey 08620	(609) 585-4811
Nelco Manufacturing Inc.	P. O. Box 774 715 E. Reno Oklahoma City, OK 73104	Telex #796056
Turbo Blast	7192 N. Washington Thornton, Colorado 80229	(303) 289-4680
Mike Swain	P. O. Box 1606 Ruston, LA 71270	(318) 255-6396
Douglas Call Co., Inc.	5741 Bayside Road Virginia Beach, Virginia 23455	(804) 460-3336

Figure C-1. Shotblast equipment cleans deck at rate of 12 yd^2/min. Smaller unit removes paint lines (Rivanna River).

Figure C-2. Shotblast equipment cleans 7-ft-wide path (Rivanna River).

2500

Figure C-3. Deck surface is prepared with shotblasting equipment which cleans at rate of 2 yd^2/min and cleans 20-in-wide path (Beulah Road).

APPENDIX D

RESIN APPLICATION

2502

Figure D-1. Spray gun application of resin (Rte. 123 over I-95).

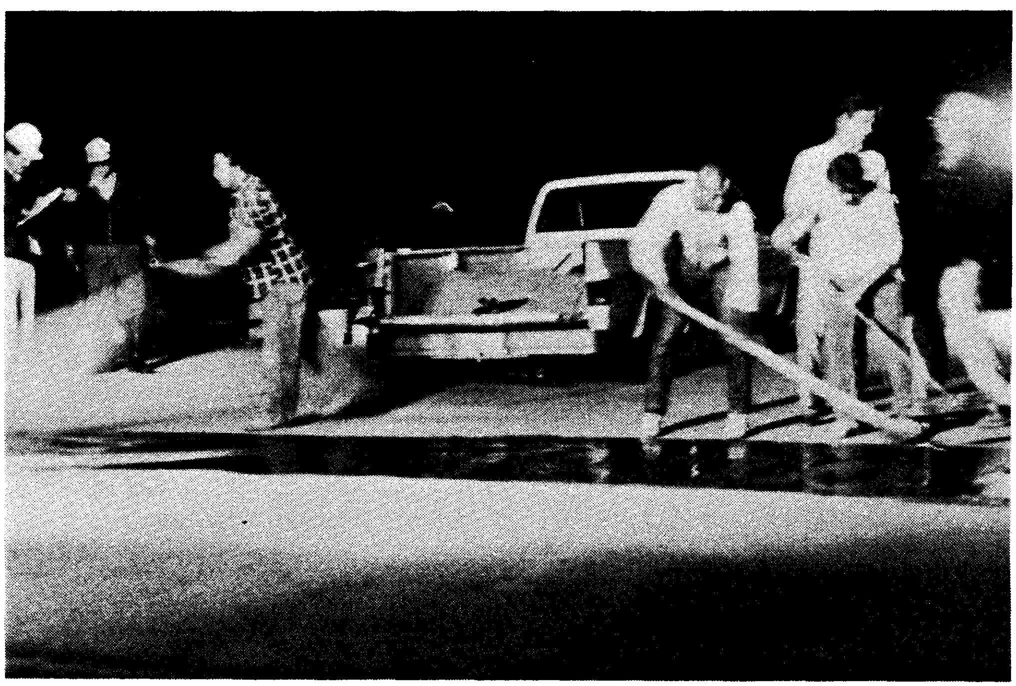

Figure D-2. Hand application of resin and aggregate (frontage road over Rte. 50)

2503

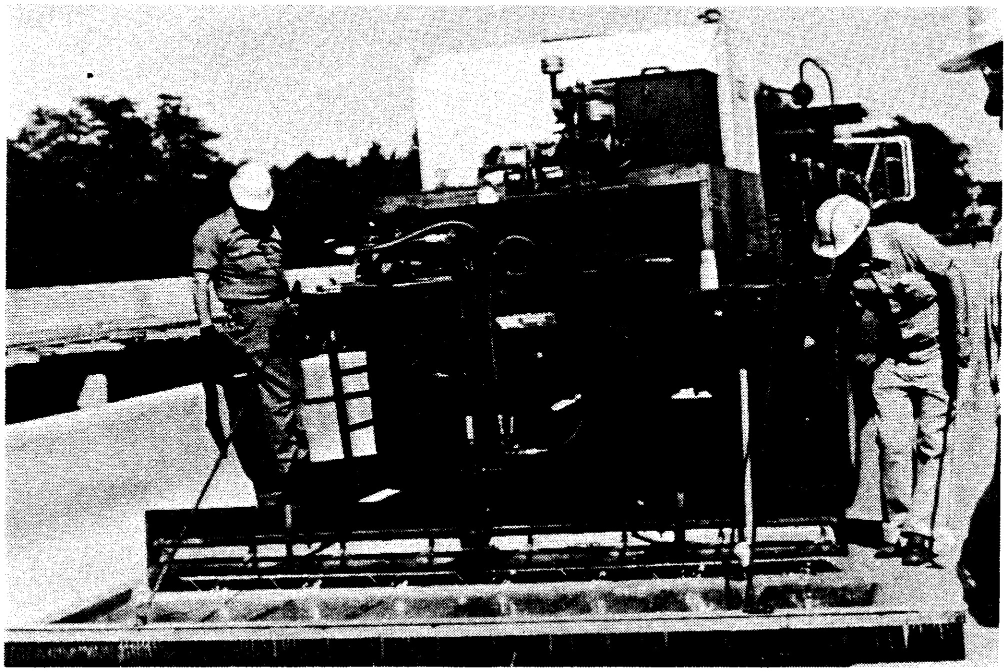

Figure D-3. Application of resin with spray bar. Broom brushes first layer into concrete (Williamsburg).

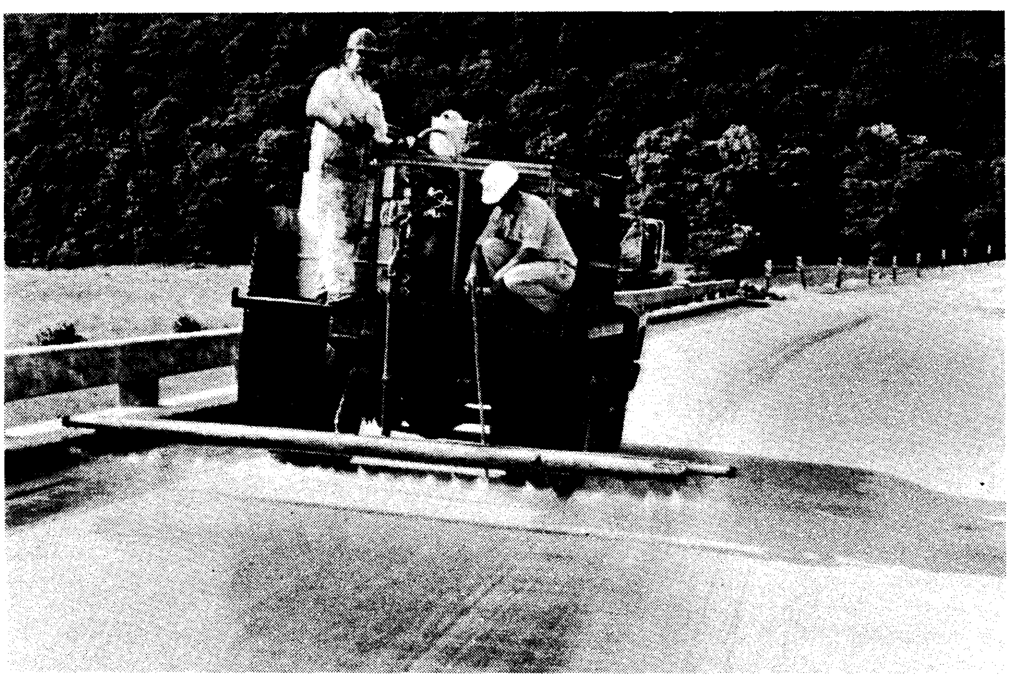

Figure D-4. Application of resin with spray bar (Swan Creek).

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APPENDIX E

AGGREGATES -- SOURCES AND APPLICATION

Sources of Sand

Company	Address	Telephone Number
Jesse S. Morie & Son, Inc.	1201 N. High Street Millville, New Jersey 08332	(609) 327-4500
Whitehead Brothers Company	P. O. Box 259 River Road Leesburg, New Jersey 08327	(609) 785-2090
Foster-Dixiana Sand, Inc.*	P. O. Box 5447 Columbia, South Carolina 29250	(803) 794-2872

* Sand was not used in overlays which were evaluated.

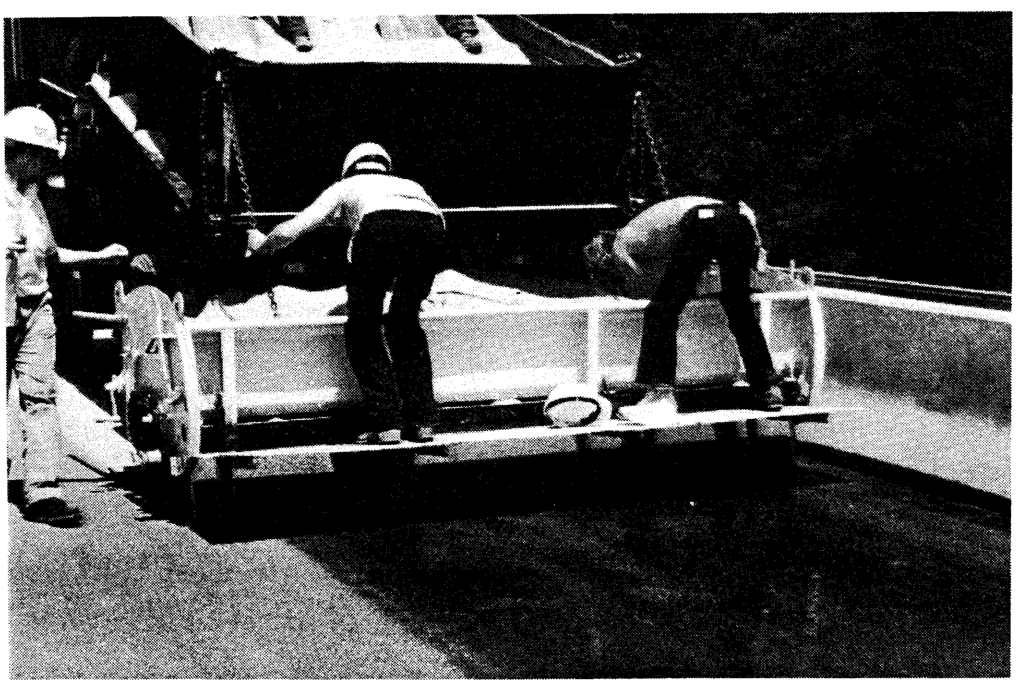

Figure E-1. Silica aggregate is broadcast over resin using dump truck and chip spreader (Williamsburg).

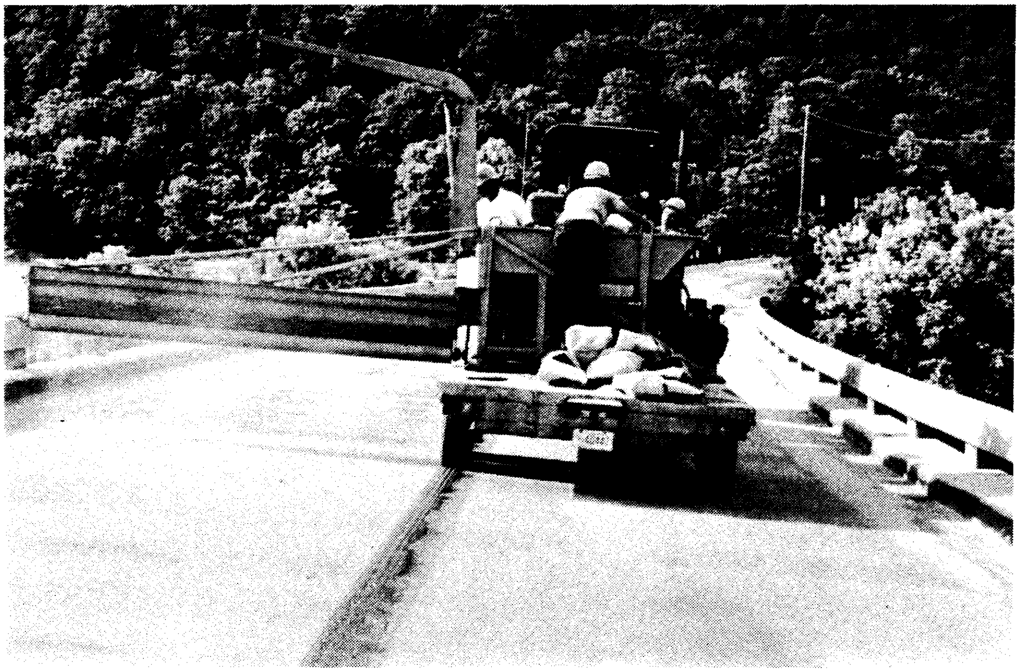

Figure E-2. Application of aggregate with wing spreader (Swan Creek).

Figure E-3. Aggregate is blown into air with sandblasting equipment. (Rte. 123 over I-95).

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APPENDIX F

MISCELLANEOUS

Figure F-1. Sweeper-broom type vacuum truck removes excess aggregate (Williamsburg).

Figure F-2. Bulk storage of resin and aggregate (Rivanna River).

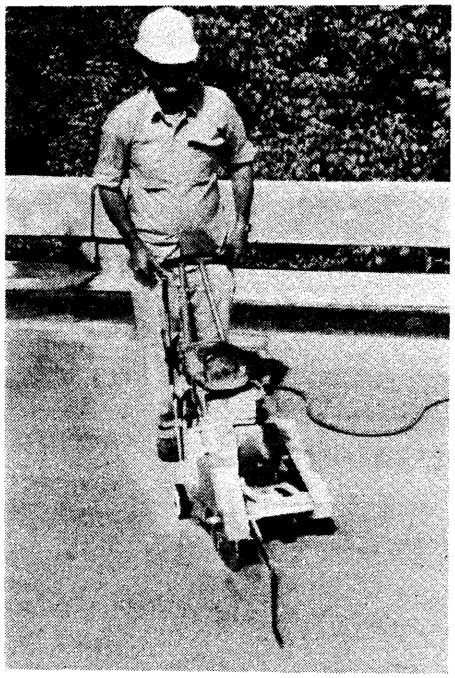

Figure F-3. Overlay must be saw cut over joints (Swan Creek).

2512