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FINAL REPORT

POLYMER CONCRETE OVERLAY ON BEULAH ROAD BRIDGE

- Condition of Overlay After One Year in Service -

by

Michael M. Sprinkel
Research Scientist

Virginia Highway & Transportation Research Council
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SUMMARY

An evaluation of the thin polymer concrete overlay placed on the Beulah Road bridge indicates that the overlay is securely bonded to the base concrete and is providing low permeability and high skid resistance after 1 year of service life. The lane constructed with 90-570 resin is more flexible and therefore is providing better protection than the lane constructed with LB183 resin. It is recommended that the performance of the lane constructed with the 90-570 resin be monitored over a 10-year period and that the Department use a resin comparable to 90-570 in the construction of needed polymer concrete overlays.

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INTRODUCTION

This is the second and final report resulting from agreements between the Federal Highway Administration (FHWA) Demonstration Projects Division and Implementation Division, the Virginia Department of Highways and Transportation, and the Federal Aviation Administration for the construction and evaluation of a thin polymer concrete (PC) overlay on bridge no. 6232 on Route 675 (Beulah Road) over the Dulles International Airport Access Highway in Fairfax County, Virginia. The project was conducted under FHWA Demonstration Project No. 51, Bridge Deck Repair and Maintenance, which is directed to the extension of the service life of bridge decks.

The purpose of this report is to reflect the condition of the PC overlay after 1 year of service life and the knowledge gained of the potential of thin PC overlays for extending the service life of bridge decks.

The overlay was installed on May 4, 5, 6, and 7, 1982, and the details of the installation and initial condition of the overlay can be found in the first report.(1) The northbound lane was constructed with LB183 resin and the southbound lane with 90-570 resin. This present report presents the data reflecting the performance of the two resins during the first year of service life.

The first part of the report deals with the bond between the overlay and the deck concrete and attempts to answer the question, How long will the overlay stay down? The next part deals with the protection provided by the overlay and attempts to address the question, How well is the overlay preventing the infiltration of water and salt and thereby preventing corrosion of the reinforcing steel? The third part compares the tensile properties of the resins and notes how these properties affect the performance of the PC overlays.

STRENGTH OF BONDS

Shear Strength

To obtain an indication of the shear strengths of the portland cement concrete base and the bond at the interface between the PC overlay and the base, cores were subjected to two tests. For one test, the shear force was directed through the bond interface; for the second it was directed through the concrete approximately 2.5 in. (6.4 cm) below the bond interface to obtain an indication of the shear strength of the portland cement concrete. The load was applied at 10,000lb./min. (4356 kg/min.) with the rig shown in Figure 1.

Table 1 shows the shear strength and the types of failures for cores taken from the Beulah Road bridge in 1982 and in 1983. Although the cores taken in 1982 were 2.75 in. (7.0 cm) in diameter and those in 1983 were 4.0 in. (10.2 cm), there is no evidence that the difference in size affected the results. As can be seen from the table there was no significant difference between the shear strengths for the portland cement concrete but the 1983 strengths for the bond interface were lower than those for 1982. Of particular significance is the deterioration in strength for the bond of the LB183 resin during the first year. Whereas the strength of this bond was greater than that of the base concrete in 1982, in 1983 it had decreased an average of 56% to a value only 52% that of the base concrete. The bond for 90-570 resin experienced a 25% loss in strength during the first year, but the strength was still 89% that of the base concrete. The loss in shear strength may be attributed to the thermal stress that developed during the 1 year in service and that can be expected to continue.

The modes in which the cores failed in the shear tests also provided evidence that the strength of the bond deteriorated during the first year. In 1982 the only failures were in the base concrete; in 1983,failures were noted in the bond interface, the base concrete, and sometimes in both.

Further evidence of the breakdown in shear strength with cycles of temperature change is shown in Figure 2, which shows the results of shear tests on specimens prepared in the laboratory at the Research Council. The concrete base of each specimen consisted of a section 4 in. (10.2 cm) in diameter and 2.25 in. (5.7 cm) thick cut from a 4-in. (10.2-cm) x 8-in. (20.4-cm) cylinder. The base concretes were fabricated to have four different 28-day compressive strengths as shown in Figure 2. A PC overlay constructed with 90-570 resin was placed on one sawn concrete surface of each specimen. Fine aggregate was applied to the overlays in an excessive amount (approximately 56 lb./yd.^{2} [30 kg/m^2]) and at rates of 0 and 14 lb./yd.^{2} (0 and 7.6 kg/m^2). The curves are based on the averages of tests on two specimens of concrete representing each level of design strength and subjected to either 0, 10, or 24 thermal cycles. The cycles were applied at the rate of 1 per day with the temperature changing from 0°F.(-18°C) to 100°F. (38°C).

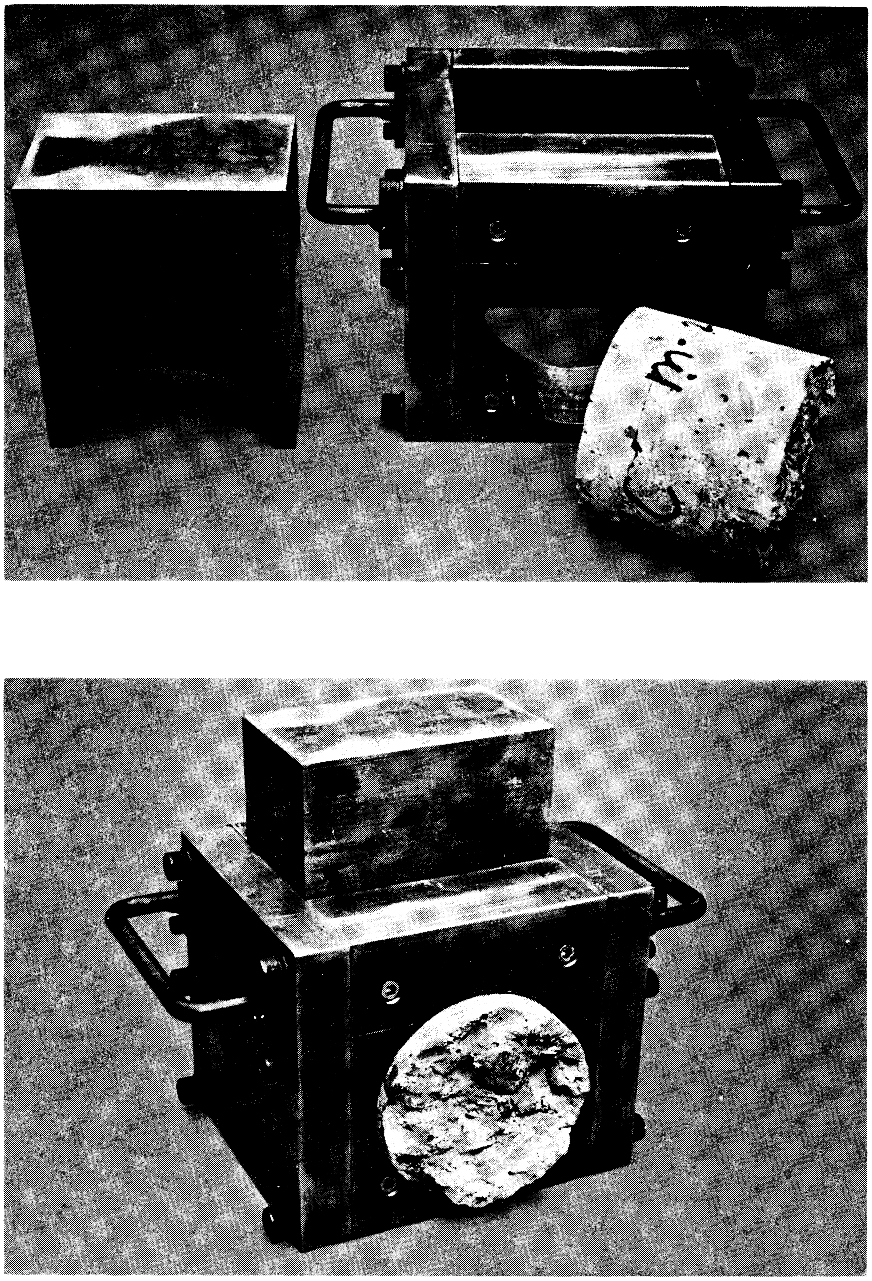


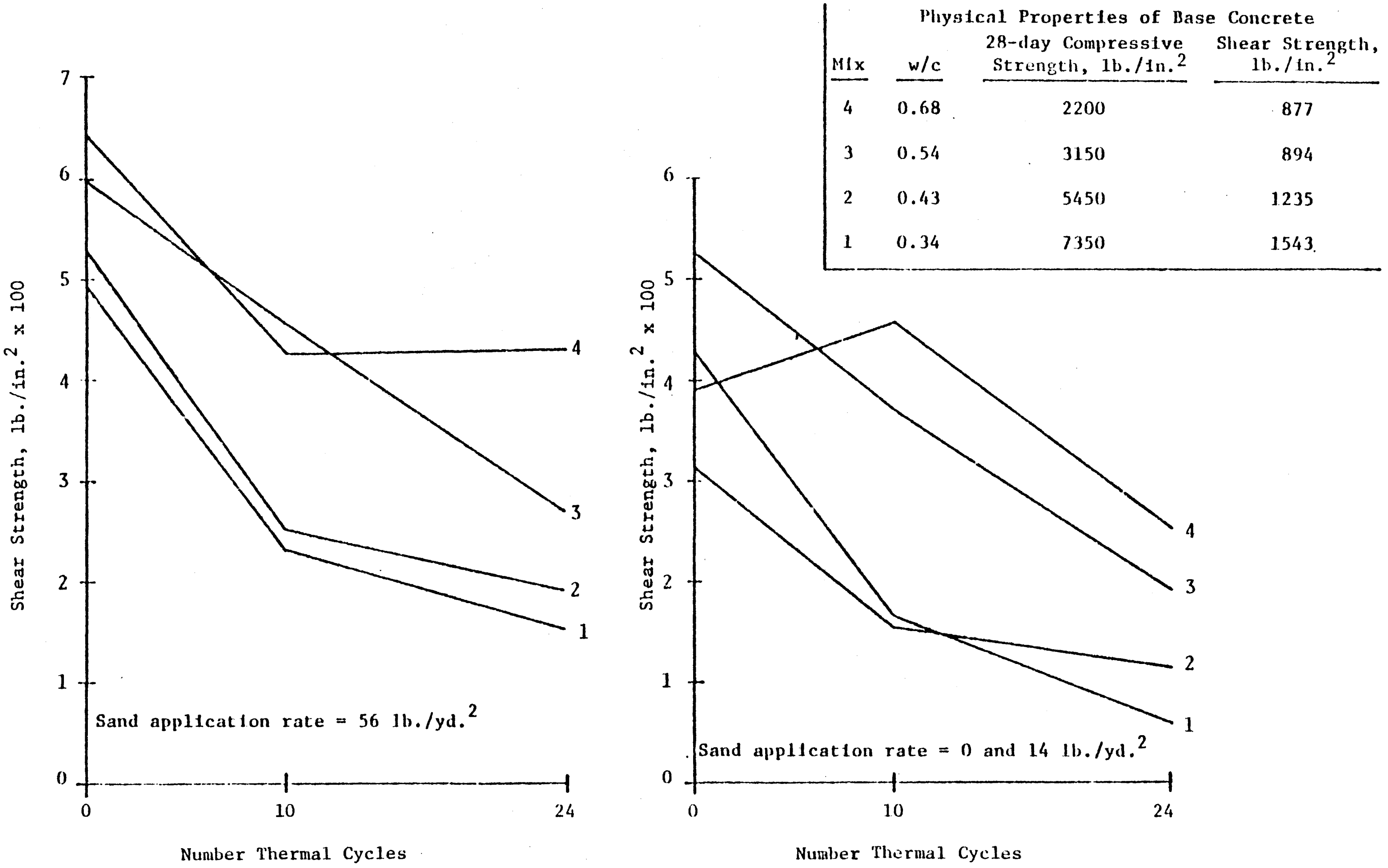
Figure 1. Apparatus used to subject cores to shear.

Table 1

Shear Strength of Cores from Beulah Road

	LB183 Resin					90-570 Resin				
	Shear Strength, lb./in.^{2}		No.Failures at Indicated Location			Shear Strength, lb./in.^{2}		No. Failures at Indicated Location		
Year	Concrete	Bond Interface	Bond	Concrete	Both	Concrete	Bond Interface	Bond	Concrete	Both
1982	Avg. 776	1,001	0	4	0	Avg. 824	972	0	3	0
	S.D. 76	229				S.D. 164	175			
1983	Avg. 838	436	1	1	1	Avg. 823	730	0	0	4
	S.D. 38	140				S.D. 165	108			

(6.89 kPa = 1 lb./in.^{2})



Physical Properties of Base Concrete

Mix	w/c	28-day Compressive Strength, lb./in.^{2}	Shear Strength, lb./in.^{2}
4	0.68	2200	877
3	0.54	3150	894
2	0.43	5450	1235
1	0.34	7350	1543

Figure 2. Shear strength of bond interface as function of number of thermal cycles for different base concrete strengths.
(6.89 kPa = 1 lb./in.^{2}) (0.54 kg/m^2 = 1 lb./yd.^{2})

Figure 2 shows that regardless of the strength of the base concrete, the shear strength of the bond interface decreased as the number of thermal cycles increased. Also, the highest shear strengths in the bond interface were achieved with the base concrete having the lowest design strength. This implies that the more permeable low strength base concrete absorbed more of the resin, provided more mechanical bond, and yielded more under stress and therefore subjected the bond interface to less stress. Finally, Figure 2 shows that when an excess of aggregate (56 lb./yd.^{2} [30 kg/m^2]) was used in the overlay the shear strengths at 0, 10, and 24 cycles were higher than when 0 and 14 lb./yd.^{2} (0 and 7.6 kg/m^2) were used, because the thermal stress is less when an excess of aggregate is used in the overlay.(1)

The mode of failure for the specimens prepared in the laboratory was similar to that of the cores taken from the Beulah Road bridge. At 0 cycles, which can be compared with the data for the cores taken in 1982 (Table 1), most failures were in the base concrete or involved the base concrete. At 10 and 24 cycles, which can be compared with the data for the cores taken in 1983, most failures were in the bond interface, and the few failures that involved the base concrete were in the two lower strength concretes.

Of additional interest is the fact that the shear strength of the bond interface at 0 cycles was lower for all specimens prepared in the laboratory than for the cores from the bridge. There are two possible explanations. First, the A174 coupling agent that is added to the resin helps bond the resin to the silica in the aggregate, and this effect would be less pronounced for the siliceous gneiss coarse aggregate used in the laboratory specimens which contain less silica than the chert aggregate used in the Beulah Road bridge. A second explanation is that the shear strengths of the base concrete in the lab specimens were generally higher than those of the base concrete in the Beulah Road bridge.

Of particular importance is the fact that despite the loss in bond strength that occurred with both resins as a result of thermal stresses, a second set of specimens identical to those that had been subjected to the shear tests and constructed with 90-570 resin and 56 lb./yd.^{2} (30 kg/m^2) of aggregate withstood 300 thermal cycles without becoming debonded. The remaining specimens in the second set prepared with 0 and 14 lb/yd.^{2} (0 and 7.6 kg/m^2) aggregate have delaminated in the vicinity of the bond interface. Based on the performance of these specimens, shown in Figure 3, it is reasonable to expect that a PC overlay properly constructed with 90-570 resin will stay bonded much longer than the 5 years projected in reference 1.

Figure 3. Condition of test specimens after 300 thermal cycles; aggregate application equals 0 and 14 lb./yd.^{2} (0 and 7.6 kg/m^2), left, and 56 lb./yd.^{2} (30 kg/m^2), right.

Tensile Strength of Bond

One-inch diameter cores were removed from the Beulah Road bridge in 1982 and again in 1983 and subjected to a tensile test in which an attempt was made to pull the overlay from the base concrete. The average tensile strength of the composite and the mode of failure are shown in Table 2. Note that the tensile strength of the cores with the LB183 overlay decreased an average of 28% during the first year, but, more importantly, the tensile strength of the cores with the 90-570 resin did not change, which suggests that a longer service life can be expected for the 90-570 resin. The results of the tensile tests agree in pattern with those of the shear tests.

Table 2

Tensile Strength of Cores from Beulah Road

Year	LB183 Resin				90-570 Resin			
	Tensile Strength, lb./in.^{2}	No. Failures at Indicated Location			Tensile Strength, lb./in.^{2}	No. Failures at Indicated Location		
		Polymer	Bond	Concrete		Polymer	Bond	Concrete
1982	Avg. 337 S.D. 78	0	2	5	Avg. 268 Avg. 93	0	0	6
1983	Avg. 241 S.D. 48	0	2	4	Avg. 266 S.D. 53	0	1	5

(6.89 kPa - 1 lb./in.^{2})

Delamination

Table 3 shows the percentage of the overlay on the Beulah Road bridge that was delaminated at ages of 2, 24, and 47 weeks as determined with the delamtech. After 47 weeks, 1.4% of the LB183 overlay was delaminated whereas no delaminations were detected in the 90-570 overlay. Inspections of the delaminated area revealed that insufficient aggregate was placed in that portion of the overlay (see Figure 4 of reference 1). The lower aggregate content resulted in an increase in shrinkage and in thermal stress during the first winter and thereby led to premature failures in the bond and in the base concrete.

The area was repaired on June 21, 1983, using three layers of aggregate and resin 317, the latter left over from an overlay installed in Tennessee. The approximately 300 ft.^{2} (27.9 m^2) of the delaminated overlay removed amounted to 5.6% of the area covered by the LB183 resin. Because all of the overlay with the low aggregate content was not removed, additional repairs will likely be required after the next winter.

In summary, overlays constructed with both resins were soundly bonded to the base concrete initially and after 1 year of service life. An area of the LB183 overlay on the south end of the bridge debonded during the first year because insufficient aggregate was placed on that portion of the overlay. The bond strength of the LB183 overlay is decreasing more rapidly than that of the 90-570 overlay. Whereas it is anticipated that the properly constructed portion of the LB183 overlay will remain bonded at least 5 years,(1) the 90-570 overlay should remain bonded a much longer time.

Table 3

Delamination of Overlay

Date	Age, weeks	Delamination, ft.^{2} (%) LB183	Delamination, ft.^{2} (%) 90-570
5/18/82	2	0 (0)	0 (0)
10/20/82	24	0 (0)	0 (0)
3/29/83	47	75 (1.4)	0 (0)

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1 m^2 = 10.8 ft.^{2}

PROTECTION PROVIDED BY OVERLAY

Electrical Resistivity

Two weeks and 47 weeks after the overlay was installed electrical resistivity measurements (ASTM D3633-77) were made at grid points located 4 ft. (1.2 m) apart in the transverse direction and 5 ft. (1.5 m) apart in the longitudinal direction. Measurements were also made at half of these locations after 24 weeks of service life. The results are reported in Table 4. Both materials exhibited similar but good to excellent resistivity 2 weeks after they were installed. The resistivity of the LB183 overlay decreased to fair after 24 weeks of service life, but that of the 90-570 overlay was still good to excellent after 24 weeks and good after 47 weeks.

The test provides a good indication of the extent of cracking in an overlay. A low reading is indicative of a crack at the test location. The crack allows water to penetrate the overlay and lower the resistance in the electrical circuit.

The 90-570 overlay is more flexible than the LB183, and therefore less prone to cracking to relieve the stress caused by temperature changes, shrinkage, and reflective cracking.

Table 4

Electrical Resistivity Measurement, Percentage of Total Number of Readings

		Range of Electrical Resistivity, Ohms/Ft.^{2}			
Age, wk.	Product	Poor $<10^4$	Fair 10^4 to $<10^6$	Good 10^6 to 10^8	Excellent $> 10^8$
2	LB183	0	6	15	79
2	90-570	1	2	13	84
24	LB183	2	88	9	1
24	90-570	0	1	41	58
47	LB183	2	80	17	1
47	90-570	0	11	78	11

10.8 Ohm/m^2 = 1.0 Ohm/ft.^{2}

Permeability

A rapid test recently developed by the Portland Cement Association for the FHWA was used to determine the permeability to chloride ion of 4-in. (10-cm) diameter cores removed from the Beulah Road bridge, and the results are shown in Table 5. A permeability of 2,214 coulombs was determined for the base concrete. After 2 weeks of service life, the permeability of the base concrete with a PC overlay was 2.9 coulombs for LB183 and 0.9 for 90-570. After 24 and 47 weeks of service life, additional cores were taken. Cores containing the LB183 overlay showed an increase in permeability, but the permeability of the cores with the 90-570 overlay was about the same as when the overlays were installed. The permeability data support the electrical resistivity data in that both indicate a deterioration in the waterproofing characteristics of the LB183 material after only 24 weeks of service life. Since the overlay had not been subjected to freezing temperatures after 24 weeks, the breakdown must have been related to shrinkage or to reflective cracking. Prior to placement of the overlays, a greater number of transverse cracks were observed in the lane overlaid with LB183 than in the other lane.

Cores taken from the LB183 overlay after 47 weeks of service life showed a greater permeability than ones taken at 24 weeks, which suggests that the thermal stress to which the overlay was subjected during the first winter caused additional cracking. Of greatest significance is the fact that the cores taken from the 90-570 overlay exhibited a permeability of only 1 coulomb after 47 weeks of service. Clearly, this represents the best 1-year performance of any thin PC overlay placed in Virginia.

Table 5

Permeability Data, Coulombs

Date		3/01/82	5/18/82	10/20/82	3/29/83	5/18/82	10/20/82	3/29/83
Age, wk.		-9	2	24	47	2	24	47
Material	Span	Concrete	LB183	LB183	LB183	90-570	90-570	90-570
	A	2308	0.5	52	809	-	-	-
	B	-	0.7	-	-	0.5	0.3	2.2
	C	-	3.7	248	859	-	-	-
	D	-	-	-	-	2.2	0.0	5.1
	E	-	53	447	521	-	-	-
	F	2124	-	-	-	0.7	0.7	0.1
Log. Avg.		2214	2.9	179	713	0.9	0.1	1.0

To further examine the permeability of the 90-570 resin, laboratory prepared specimens identical to the ones subjected to the shear tests were subjected to 300 cycles of temperature change at the rate of 3 cycles per day, and permeability tests were conducted at 0, 10, 50, 100, 200, and 300 cycles. The results, which are based on the average of tests of two or more specimens at each number of test cycles, are shown in Figure 4. Also shown in this figure are the results of tests on cores removed from the Beulah Road bridge, the bridges in Williamsburg,(2) and a bridge with a latex overlay.

It can be seen from Figure 4 that it is not obvious that the 90-570 overlay is significantly better than the LB183 overlay from the standpoint of permeability. However, it must be remembered that the base concrete prepared in the laboratory had an average permeability of 7,400 coulombs, a value significantly higher than that of the base concrete in the Beulah Road bridge. Test results for the overlay are affected by the permeability of the base concrete, since the 0.5 in. (1.3 cm) thick PC overlay accounts for only 25% of the 2 in. (5.1 cm) thickness of the test specimen.

Based on the data in Figure 4, one can conclude that both resins experienced an increase in permeability when subjected to cycles of temperature change. For the same number of thermal cycles, the permeability of the 90-570 resin was less than that of the LB183 resin. Also, if the results obtained with the lab specimens and the cores removed from the Beulah Road bridge are averaged, one can conclude that after 300 cycles the permeability of a 0.5 in. (1.3 cm) thick layer of 90-570 resin and aggregate was about equal to that of a 1.25 in. (3.2 cm) thick overlay of latex modified concrete. If it is assumed that 1 year in service is equivalent to 50 thermal cycles, then the 90-570 and the LB183 overlays should provide a permeability less than or equal to that of a 1.25 in. (3.2 cm) thick latex overlay for at least 6 years. The performance of the overlays must be observed for a number of years to allow a more accurate projection of the permeability to be expected after 6 years.

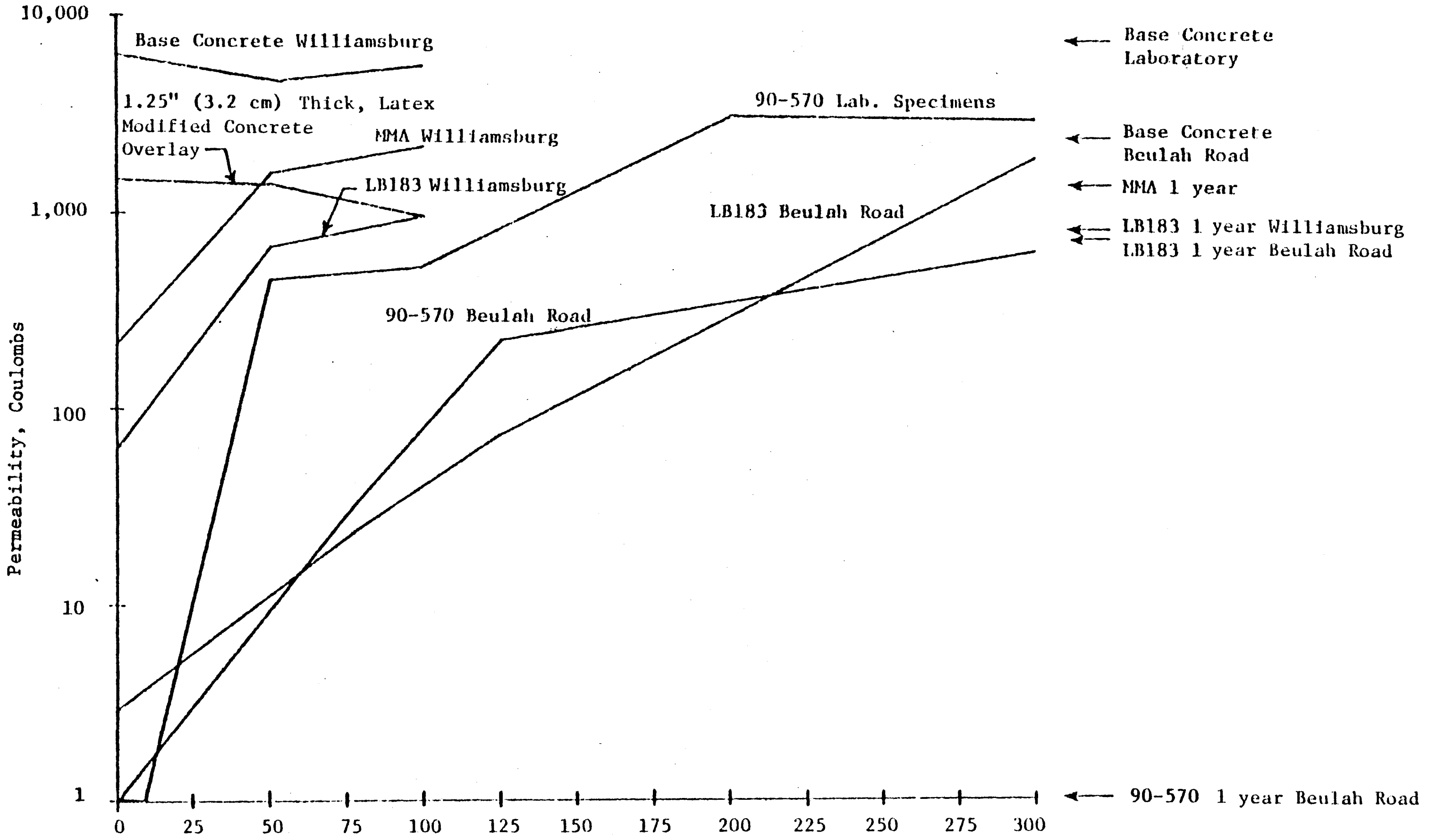

Figure 4. Permeability to chloride ion of PC overlays as a function of number of thermal cycles.

Shrinkage

It was believed that the LB183 resin cracked more than the 90-570 resin because it exhibited a higher shrinkage. However, recent measurements indicated no major differences among the shrinkages of the two resins and resin 317.

Table 6 shows the results of 24 hr. shrinkage tests conducted on specimens prepared with the 3 resins and with two aggregate contents; no aggregate and an aggregate-to-resin ratio by weight of 4 to 1. Two sizes of molds were used for the tests. The results in Table 6 are based on the average of three specimens, except as otherwise noted. Three of the specimens are shown in Figure 5. The LB183 specimen with no aggregate cracked as a result of shrinkage-induced stress, but it was about the same length as the 90-570 specimen. The 90-570 resin specimen with aggregate is about 0.2 in. (0.5 cm) longer than the other two specimens.

From Table 6 and Figure 5 it can be concluded that a shrinkage of approximately 2% can be expected when no aggregate is used and a shrinkage of 0.2% is typical when the aggregate-to-resin ratio by weight is 4 to 1. It is obvious that the principal way to minimize shrinkage is to load the resin to excess with aggregate. Since the LB183 resin does not shrink significantly more than the other resins, one must conclude that it cracks more as a result of shrinkage-induced stress because it is less flexible and therefore less able to strain to accommodate the stress.

Table 6

Percentage Change in Length in First 24 hrs.

	Specimen Size	
Product	3 x 3 x 11½ in.	1 x 1 x 11½ in.
LB183, no aggregate	3.2[a]	1.8[b]
4-1 ratio	0.3[b]	0.1[b]
90-570, no aggregate	2.6	1.4[b]
4-1 ratio	0.2	0.2[b]
317, no aggregate	-	2.4
4-1 ratio	-	0.2

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[a] Two specimens, both of which contained many shrinkage cracks.

[b] One specimen

2.54 cm = 1.0 in.

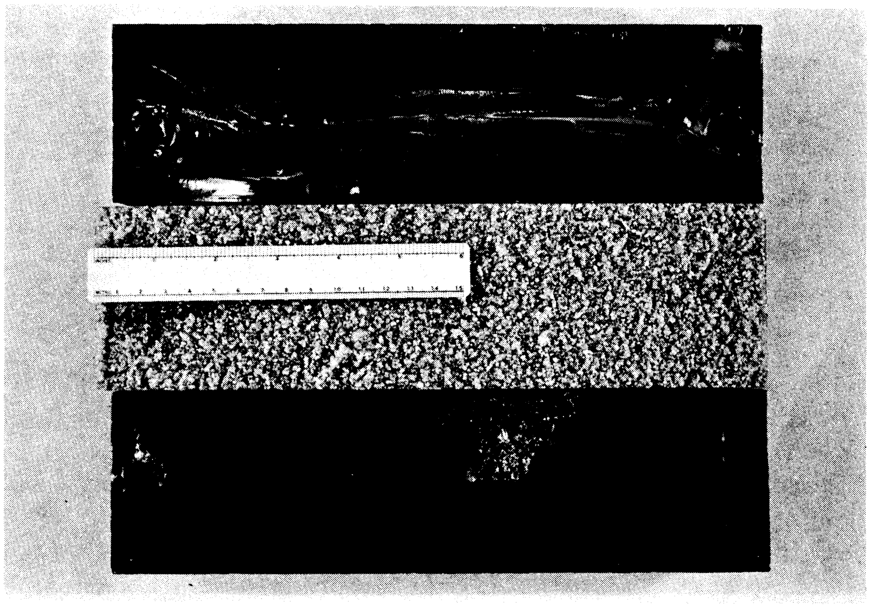

Figure 5. Shrinkage specimens: top LB183, no aggregate; center 90-570, aggregate; and bottom 90-570, no aggregate.

Half-Cell Potential

Copper sulfate half-cell potentials (ASTM C876-77) were measured at grid points spaced 4 ft. (1.2 m) apart over the entire deck surface on March 1 and 2, 1982, and at grid points spaced 4 ft. (1.2 m) by 5 ft. (1.5 m) on March 29 and 30, 1983. The results, shown in Table 7, imply that there was a high probability that no corrosion was occurring 9 weeks prior to and 47 weeks subsequent to the installation of the overlay. Values could not be determined in May 1982, 2 weeks after the installation of the overlay, because there were no cracks in the overlay to allow the completion of the electrical circuit.

Table 7

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

Date	Lane	Product	Range (-Volts CSE) < 0.20	 0.20 to 0.35	 > 0.35
3/01/82	NBL	LB183	99.8	0.2	0
3/02/82	SBL	90-570	100.0	0	0
3/29/83	NBL	LB183	98.9	1.1	0
3/30/83	SBL	90-570	99.7	0.3	0

Rutting in Wheel Paths

A 12-ft. (3.7-m) straightedge was used to measure rutting in the wheel paths (see Figure 6). The device has 6 scales spaced 2 ft. (0.6 m) apart. Measurements are made by depressing the six scales until they touch the surface of the deck. The readings are recorded. The rutting in a wheel path is computed by subtracting the reading on the scale located in the center of the wheel path from the average of the readings for the two adjacent scales. Measurements were made at 10-ft. (3.1-m) intervals along the length of the bridge in both lanes and the averages are reported in Table 8. The worst rutting was noted in the right wheel path of the southbound lane prior to and after placement of the overlay. The overlay tended to fill low areas, so the rutting was less after it was placed. High areas were found in the left wheel paths of both lanes after the overlays were installed.

The amount of wear, computed by subtracting the measurements obtained on March 29, 1983, from the measurements obtained on May 18, 1982, showed less rutting in 1983 than in 1982 in all four wheel paths. However, because the difference was less than the precision of the straightedge (1/32 in. [0.8 mm]), it can only be concluded that after 47 weeks of service life no wear could be detected in either lane.

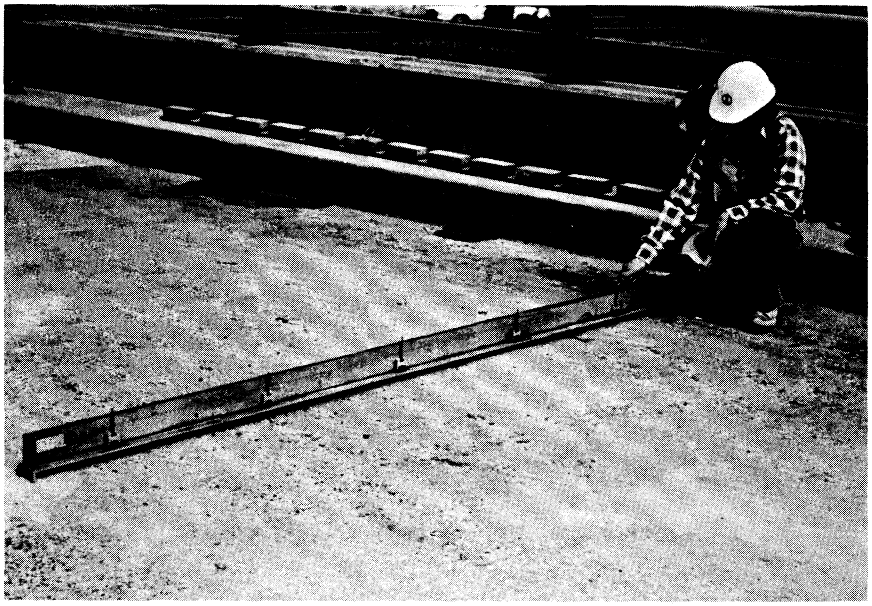

Figure 6. Straightedge used to measure rutting.

Table 8

Rutting in Wheel Paths, 1/32 in., (0.8 mm)

	SBL		NBL	
Date	Right Wheel Path	Left Wheel Path	Left Wheel Path	Right Wheel Path
3/01/82	3.6	(0.9)[a]	0.3	1.2
5/18/82	1.5	(2.4)	(0.5)	1.0
3/29/83	1.3	(2.5)	(0.7)	0.8
Wear (first 47 weeks)	(0.3)	(0.1)	(0.2)	(0.3)

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[a] (Relatively higher in wheel path)

Skid Numbers

Skid numbers were determined in tests at 40 mph (64 km/hr.) in each lane 3 weeks before and 4, 13, and 50 weeks after the PC overlay was installed. The results are reported in Table 9. The concrete surface exhibited high numbers prior to the overlay, and even higher numbers afterwards. The low reading found for the LB183 resin after 4 weeks of service life was caused by asphalt tracked onto the lane from an approach area that had been given a new surface the same week. After 50 weeks of service life the lane with the LB183 resin exhibited slightly higher skid numbers than the lane with 90-570 resin, but the numbers obtained in both lanes were excellent and higher than the ones determined for the base concrete prior to placing the overlays. The skid resistance of the lane with the 90-570 resin should be monitored over the next few years since it is the only overlay of its type in Virginia.

Table 9

Skid Numbers for 40 mph (64 km/hr.) Tests

		Treaded Tire		Bald Tire	
Date	Age, wk.	LB183	90-570	LB183	90-570
4/15/82	-3	52	51	39	36
6/03/82	4	44	57	36	51
8/02/82	13	53	55	47	49
4/19/83	50	58	56	49	45

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[a] 3 weeks before PC overlay placed.

[b] Asphalt had been tracked onto bridge.

TENSILE PROPERTIES

It has been illustrated that the bond strength and the protection provided by the overlay constructed with the 90-570 resin were better than those of the overlay constructed with LB183 resin. For example, the shear and tensile strengths of the bond interface deteriorated much more for the latter than for the former during the first year of service life. Also, the resistivity of the LB183 overlay decreased and the permeability increased significantly during the first year of service life, whereas the 90-570 overlay exhibited good resistivity and low permeability after 1 year. Since both products are polyester resins, it is necessary to determine the physical properties of the two products which led to the superior performance of one over the other.

The most obvious difference between the two products can be determined using ASTM D638-80, "Standard Test Method for Tensile Properties of Plastics." The results of tests conducted in accordance with this procedure are shown in Table 10 and Figure 7.(3) Data for resin 317, which was used on a bridge in Tennessee, are included in Table 10 and Figure 7. The tests were conducted on specimens 0.13 in. (0.32 cm) thick, 0.50 in. (1.3 cm) wide, and 8.5 in. (21.6 cm) long. A 3.0-in. (7.6-cm) gage was used. The test speed was 0.2 in./min. (0.5 cm/min.).

From Table 10 and Figure 7 it is obvious that the LB183 resin has a higher tensile strength and modulus of elasticity and a much lower elongation than the 90-570. Resin 317 has properties similar to those of 90-570. Since the LB183 resin elongates only 8.3%, it is more likely to crack when subjected to shrinkage, reflective cracking, or thermal stress than is the 90-570. The more flexible 90-570 is able to elongate and accommodate the tensile stresses and thereby provide an overlay of high resistivity and low permeability. Based on the data in Table 10, it is reasonable to conclude that a resin should have a minimum elongation of 20% to minimize the formation of cracks and thereby ensure adequate protection. A specification requiring 20% to 40% elongation seems reasonable.

Table 10

Tensile Properties of Resins

Resin	No. Spec.	Tensile Str. lb./in.^{2}		Elongation,%		Mod. of Elasticity,[a] lb./in.^{2}	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
90-570	2	2,744	107	38.4	11.8	3.64×10^4	0.55×10^4
LB183	3	5,921	485	8.3	0.0	8.50×10^4	0.94×10^4
317	3	2,858	301	23.3	8.1	4.69×10^4	0.99×10^4

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[a] Calculated at 0.05 in./in. strain

6.89 kPa = 1 lb./in.^{2}

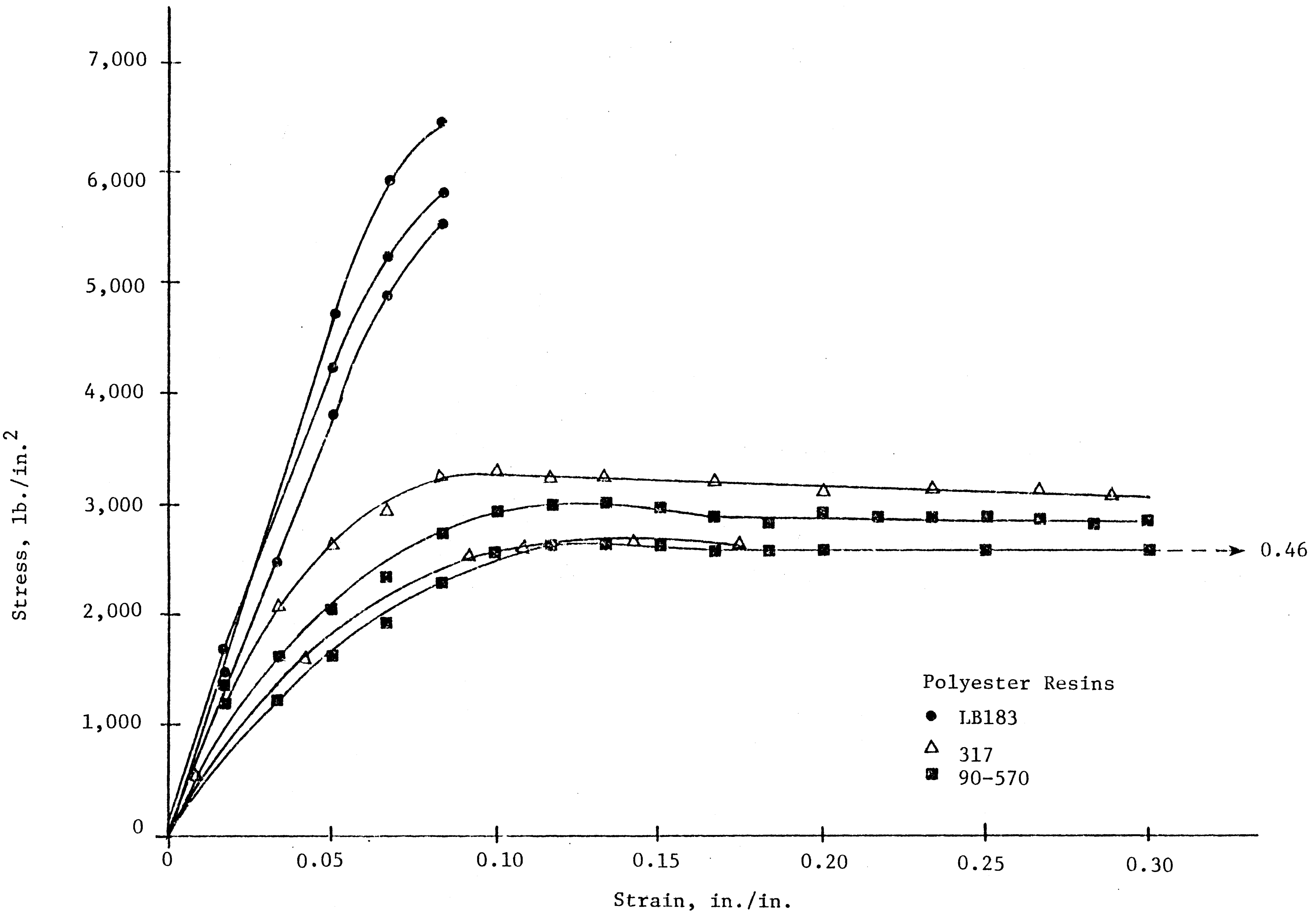

Figure 7. Stress-strain data for three resins. (See reference 3.)
(6,89 kPa = 1 lb./in.^{2})

Thermal Stress

During the winter, the overlay is in tension and the base concrete is in compression because the coefficient of thermal expansion is greater for the overlay than for the base. If the theoretical shear stress is calculated using the data reported on pages 26-30 of reference 1, but substituting the values for the modulus of elasticity in tension given in Table 10, a stress of 1.8 lb./in.^{2}/°F (22.3 kPa/°C) is found for 90-570 and no aggregate,and a stress of 4.2 lb./in.^{2}/°F (52.1 kPa/°C) for LB183 and no aggregate. Further, if it is assumed that the addition of aggregate increases the modulus of elasticity in tension in the same proportion as the addition of aggregate increases the dynamic modulus of elasticity (ASTM C215-60) as reported in Figure 9 of reference 1, then a stress of 1.8 lb./in.^{2}/°F (22.3 kPa/°C) is found for 90-570 with 56 lb./yd.^{2} (30 kg/m^2) aggregate and a stress of 5.1 lb./in.^{2}/°F (63.3 kPa/°C) for LB183 with 56 lb./yd.^{2} (30 kg/m^2) aggregate. The theoretical values for shear stress are much lower when they are computed using the modulus of elasticity in tension rather than the dynamic modulus of elasticity for the polymer overlay. Using the modulus of elasticity in tension for the PC overlay, a 70°F (39°C) drop in temperature produces stresses of 127 lb./in.^{2} (875 kPa) and 357 lb./in.^{2} (2460 kPa), respectively, for fully sanded overlays of 90-570 and LB183. Most concretes have a shear strength capable of withstanding these stresses. Since the 90-570 resin has a shear stress 36% of that for the LB183 resin, it can be expected to last much longer.

CONCLUSIONS

1. The thin PC overlay constructed with two resins, LB183 and 90-570, on the Beulah Road bridge is securely bonded to the base concrete and is providing low permeability and high skid resistance after 1 year of service life.

2. After 1 year, the condition of the lane constructed with the LB183 resin is similar to the condition after 1 year of the four overlays constructed with LB183 resin near Williamsburg in 1981.

3. After 1-year, the condition of the lane constructed with the 90-570 resin is superior to that of the other PC overlays placed in Virginia. It exhibits the highest bond strength, the least amount of cracking, and the lowest permeability.

4. The principal reason the 90-570 resin is providing superior performance compared to the LB183 is that it is more flexible as determined by ASTM D638-80.

5. The specification for PC overlays should be amended to require that the resin have properties similar to those of resin 90-570 and, in particular, exhibit an elongation of 20% to 40% as determined by ASTM D638-80.

6. Thin PC overlays are still experimental and should not be used where alternative methods for extending service life are practical. However, in situations where it is extremely important or mandatory to keep the lane closure time to 8 hours or less, a thin PC overlay constructed with a resin comparable to 90-570 can be justified, as it probably will extend the service life 5 years or more.

7. The performance of the overlay constructed with the 90-570 resin should be evaluated after 3, 5, 7, and 10 years of service life, since it is the only one of its type in Virginia and the first one of its type to be constructed.

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