

# Polymer Concrete Bridge Overlays

MICHAEL M. SPRINKEL

The current status of polymer concrete overlays for concrete bridge decks is presented. The physical and mechanical properties of the concretes used, the application methods, and the performance of the overlays are described. The economics, government support, market size, and outlook for overlays are also described. It is shown that polymer overlays constructed with epoxy, methacrylate, and polyester styrene binders and graded silica and basalt aggregates can provide skid resistance and protection against intrusion by chloride ions for 15 to 20 years and are an economical technique for extending the life of concrete decks reinforced with black steel, particularly when overlays must be constructed during off-peak traffic periods to minimize inconvenience to motorists. The outlook for polymer overlays has never been better.

Polymer concrete overlays similar to those currently in use have been installed on portland cement concrete bridge decks in many states during the past 15 years. The overlays are usually placed on decks to reduce the infiltration of water and chloride ions into the concrete and improve skid resistance, ride quality, and surface appearance (1,2). Three types of overlays are typically used:

- Multiple layer: two or more layers of unfilled polymer binder and broadcasted gap-graded, clean, dry, angular-grained aggregate;
- Slurry: a polymer aggregate slurry struck off with gauge rakes and covered with broadcasted aggregate; and
- Premixed: a polymer concrete mixture consolidated and struck off with a vibratory screed.

The objective of this paper is to describe polymer concrete overlays used on concrete decks, the candidate structures for their use, the application methods, and the performance trends. The economics, government support, market size, and outlook for polymer concrete overlays constructed in accordance with currently accepted practice are also described.

## POLYMER CONCRETES AND MORTARS

The most frequently used binders for polymer concretes and mortars are epoxy, polyester styrene, and methacrylate. The binders are usually two-component systems: one component contains the resin and the second contains the curing agent or initiator. The aggregates are usually silica and basalt. Fillers, such as coke breeze, are used to impart conductivity when the overlays are used as part of a cathodic protection system (3). Typically, uniformly graded aggregates are used with slurry

and premixed overlays, and gap-graded aggregates are used with multiple-layer overlays and are broadcast on the top of slurry and some premixed overlays.

## Monomers and Resins

Binders for polymer concretes and mortars are usually classified on the basis of the properties of the uncured and cured binder and the cured polymer concrete or mortar (Table 1 (4-8)).

Table 1 shows a typical range of values for viscosity and gel time (4-8). The viscosity of the individual or mixed components is specified to control the coating of the aggregates and the surface on which the polymer is placed. Binder resins with a low viscosity are suitable for highly filled premixed and slurry mixtures and prime coats. Resins with a higher viscosity are usually used for multiple-layer overlays to allow for proper coating and filling of the space between the gap-graded aggregates. The gel time is specified to ensure that there is enough time to place the overlay materials (minimum gel time) and that the curing will be completed within the time required to apply traffic to the overlay (maximum gel time). Some specifications have a maximum gel time of 20 min to ensure that a high early strength is obtained and a complete cure is achieved (6,7). Additional properties of the uncured binders, such as specific gravity, stability, and component content, are also sometimes specified.

Table 1 also gives the typically specified cured properties of binders (4-8) that have had a long service life. It would appear that a minimum tensile strength of 10.3 to 17.2 MPa (1,500 to 2,500 psi) is compatible with a minimum elongation of 20 to 35 percent for epoxies and polyesters. A lower tensile strength of 3.4 to 8.3 MPa (500 to 1,200 psi) is satisfactory for methacrylate binders because of the much higher tensile elongation that is typical.

## Mixture Proportions

Polymer concretes are typically made by combining polymeric binders and aggregates with gradations as indicated in Table 2. However, epoxy slurry overlays have been constructed with gap-graded aggregates similar to those shown for use in multiple-layer overlays (9). Aggregates are usually specified to be dry (less than 0.2 percent moisture), angular-grained silica sand or basalt and free from dirt, clay, asphalt, and other organic materials (5,6). Typical mixture proportions for three typical types of overlays are given in Table 3 (5-10).

TABLE 1 Properties of Binders and Polymer Concrete

Property	Epoxy	Polyester	Methacrylate	Test Method
Viscosity, cps	200–2500	75–400	1–1700	ASTM D 2393
Gel time, min	10–60	10–60	10–40	AASHTO T 237
Tensile strength, MPa	Minimum 10.3–13.8	Minimum 13.8–17.2	3.4–8.3	ASTM D 638
Tensile elongation, %	Minimum 20–30	Minimum 20–35	100–200	ASTM D 638
Slant shear bond strength, MPa	Minimum 6.9	Minimum 6.9	Minimum 6.9	ASTM C 882
Bond strength, MPa	10.3	10.3	6.9–13.8	ASTM C 882
Compressive strength, MPa	34.5	27.6–48.3	13.8–62.1	ASTM C 579
Flexural strength, MPa	13.8	13.8	9.0–20.1	ASTM C 580
Cure Time @ 32° C, HR	2	2	2	ASTM C109
Cure Time @ 24° C, HR	3	3	3	ASTM C109
Cure Time @ 16° C, HR	6–8	5–6	4	ASTM C109

1 psi = 6,894 Pa; Degrees Centigrade = 0.55 (Degrees Fahrenheit – 32)

TABLE 2 Typical Aggregate Gradations (Percentage Passing Sieve)

Sieve Size	Multiple-Layer Overlays	Slurry Overlays	Premixed Overlays
1.3 cm	—	—	100
1.0 cm	—	—	83–100
No. 4	100	—	65–82
No. 8	30–75	—	45–64
No. 16	0–1	100	27–48
No. 20	—	90–100	—
No. 30	—	60–80	12–30
No. 40	—	5–15	—
No. 50	—	0–5	6–17
No. 100	—	—	0–7
No. 140	—	—	—
No. 200	—	—	98–100
No. 270	—	—	96–100
No. 325	—	—	93–99

TABLE 3 Typical Polymer Concrete Application Rates

Overlay	Multiple-Layer Epoxy (kg/m <sup>2</sup> )	Slurry Methacrylate (kg/m <sup>2</sup> )	Premixed Polyester (kg/m <sup>2</sup> )
Thickness, cm	0.64	0.76	1.91
Prime coat	—	0.41 + 0.14/–0	0.41 + 0.14/–0
Layer 1 resin	1.1 ± 0.14	2.7 ± 0.27	5.29 ± 0.41
Layer 1 aggregate	5.4 ± 0.54	6.5 ± 0.54	38.6 ± 0.54
Layer 2 resin	2.2 ± 0.14	—	—
Layer 2 aggregate	7.6 ± 0.54	7.6 ± 2.7	—
Seal Coat resin	—	0.68 + 0.14/–0	—
Approx. resin content, %	25	24	13

1 in = 2.54 cm

1 lb/yd<sup>2</sup> = .54 kg/m<sup>2</sup>

## PROPERTIES OF POLYMER CONCRETES

### Placement Time

The time available to place polymer concrete is typically somewhat less than the gel time (Table 1) when the aggregates are broadcast into the resin and slightly greater than the gel time when the aggregates are premixed with the resin.

### Curing Time

The curing time is a function of the curing agent or initiator type and amount, binder content, and curing temperature. Typically, mixtures successfully used for bridge deck overlays have been cured for the minimum time shown in Table 1 before being opened to traffic. The times in Table 1 are typical of the minimum curing times required to prevent loss of aggregate under traffic and typical of the times required for a mortar cube (ASTM C109) to obtain a compressive strength of 6.9 MPa (1,000 psi) (2,5,6,10). A minimum curing time of 2 hr is possible at 32°C (90°F), but the minimum curing time usually needs to be increased as the curing temperature decreases. Curing times of 6 to 8 hr may be required for multiple-layer epoxy overlays placed at 16°C (60°F). Methacrylates and special formulations of other polymer concretes can be prepared to cure in 3 hr or less at temperatures below 16°C (60°F).

### Mechanical Properties

Table 1 shows typical mechanical properties of polymer concretes used in overlays that have exhibited a long service life (1,2,4-11). The Virginia Department of Transportation (DOT) requires a minimum bond strength (ACI 503R) of 1.7 MPa (250 psi) and a minimum compressive strength (ASTM C109)

of 6.9 MPa (1,000 psi) at 4 hr (5). The California DOT specifies a minimum flexural bond strength (California Test 551) of 3.4 MPa (500 psi) (8).

### Skid Resistance

New polymer concrete overlays typically have a bald tire (ASTM E524) skid number of 50 to 60. Corrective action is considered in Virginia when the number approaches 20. The skid number of polymer concrete is usually in the 30s or 40s after 15 years in service (Figure 1) (1). With the exception of the methacrylate slurry, acceptable numbers are typically being maintained throughout the life of the overlays. However, the Washington DOT recently reported the need to restore skid resistance in the wheel paths of some overlays at a 3- to 7-year frequency because of a loss of aggregate (A. H. Walley and E. H. Henley, personal communication, 1992).

### Durability

Polymer concretes used in polymer overlays are very resistant to water, deicing chemicals, acids, and petroleum products (4). Concretes tested in accordance with ASTM C666, Procedure A, modified by the addition of 2 percent sodium chloride have had a durability factor of more than 90 percent after 300 cycles (11). A durability factor above 60 percent is acceptable for concrete in Virginia. Laboratory specimens and cores removed from bridge decks with an overlay 0.64 cm (0.25 in.) thick and tested for permeability to chloride ions (ASTM T277) have shown a permeability of less than 200 C (negligible and very low) when the overlay is new. Also, overlays have shown good resistance to wear under traffic (1). However, it has been observed that the tensile strength and tensile elongation of most polymer binders decrease with age

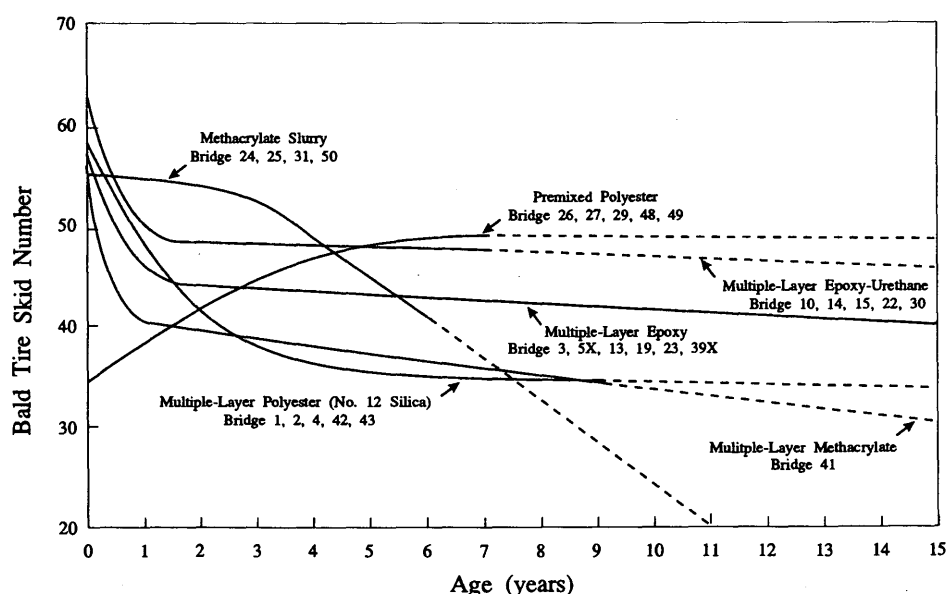


FIGURE 1 Bald tire skid number as a function of age for typical polymer overlays.

and the permeability to chloride ions increases (Figure 2). Also, the bond strength of some methacrylate and polyester overlays decreases with age (Figure 3). The methacrylate binder used in the overlay on Bridge 41 has a tensile elongation of 2 percent (ASTM D638) at an age of 1 week. Therefore, its performance is not as good as the performance of slurry overlays constructed with the more flexible methacrylate binders (Bridges 24, 25, and 31) now recommended for use (4,7,11). A methacrylate primer is also currently used with premixed

and multiple-layer polyester styrene overlays to provide a higher bond strength at a later age than is obtained without the primer (6,8). The loss in flexibility, increase in permeability, and decrease in bond strength with age control the life of the overlay. Projections based on Figures 1, 2, and 3 suggest that, with the exception of the methacrylate slurry, polymer overlays constructed in accordance with currently recommended practice should have a service life of 15 to 20 years (1,10).

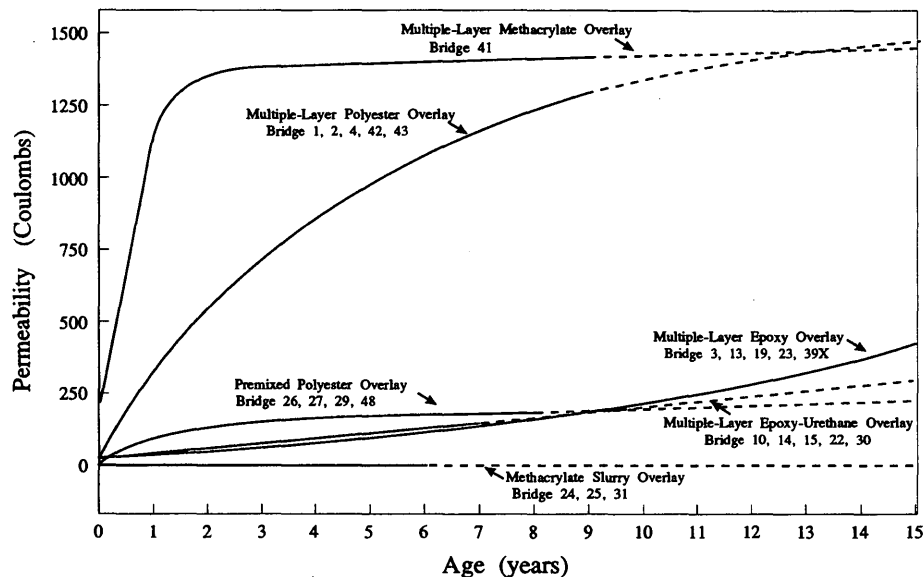
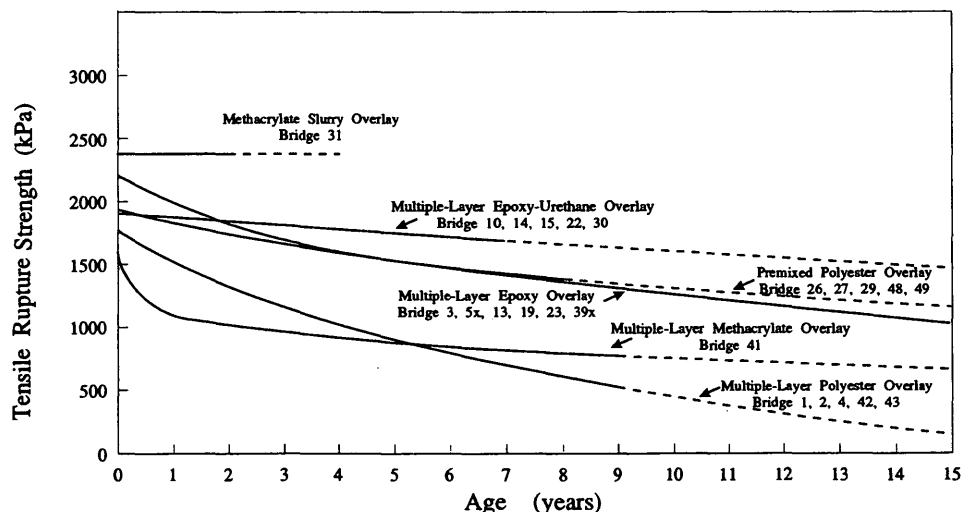


FIGURE 2 Permeability to chloride ions for typical polymer overlays as a function of age. Permeability increases with age but should be less than 1,000 C for 15 to 20 years for properly constructed overlays other than multiple-layer polyester and methacrylate.



1 psi = 6.89 kPa

FIGURE 3 Tensile bond strength (ACI 503R) as a function of age for typical polymer overlays. Properly constructed overlays (except multiple-layer polyester) should remain bonded for 15 to 20 years; delaminations can occur when bond strength drops below 0.69 MPa (100 psi).

## WHERE SHOULD POLYMER OVERLAYS BE USED?

Concrete decks that are likely candidates for an overlay are those with a chloride ion content at the top mat of rebar of less than  $1.2 \text{ kg/m}^3$  ( $2 \text{ lb/yd}^3$ ), a concrete cover over the reinforcing bars that has a permeability in excess of 2,000 C (AASHTO T277), a clear cover over the rebar of less than 5 cm (2 in.), a cover that is not properly air entrained, a cover that is extensively cracked (particularly decks that were constructed without epoxy-coated reinforcement), and decks that have been patched or need extensive patching. Decks that have a bald tire skid number (ASTM E524) less than 20 at 40 mph or have poor ride quality are also candidates for overlays. Finally, bridges that are candidates for polymer overlays are those that are in need of a skid-resistant wearing and protective surface but have peak-hour traffic volumes that are so high that it is not practical to close a lane to apply the surface except during off-peak traffic periods. Polymer overlays are one of the few surfaces that can be installed with short periods of lane closure.

Multiple-layer polymer overlays are best suited for decks that have good ride quality since the overlay tends to follow the contours of the surface. Slurry and premixed overlays are best suited for decks with many surface irregularities. Although epoxy overlays are less sensitive to a moist substrate than polyesters and methacrylates, to obtain maximum bond strength and durability, all the concretes should be placed on a surface that is dry. Portland cement concrete decks with a tensile rupture strength of less than 1.0 MPa (150 psi) should not be overlaid with polymer concrete because the overlay will most likely spall as a result of failures in the substrate.

## APPLICATION

The successful application of a polymer concrete overlay includes use of acceptable materials, adequate surface preparation, proper batching and placement of materials, and adequate curing before the overlay is subjected to traffic.

### Surface Preparation

Surfaces must be sound, clean, and dry in order to obtain a high bond strength. Concrete that does not have a tensile rupture strength of at least 1.0 MPa (150 psi) must be removed and replaced so that the overlay can bond to a sound substrate. Large cracks should be filled ahead of time.

Once the deck has been patched and large cracks have been repaired, the surface should be cleaned by shotblasting (Figure 4) and other approved cleaning practices to remove asphaltic material, oils, dirt, rubber, curing compounds, paint, carbonation, laitance, weak surface mortar, and other detrimental materials that may interfere with the bonding or curing of the overlay. Grit blasting must be used to clean along the edges of the deck and other areas that cannot be cleaned by shotblasting. The test method prescribed in ACI 503R should be used to determine the cleaning practice (size of shot, flow of shot, forward speed of shotblast machine, and number of passes) necessary to provide a tensile bond



**FIGURE 4** Shotblast equipment is available in a range of sizes; shown are units that blast strips 23 and 183 cm (9 in. and 6 ft) wide.

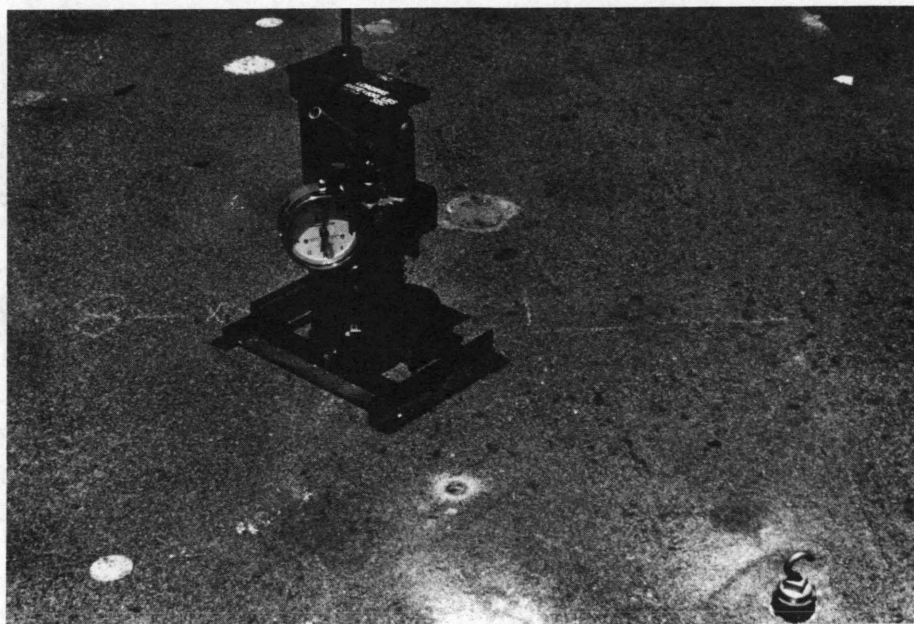
strength greater than or equal to 1.7 MPa (250 psi) or a failure area at a depth of 0.64 cm (0.25 in.) or more into the base concrete greater than 50 percent of the test area (Figure 5). A test result should be the average of three tests on a test patch of the overlay of at least  $30 \times 91 \text{ cm}$  ( $1 \times 3 \text{ ft}$ ). One test result should be obtained for each span or  $418 \text{ m}^2$  ( $500 \text{ yd}^2$ ) of deck surface, whichever is the smaller area. The cleaning practice should be approved if passing tensile adhesion test results are obtained for each test patch (1,5–7). Figure 6 shows that the temperature of the overlay can affect the test result, and therefore the overlay temperature at the time of the test should be recorded.

### Methods of Application

The overlay should be placed the same day the surface is shotblasted. Areas that are not overlaid should be shotblasted again just before the overlay is placed.

Multiple-layer overlays are typically constructed by applying the binder (Figure 7) to the surface and broadcasting a gap-graded aggregate to excess over the binder (Figure 8). Once the binder has cured, the unbonded aggregate is removed and a second layer is applied. Approximately  $5.4 \text{ kg/m}^2$  ( $10 \text{ lb/yd}^2$ ) of aggregate is broadcast onto  $1.1 \text{ kg/m}^2$  ( $2 \text{ lb/yd}^2$ ) or resin for Layer 1, and approximately  $7.6 \text{ kg/m}^2$  ( $14 \text{ lb/yd}^2$ ) of aggregate is broadcast onto  $2.2 \text{ kg/m}^2$  ( $4 \text{ lb/yd}^2$ ) of resin for Layer 2. The resin content of the overlay is about 25 percent by weight (Table 3) (5,6).

Slurry overlays are typically constructed by application of a prime coat at  $0.41 \text{ kg/m}^2$  ( $0.75 \text{ lb/yd}^2$ ), followed by a slurry mixture (Figure 9) consisting of about  $2.7 \text{ kg/m}^2$  ( $5 \text{ lb/yd}^2$ ) of binder,  $3.8 \text{ kg/m}^2$  ( $7 \text{ lb/yd}^2$ ) of silica sand, and  $2.7 \text{ kg/m}^2$  ( $5 \text{ lb/yd}^2$ ) of silica flour (Table 2). This is followed by a broadcast to excess of a gap-graded aggregate as used in multiple-layer

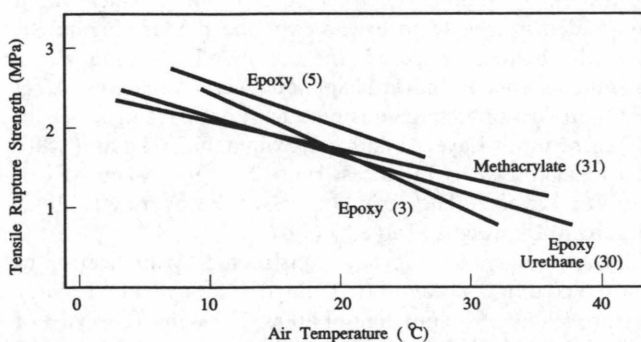


**FIGURE 5** Tensile adhesion test shows that use of polymer materials and proper surface preparation procedures results in adequate bond strength.

overlays (Table 2) and the application of a seal coat at  $0.68 \text{ kg/m}^2$  ( $1.25 \text{ lb/yd}^2$ ). Including the prime coat and the seal coat, the binder content of the overlay is about 24 percent (Table 3) (7).

Premixed overlays are constructed by mixing the aggregates shown in Table 2 with about 12 percent binder by weight (Table 3) (8,10). A primer is usually applied at the rate of about  $0.41 \text{ kg/m}^2$  ( $0.75 \text{ lb/yd}^2$ ) to enhance the bond strength. A vibratory screed is used to strike off and consolidate the concrete (Figure 10). Continuous batching and paving equipment has been used to place some overlays (Figure 11). Acceptable skid resistance can be obtained by placing grooves in the freshly placed concrete or by broadcasting aggregate onto the surface.

The thickness of the overlays is typically about 0.64 cm (0.25 in.) for the multiple layer, 0.79 cm (0.31 in.) for the slurry, and a minimum of 1.3 cm (0.5 in.) for the premixed.



**FIGURE 6** Tensile rupture strength (ACI503R) versus test temperature for polymer overlays.

## QUALITY-CONTROL TESTS

The tests and test results required to ensure that an overlay with a life of 15 to 20 years is installed have been described and may be summarized as follows:

- **Resin.** A sample of resin should be obtained for each 3785 L (1,000 gal) of resin to be used. The viscosity, gel time, tensile strength, tensile elongation, and bond strength of the resin should be measured and the resin accepted when values as shown in Table 1 are obtained.

- **Aggregate.** A sample of aggregate should be obtained for each 45 350 kg (100,000 lb) of aggregate to be used. The gradation should be measured and the aggregate accepted when values as shown in Table 2 are obtained. Aggregates that will be subject to wear shall be silica or basalt and shall have a Mohs' scale hardness of about 7.

- **Polymer concrete.** The samples of resin and aggregate should be used to prepare specimens of polymer concrete. The specimens should be tested and should exhibit the properties shown in Table 1.

- **Surface preparation.** Procedures should be approved when test patches constructed with approved materials are found to have a minimum tensile rupture strength of 1.7 MPa (250 psi). When tensile tests cause failures in the base concrete at depths greater than 0.64 cm (0.25 in.) and at strengths less than 1.0 MPa (150 psi), the concrete should be removed and replaced with higher quality concrete before preparation of the surface and placement of new test patches. When the surface is being prepared, it should be cleaned thoroughly, at least as well as it is before the placement of the test patches. Before placement of the overlay materials, the surface should be inspected to ensure that the surface is properly prepared, free of dust, and dry.





**FIGURE 7** Epoxy mixture is spread over deck with notched squeegees; basalt aggregate is broadcast to excess from back of dump truck.

- **Application.** The application should be monitored to ensure that the gel times as shown in Table 1 and the application rates as shown in Table 3 are achieved.

- **Curing.** Before the overlay is opened to traffic, it should be cured for the minimum time shown in Table 1 and also as required to obtain a compressive strength of 6.9 MPa (1,000 psi) in field-cured cubes (ASTM C109).

## COSTS

The cost of an overlay is a function of the cost of materials, surface preparation, labor, equipment, overhead, and traffic

control. Table 4 gives typical costs in 1991 in Virginia of the three most frequently used overlays constructed with the mixture proportions shown in Table 3. The estimates are based on the following material costs:

- Polyester: \$2.20/kg (\$1.00/lb)
- Epoxy: \$3.30/kg (\$1.50/lb)
- Methacrylate: \$7.72/kg (\$3.50/lb)
- Aggregate: \$0.07/kg (\$0.03/lb)

Costs can be expected to vary on the basis of the local labor rates and competitive bidding. Multiple-layer epoxy overlays are typically constructed in Virginia at a cost of \$30 to \$42/



**FIGURE 8** Aggregate spreader oscillates in transverse direction, broadcasting basalt aggregate to excess onto epoxy binder. Aggregate should be placed within 5 min after binder is mixed.



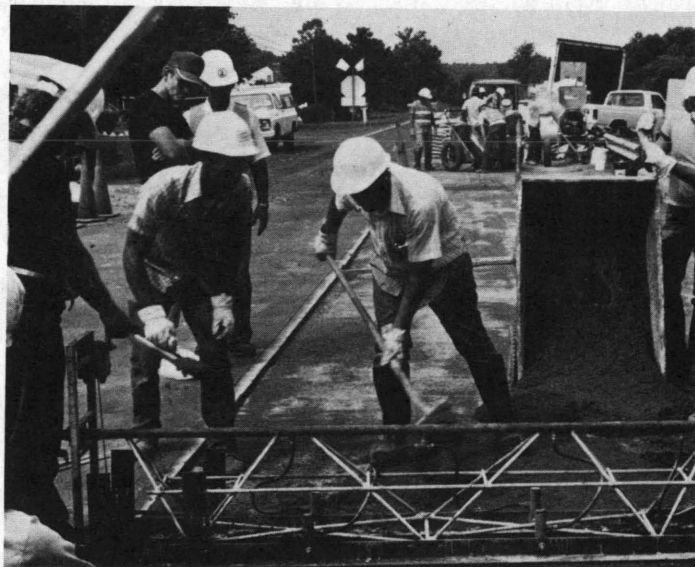
**FIGURE 9** Methyl methacrylate slurry overlay should be struck off with gauge rakes set to provide a layer of slurry at least 0.48 cm (0.19 in.) thick. Aggregate should be broadcast to excess onto slurry within 5 min after slurry is placed.

m<sup>2</sup> (\$25 to \$35/yd<sup>2</sup>). The premixed polyester overlay that is frequently used in California costs slightly more. The methacrylate slurry has been used less than polyester and epoxy because of the higher cost. A polyester/methacrylate hybrid binder has been substituted for the methacrylate to provide a slurry overlay at a cost that is competitive with multiple-layer epoxy and premixed polyester overlays (memo). The successful use of polymer overlays in California, Ohio, New York, Virginia, Washington, and other states demonstrates

that polymer concrete bridge overlays are an economical alternative for extending the life of bridge decks.

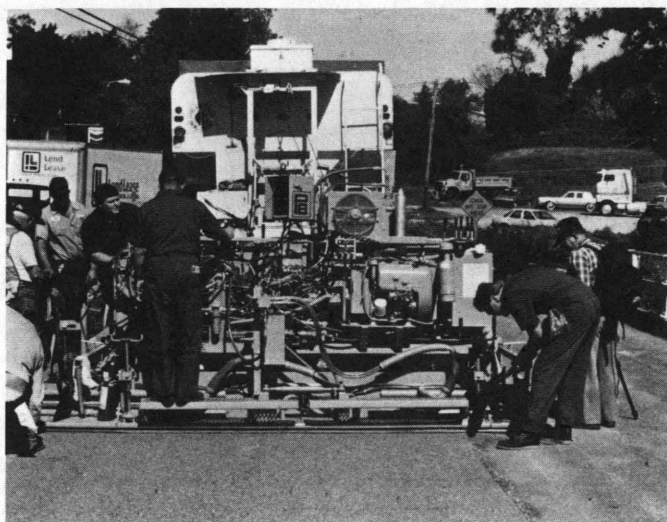
#### GOVERNMENT SUPPORT

Government support of currently used polymer overlay systems has gradually increased in recent years. Most installations have been funded by state DOTs, some by city govern-



**FIGURE 10** Polyester styrene resin concrete may be consolidated and struck off with transverse vibrating screed. Primer should be applied with rollers, brooms, or squeegees approximately 1 hr before premixed polyester styrene resin concrete overlay is placed. Typically, primer must gel on deck before placement of overlay.





**FIGURE 11** Vibrating slipform paver is used to apply premixed polyester styrene resin concrete overlay to deck that received a primer approximately 1 hr earlier. Mobile concrete mixer is used to supply freshly mixed concrete to paver.

ments, and a few by the Demonstration Projects Division of FHWA. The leading users of polymer overlays are the DOTs in California, New York, Ohio, Virginia, and Washington. Trends of use are shown in Table 5.

Additional government and industry support is found in a task force recently formed by the Associated General Contractors of America (AGC), AASHTO, and American Road and Transportation Builders Association (ARTBA), "Polymer Concrete Bridge Overlays" (Task Force 34). The task force has the objective to develop specifications for polymer concrete bridge overlays. The task force has a chairman and approximately one-third of the members from state DOTs, a secretary and coordinator from FHWA, and other members from industry representing the AGC and ARTBA. Once the specifications are available, it is anticipated that other DOTs will begin to use polymer overlays.

Finally, federal legislation (the Intermodal Surface Transportation Efficiency Act of 1991, or ISTEA) provides for \$119.5 billion for highway construction and repairs to be spent from 1992 through 1997 (12). Approximately \$362 million will go to Virginia for bridges, or about \$60 million/year. Part of

the \$60 million could be used for polymer overlays in Virginia, and a similar amount could be used by each of the other DOTs.

#### MARKET SIZE AND OUTLOOK

The market for polymer overlays can be many times larger than the \$2 million 1991 average reflected by the five states given in Table 5. If all 50 states would use \$2 million of overlays per year, a tenfold increase and a \$100 million annual market would be possible in the United States.

The outlook for polymer overlays has never been better. Task Force 34 activity should provide the specifications for successful use of polymer overlays by other DOTs and cities, and ISTEA should provide the funding necessary.

#### CONCLUSIONS

Multiple-layer epoxy and premixed polyester styrene overlays constructed with graded silica and basalt aggregates can pro-

**TABLE 4** Typical Costs of Polymer Overlays in 1991 in Virginia

Overlay	Multiple-Layer Epoxy (\$/m <sup>2</sup> )	Slurry Methacrylate (\$/m <sup>2</sup> )	Premixed Polyester (\$/m <sup>2</sup> )
Materials	12	30	18
Surface preparation	4	4	4
Labor, equipment, overhead	18	18	18
Traffic control	1	1	1
Total	35	53	41

\$1/yd<sup>2</sup> = \$1.2/m<sup>2</sup>

TABLE 5 Estimated Annual Expenditures on Polymer Overlays (in Millions of Dollars)

	1986	1987	1988	1989	1990	1991
California <sup>a</sup>	0.40	N.A.	2.22	0.25	0.52	3.17
Virginia	1.33	0.55	1.08	1.01	1.50	2.83
Washington <sup>b</sup>	0.69	0.62	0.16	0.04	0.68	0.53
Ohio <sup>c</sup>	0.10	0.23	0.21	0.10	0.65	0.32
New York <sup>d</sup>	N.A.	N.A.	1.42	0.00	0.29	2.40

<sup>a</sup> Personal communication with Rick Maggenti, California Department of Transportation.

<sup>b</sup> Personal communication with DeWayne Wilson, Washington Department of Transportation.

<sup>c</sup> Personal communication with James Barnhart, Ohio Department of Transportation.

<sup>d</sup> Personal communication with Cathy Cowan, New York Department of Transportation.

vide skid resistance and protection against intrusion by chloride ions for 15 to 20 years and can provide an economical technique for extending the life of portland cement concrete decks constructed with black reinforcing steel. Polymer overlays constructed with flexible methacrylate binders may have a shorter service life because of low skid numbers. The market for polymer overlays could increase by a factor of 10, and the outlook has never been better.

## RECOMMENDATION

Departments of transportation should use polymer overlays as described herein to provide bridge decks with skid resistance and protection against intrusion by chloride ions.

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