Polymer Concrete Overlay Test Program
Lebanon Ditch Bridge

Final Report

Basic Agreement DOT-FH-11-8876
Task Order No. Seven

by

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Research Section
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This report presents information on the installation of a thin polymer concrete overlay and the evaluation of its durability after a 15-month in-service period. The project was performed by the Oregon State Highway Division under the sponsorship of the Federal Highway Administration. In addition to the construction project in Oregon, technical assistance and technology transfer were provided to engineers in Oklahoma, New York and California when requested by the FHWA contract manager.

In August 1981, the Oregon State Highway Division placed a 1 in. (25.4 mm) thick polyester styrene polymer concrete overlay on the Lebanon Ditch Bridge in Lebanon, Oregon. The bridge which was constructed in 1947 is located at milepoint 13.56W on Oregon Highway 16. Prior to the overlay the deck had exposed and polished aggregate in the wheel tracks and moderate transverse cracking throughout. The overall condition of the bridge was very good.

Unlike previous polymer concrete overlays in Oregon, the experimental concrete was mixed in a concrete-mobile mixer and finished with a conventional bridge deck finishing machine. The equipment was rented from local contractors who provided experienced operators for this implementation project.

The polymer concrete used in the project was composed of a medium viscosity polyester styrene resin and a 1/2 in. (12.7 mm) minus natural aggregate. The overlay was installed by an eight-man bridge maintenance crew, two laboratory technicians who prepared and dispersed the resin, and two equipment operators.

The installation of the polyester styrene polymer concrete was considered marginally successful as the ride quality of the overlay was not entirely up to an acceptable standard. The surface was open in some locations and generally rough riding. Misproportioning of the aggregate and resin was cited as the major cause of the open areas and the finishing machine was the principal cause of the uneven surface. It was not until after the overlay was installed that other conventional concrete overlays that were finished with the same finishing machine were found to have similar roughness problems.

During the week following construction, minor repairs were made to the open areas by applying resin and No. 8 chips. This remedy improved the ride quality noticeably.

Two months before the overlay was installed, preliminary work began with the testing of aggregates and resins. Several commerical sources of dry aggregate were examined and found to be unsatisfactory. A mixture of 3/8 in. (9.5 mm) to No. 4 stones, sand and Type F pozzolan was finally formulated and found to be accceptable. The specific aggregate gradation is presented in Table 1. MR11044, a resin produced by U.S.S. Chemical, was selected as the binder after laboratory testing.

Originally, a Bidwell low slump finishing machine was chosen for the project but the high rental fee requested by two different Oregon owners forced the state to search for comparable equipment. A heavy, vibratory screed was finally located and successfully tested when a 6 x 12 ft (1.8 x 3.6m) polymer concrete overlay was placed on a concrete slab. When the polymer concrete was found to be well compacted and the finished surface rated acceptable, this machine was rented from Siuslaw Construction Company at one third the cost of the Bidwell low slump concrete finishing machine.

During the week immediately preceding the overlay, the various chemical components were blended into the barrels of resin with a Lightnin Mixer Model No. 10X. Each drum was stirred for a minimum of 30 minutes to ensure adequate blending. Only the initiator was omitted. Seven barrels of resin received the components for the polymer concrete and one barrel was charged with chemicals for the tack coat. The chemical components and their proportions are listed in Table 2.

Two 1-in. Sherwood gear pumps, which were provided by the Daffin Mobile Mixer Company, were also calibrated at the laboratory before the overlay was placed. The pumps were driven by two 3/4 HP (dc) electric motors. The rate of speed of the motors was individually regulated by a portable control panel and this determined the amount of resin discharge from each pump.

On the Monday and Tuesday preceding the overlay, a pneumatic MacDonald scabbler was used to remove the top 1/8 in. (3.1 mm) of surface mortar

Table 1

Aggregate Gradation for Polymer Concrete

Sieve Size	% Passing
3/4	100
1/2	94-100
3/8	83-89
4	47-53
16	39-45
50	16-22
100	6-10
200	4-8

Table 2

Resin Formulation

		Polymer Concrete	Tack Coat
Resin	MR11044	10% by wt agg.	100%
Initiator	Hi-Point 90	0.95% by wt resin	0.95% by wt resin
Promoter	Cobalt Napthenate (12% Cobalt)	0.25% by wt resin	0.25% by wt resin
	N,N, Dimethyl Aniline	0.20% by wt resin	0.20% by wt resin
Crosslinking Agent	(A-174) Organosilane	0.75% by wt resin	1.50% by wt resin
Inhibitor	t-b-Hydroquinone	200 ppm	200 ppm
Wetting Agent	Surfynol 440	-------	1.0% by wt resin

from the deck. The rate of preparing the deck was approximately 150 sq.ft/hr (13.9 sq m/hr). When the scabbling was completed, the deck was cleaned by compressed air. Anchor bolt holes were also drilled into the deck to secure a 1-in. (2.54 cm) channel which served as a side form. Although the finishing machine was capable of finishing the 34 ft (10.4m) wide deck at one time, a decision was made to place the overlay in two longitudinal panels. The deck was divided into a 14 ft (4.3 m) and 20 ft (6.1 m) panel to reduce the manpower that would be required to overlay the entire deck in one pass.

While three members of the bridge maintenance crew worked at the bridge site, the remainder of the crew mobilized the supplies and equipment. The coarse aggregate was purchased predried, in 90 lb (27.2 kg) sacks while the sand and pozzolan came in 80 and 60 lb (36.3 and 27.2 kg) sacks respectively. Since there were only two aggregate bins on the concrete mobile mixer, the sand and pozzolan had to be premixed. This was accomplished by hand as the materials were loaded into 5 cu yd (4.2 cu m) dump trucks.

On the morning of the overlay, all traffic was detoured from the bridge. Immediately thereafter, the pipe rails for the finishing machine were set and adjusted to grade while the side form channel was bolted to the deck. During this time the concrete mobile mixer was calibrated to discharge the correct porportions of aggregate. The mobile mixer was adjusted to produce 4 cu ft (0.11 cu m) of polymer concrete per minute. By 11:30 a.m. all of the preparatory work was complete and the finishing machine was placed on its rails. Before beginning the overlay the clearance between the screed and the deck was measured at numerous locations along the bridge to check the overlay thickness. Final grade adjustments were then made to screed rails where necessary.

The Concrete-Mobile mixer was used primarily to proportion the coarse and fine aggregate and to mix the polymer concrete. The resin had to be supplied to the mixer from an adjacent truck. A floor plan was prepared to accommodate the barrels of resin and solvent, the motors and pumps and a generator. Topless half barrels were used as mixing basins when the initiator was added to the resin and before it was discharged into the mixing chamber of the mobile mixer. Only 18 gal (68.1 l) of resin were initiated at any one time to reduce the potential waste should the 15-minute pot life be exceeded.

The success of the application depended on several synchronized activities. First, the tack coat resin had to be initiated and appplied to the deck just before the overlay was placed. While this was occurring, the resin in one half barrel was initiated and mixed thoroughly for 30 seconds. It was then pumped to the mixer. Precise timing between pumping the resin and adding the aggregate into the mixing chamber was a very critical function.

A trial batch of polymer concrete was prepared just off the end of the bridge shortly before the overlay began. The purpose of this batch was to visually check the consistency of the mix. After running the mixer for one minute, the polymer concrete began to look well mixed and it appeared to have good workability. This polymer concrete was wasted on the roadway shoulder. The mobile mixer and the resin truck were then directed onto the deck to begin the overlay.

The overlay began when the resin tack coat was initiated, mixed and spread on the first 14 by 9 ft (4.2 by 2.7 m) section of deck with 24-in. (0.61 m) brooms. When an attempt was made to pump the resin from the mixing basin into the mixing chamber of the mobile mixer, nothing happened. The resin used in the trial batch had solidified in the pump and in two hoses during the 20-minute delay. The pump was dismantled and cleaned and the hoses were replaced. After a 45-minute delay, work resumed.

A second resin tack coat was applied over the first as mixing of the first batch of polymer concrete began. Once the work commenced, the 14 by 75 ft (4.2 by 22.8 m) strip was completed nonstop in 35 minutes. Because there were no interruptions, the pumps and hoses were not flushed with a cleaning solvent until the strip was completed. After the last batch was mixed, the entire pumping system was flushed several times with methylene chloride.

During the installation of the first panel some finishing problems developed when too much material was deposited in front of the screed. Even though there were two augers in front of the screed for spreading the polymer concrete, they were not effective in maintaining the proper amount of material to be finished. The surplus polymer concrete had to be moved ahead by hand. There were several instances when excessive amounts of polymer concrete created a large roll on the edge of the screed. Because the polymer concrete was sticky some pick-up occurred and depressions resulted in the overlay surface. Attempts to repair these areas by hand during construction were not successful. In addition to this problem, poor proportioning of the aggregate and resin caused some areas to have excessive resin while other areas were very dry.

One other problem area occurred adjacent to the curb line where the finishing machine was not able to consolidate the concrete. The screed only traveled to within 2 ft (0.61 m) of the curb leaving this area to be finished by hand. Attempts to smooth this section with rakes and shovels were not successful and the polymer concrete was not compacted in this area.

Slightly more than one hour was required to prepare for the placement of the 20 ft (6.1 m) wide panel of polymer concrete. During this time the finishing machine was returned to the starting position and the side form was unbolted and removed from the deck. The removal was uncomplicated because a light coating of grease served as a very good bond breaker. Several revisions were also made in the installation procedure to improve the overlay quality. First, better communications were established between the mobile mixer and the resin truck to minimize the errors in proportioning the polymer ingredients. Second, a smaller quantity of polymer concrete was prescribed for placement in front of the screed by the mobile mixer. This reduced the amount of roll on the edge of the screed and a smoother surface was attained. Third, an effort was made to consolidate the polymer concrete in the 2 ft (0.61 m) wide strip adjacent to the curb.

Just before the installation of the 20 ft (6.1 m) wide panel began, the resin tack coat was spread over the first 20 by 10 ft (6.1 by 3.05 m) section by brooming. As soon as the tack coat was applied, the mixing of the polymer concrete began. Because of the experience gained on the first panel, the installation was greatly improved.

Approximately half way through the pour, a fuse blew in the control box causing the work to cease. The fuse was replaced and the installation continued until additional problems developed in one of the two speed controls. The mixing was finally completed by running each motor alternately from the one good control.

The quality of the 20 ft (6.1 m) panel was clearly superior to that of the initial pour. There were no areas when insufficient resin was readily noticeable but the overlay surface was still slightly wavy. Because of the speed of application, the 15-minute pot life of the polymer concrete did not present any significant problems.

The weather conditions during the installation were very favorable with temperatures in the low 80's (27 C). This caused the polymer concrete to cure rapidly which enabled traffic to be placed on the overlay 1 1/2 hours after construction.

When the overlay was inspected two days after it was placed, some slight ravelling was found in the dry areas of the 14 ft (4.3 m) strip. The rideability of this strip was less than desirable also. The 20 ft (6.1 m) strip on the other hand looked fairly good. Arrangements were immediately made to repair the 14 ft (4.3 m) strip.

One week after construction, repairs were made to the experimental overlay. Using surplus resin and No. 8 Wedron sand, a chip seal was applied to the dry and irregular areas within the 14 ft (4.3 m) strip.

The resin was broomed onto the overlay surface and the sand was broadcast by hand. Where deep depressions existed, several applications of sand were needed to completely fill the voids. This remedial repair improved the ride quality to some degree.

The breakdown of the costs that were incurred to install the polymer concrete overlay follow:

		Cost Per Sq Yd
Materials		
Resin	$2,900	
Aggregates	930	
Chemicals	852	
Misc. Supplies	350	
	$5,032	$17.76
Equipment		
Concrete Mobile Mixer	$ 850	
Finishing Machine	1,500	
State Equipment	550	
Scabbler	350	
	$3,250	$11.47
Labor		
Preparation & Clean Up	$3,700	
Overlay	1,300	
Traffic Control	500	
	$5,500	$19.41
	Total Cost Per Sq Yd	$48.64

Evaluation and Comments

A method for placing a polyester styrene polymer concrete overlay with conventional construction equipment was demonstrated on the Lebanon Ditch Bridge project. Although not all of the proportioning problems were overcome, advancements were made in developing a viable polymer concrete overlay system. The concrete mobile mixer proportioned the aggregates and mixed the polymer concrete satisfactorily but the performance of the finishing machine used on the project was not entirely acceptable. The polymer concrete was well compacted but a smooth riding surface was not obtained. The use of the conventional construction equipment greatly reduced the manpower requirements and increased the rate of production.

The polymer concrete overlay was inspected on several different occasions during the 15-month period after construction and some additional raveling of the surface was noted each time. The last inspection was made after the overlay was in-service for 15 1/2 months and at that time the overall performance was rated as only fair. Serious raveling had occurred in the dry areas that were not patched after installation. Almost all of the major defects were found near the meet between adjacent panels and on the side of the first strip. Improvements in proportioning and finishing during the second pour are obvious. Both cores and a chain drag test have indicated the overlay to be well bonded to the deck. The cores also showed the overlay to be well consolidated.

The polymer concrete overlay system should still be considered experimental until precise proportioning of the aggregates and resin has been perfected.

Technical Assistance

One of the tasks stated in the FHWA contract was for Oregon to provide technical assistance to other transportation agencies in the construction of Type A polymer concrete overlay when requested by the contract manager. On three different occasions technical assistance or technology transfer was provided.

During the week of October 18, 1981, a representative from the Oregon State Highway Division traveled to Perry, Oklahoma to assist in the installation of a polymer concrete overlay. The project was not successful because over 200 sq ft (18.5 sq m) of the overlay disbonded and had to be replaced. Bad weather conditions, insufficient deck preparation and improper mixing of the initiator into the tack coat may have contributed significantly to the bond failure.

A Daffin concrete mobile mixer and a Bidwell low-slump concrete deck finishing machine were used to mix and finish the polymer concrete. A smooth, well consolidated overlay was generally attained. There were, however, areas that exhibited either an excessive or deficient resin content due to poor proportioning and improper tack coat application.

The bridge selected to receive the polymer concrete overlay in Oklahoma had no signs of structural distress or corrosion related problems. The deck had many short longitudinal cracks in both end spans that were reported to be caused by shrinkage during curing.

The overlay project got behind schedule before it started because the detour signs were not installed, the turn-offs were not paved and the preparation of the deck was not completed. The preparation of the deck consisted of only sandblasting with a fine grit sand. This produced only marginal results as several areas of weak surface mortar were found during an inspection when the sandblasting was completed. Suggestions to scarify or scrabble the deck were not heeded because of a lack of time to acquire the equipment.

Prior to placing the overlay, a meeting was held in the district maintenance conference room to discuss the project in detail. The representative from Oregon gave a slide presentation showing past installations and answered questions about the overlays.

A small trial batch of polymer concrete was also placed in the maintenance yard to acquaint the workers with the polymer materials and to test the construction equipment. The demonstration was successful.

On Wednesday, October 21, 1981, a 3/4 in. polymer concrete was placed on a portion of the deck. The overlay was not completed because a heavy rain began to fall after one-16 ft (4.9 m) panel and half of a second 16 ft (4.9 m) panel were paved. The mixing, placing and finishing of the polymer concrete was accomplished without too much difficulty. Although the original mix design called for a 10% resin content, this loading was decreased slightly when the surface became flooded with resin. The excessive resin was not apparent until the material was consolidated. A later analysis by Oklahoma attributed the flooding to excessive tack coat material which was applied just prior to the overlay.

Derakane 411-C-50, a vinyl ester resin, was used in both the polymer concrete and the tack coat. There were no apparent problems in coating the aggregate in the mixing chamber chamber of the mobile mixer. There was some difficulty however in dissolving the initiator, a benzoyl peroxide paste, into the tack coat resin during the first day. Even though the liquid was stirred vigorously for over one minute some large lumps of paste were found at the bottom of the containers after the tack coat was applied.

The weather conditions during the first day were less than ideal, as it was very windy and the temperatures were in the high 40's (4.0 C).

On Thursday, the Oklahoma DOT decided to delay the resumption of the overlay until Friday because the deck was still too wet to attain good bond. On Friday the overlay was resumed until the resin supply was depleted. An area measuring aproximately 8 x 30 ft (2.4 x 9.1 m) was left uncovered. This area was eventually patched with a polymer concrete made with a vinyl ester resin (DPV-706) produced by Shell Development of Houston, Texas.

The recommendations that were made after this project was concluded were:

(1) The deck should be scarified to remove loose and weak surface mortar. Sandblasting alone will generally not produce an acceptable surface.

(2) Sufficient quantities of materials must be acquired to complete the overlay. A 15 to 20% contingent quantity is desirable to accommodate waste and overrun. Since the resin and chemicals are not readily available this is essential to avoid lengthy delays.

(3) A carefully prepared work plan should be developed well in advance of the overlay.

(4) Special care must be exerted to ensure the initiator is well distributed in the resin.

(5) Work to develop a spray system for applying the resin tack coat should receive immediate attention.

(6) An automatic system for proportioning the resin and aggregate components should receive the highest priority.

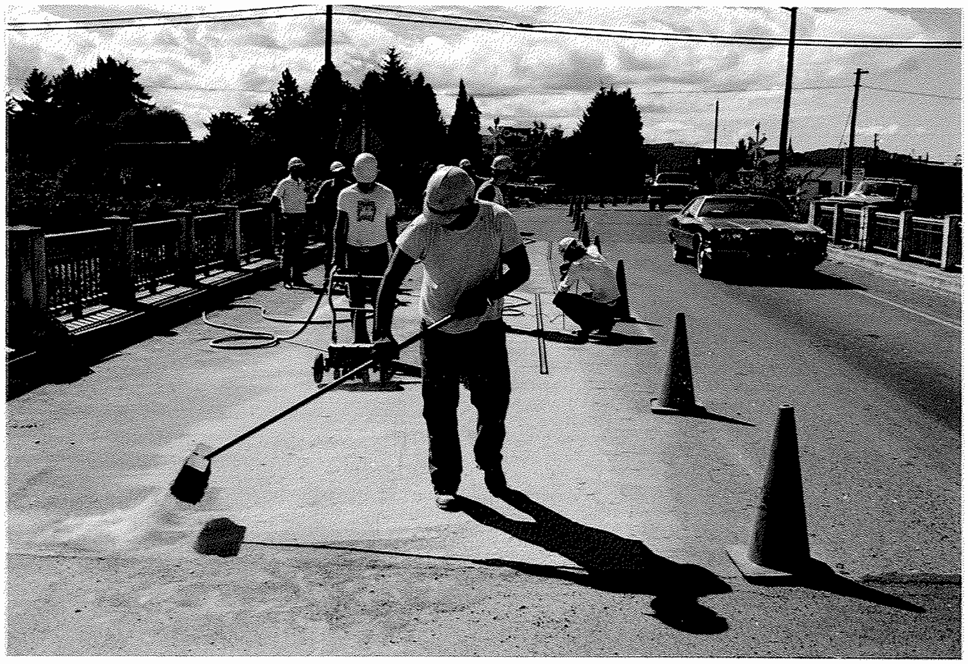
On June 8-9, 1982, a representative from Oregon met with personnel at Brookhaven National Laboratory to discuss recent research findings and to review the work plan for the polymer concrete overlay project in Oregon. The meeting was attended by John Bartholomew, the contract manager for the Federal Highway Administration.

After the meeting a tour of the research facilities was conducted and a methyl methacrylate polymer concrete overlay was placed on a steeply sloped slab. This demonstration eliminated some of the concerns about placing the polymer concrete on a deck with a steep cross slope in Oregon.

Finally, in October 1982, an inspection was made of an experimental overlay project in California. This overlay was placed in a one-mile section of badly abraded portland cement concrete pavement. Three experimental materials was used in the overlay which measured between 3/8 to 3/4 in. (9.5 to 19 mm) thick. The materials tested were (1) Adhesive Engineering Concresive 2020, a methyl methacrylate polymer concrete, (2) Dry Mix Product Company's magnesium phosphate concrete and (3) a generic polyester styrene polymer concrete made Reichhold Chemical's polylite 98-507 resin. Each of the three concretes were mixed in a 9-cu ft mixer at the site and finished with a light weight vibratory screed. Of the three quick setting concretes, the polyester styrene polymer concrete was performing slightly better than the other two when inspected two months after construction. There were no reflective cracks in the polyester styrene system while some minor cracking was found in the methyl methacrylate and magnesium phosphate materials. Some surface roughness due to screed drag was found in the outside lane in all three sections while the inside lane was generally trouble free.

The durability of the thin overlays under high traffic volume and severe weather conditions will be determined after a winter season.

In addition to the field inspection, a meeting was held at the Caltrans labaoratory in Sacramento with a concrete research engineer. Slides of Oregon's most recent polymer concrete overlay project were presented and an exchange was made of information on polymer concrete technology.

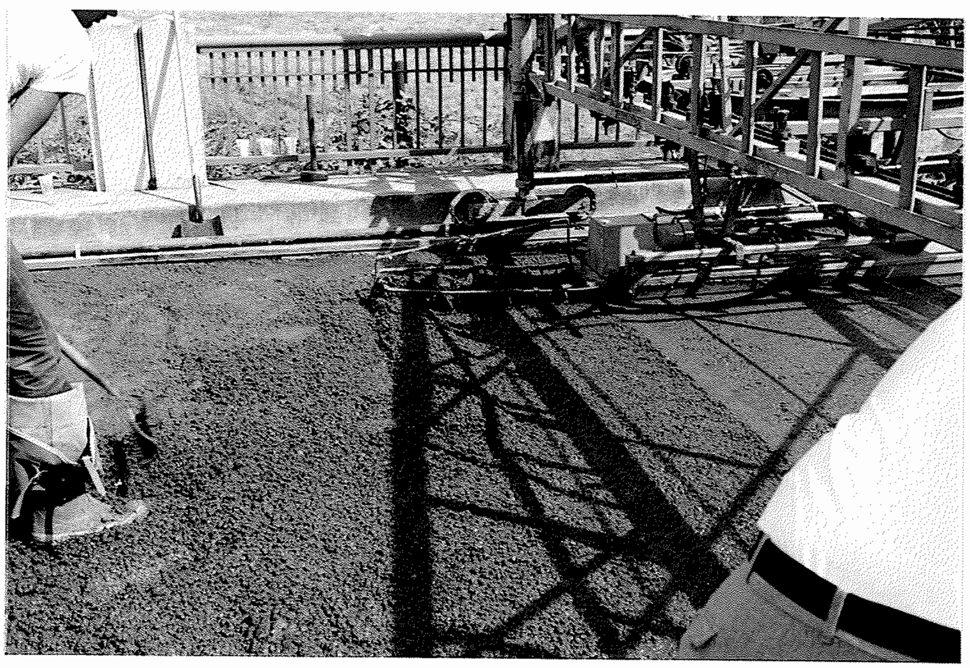


1. Preparing deck with MacDonald Scabbler

2. Applying Resin Tack Coat

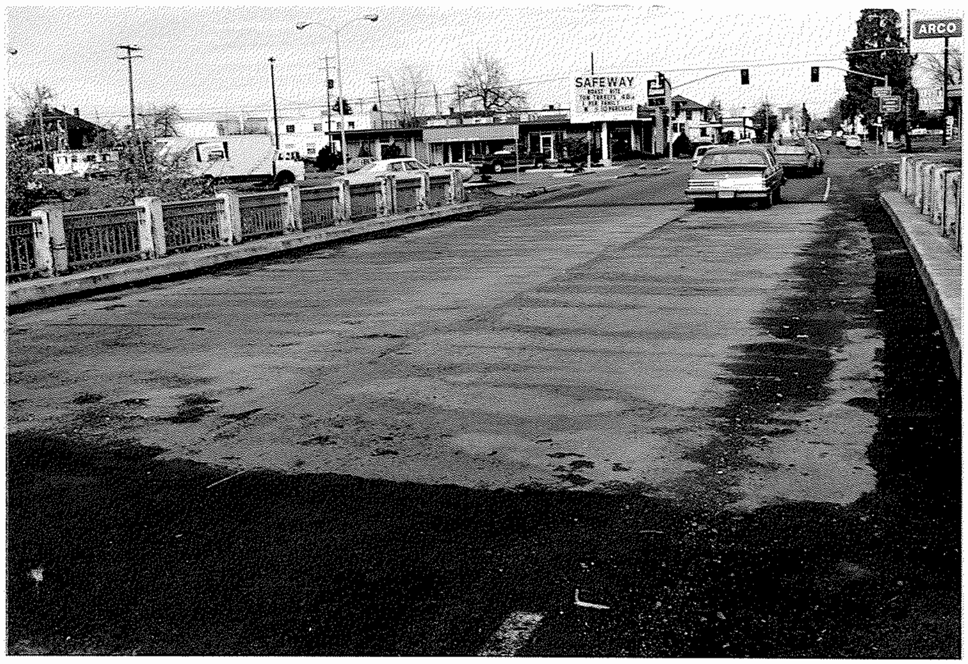
Lebanon Ditch Bridge

3. Mixing Polymer Concrete in Concrete Mobile Mixer



4. Finishing the Polymer Concrete with a Vibrating Screed

Lebanon Ditch Bridge



5. Overlay Surface after Construction

6. Overlay surface with ravelled areas after 15 months under traffic

Lebanon Ditch Bridge