Interim Report

POLYMER CONCRETE OVERLAY OF CLACKAMAS RIVER BRIDGE

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

By

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During the week of August 15, 1983, a thin methyl methacrylate polymer concrete overlay was placed on a portion of the Clackamas River Bridge on Highway 99E in Oregon City. The purpose of this overlay was to determine the skid number of an FHWA formulated polymer concrete and to observe its wearing characteristics. The polymer concrete overlay was applied to a portion of the two northbound lanes during a two day period by 16 state bridge maintenance workers.

The polymer materials for this project were purchased from Dural International, Inc. of New York after they were determined to be the low bidder. The specifications for the polymer materials were taken from the FHWA report entitled "Polymer Concrete Patching" report number FHWA-IP-82-10. These formulations were developed by Brookhaven National Laboratory for FHWA and had been successfully used for patching portland cement concrete. After the contract to furnish the polymer materials was awarded, Dural began purchasing the various ingredients for the powder component. All items were readily available except for the designated initiator, BFF-50. Permission was granted for another benzoyl peroxide initiator, BCP-35 to be substituted at 42% higher concentration. The exact formulations for the polymer materials are shown in Table 1. The aggregate used in making the polymer concrete was acquired from Lone Star Industries, a local producer. The gradation of the aggregate is presented in Table 2.

Table 1

POLYMER CONCRETE FORMULATIONS

Material	Manufacturer	Weight percent
Polymer Concrete Powder		
Round Silica sand (see table 1A for particle size distribution)	Morie Sand Co. or Equivalent	75.60
Calcium carbonate - CR 12	Georgia Marble Co.	20.00
Crylcon 4160	Dupont de Nemours	3.00
S-440	Air Products and Chemical Co.	0.64
BCP-35	Noury Chemical Co.	0.50
TiO_2	Dupont de Nemours	0.25
Carbon Black	Fisher Chemical Co.	0.01
		100.00
Polymer Concrete Liquid		
Methyl methacrylate	Dupont de Nemours	99.00
N, N-dimethyl-p-toluidine	RSA Corp.	1.00
		100.00

Table 1 (continued)

Polymer Concrete Primer

Methyl methacrylate	Dupont de Nemours	82.00
S-440	Air Products and Chemical Co.	1.00
A-174	Union Carbide	1.00
Crylcon 4160	Dupont de Nemours	15.00
N, N-dimethyl-p-toluidine	RSA Corp.	1.00
		100.00

Table 1A

Round Silica Sand Gradation

Sieve Size	% passing
#10	100
16	80 ± 6
30	35 ± 6
50	18 ± 6
100	10 ± 6
200	2 maximum

Table 2

Polymer concrete aggregate gradation

Sieve Size	% passing
3/8	100
1/4	39
4	6
8	1

The condition of the deck prior to the overlay was generally good except for the surface texture. The deck which was constructed in 1933 and carried an ADT of 34,500 vehicles on four lanes had exposed and polished aggregate in 1/2± inch deep wheel tracks.

Before the Clackamas River Bridge was chosen for the experimental overlay a condition survey was made. The tests performed during this survey included 1) half-cell potential measurements 2) chloride ion concentration 3) determination of rebar cover 4) wheel rut measurements 5) a delamination detection test, and 6) a measurement of the skid number.

Table 3

Summary of deck condition survey

Clackamas River Bridge No. 1617

Date tested June 3, 1983

Test results

Half-cell test	0.03 to 0.23 volts
Rebar cover	$1\frac{1}{4}$" minimum
Wheel rut depth	3/8" to 5/8"
Delaminations	16± sq. ft.
Chloride ion concentration	(Typical)
	0" to $\frac{1}{2}$" 2.8 lbs/cy
	$\frac{1}{2}$" to 1" 1.8 lbs/cy
	1" to $1\frac{1}{2}$" 0.7 lbs/cy
	$1\frac{1}{2}$" to 2" 0.4 lbs/cy
Cracks	Minor transverse cracking was found throughout the deck
Skid number	SN_{40}= 36.2

Within one month after ordering the polymer materials, they arrived at the Oregon State Highway maintenance yard in Milwaukie. Soon after the materials were received, several small batches of concrete were produced to determine optimum aggregate and resin loading and to measure the time required for curing. Using a 3/8" to #8 aggregate gradation, the percent of aggregate to polymer powder was varied at 70, 80 and 90 percent. The polymer concrete containing 70 and 80 percent aggregate had good workability while the 90 percent loading produced a mix which was difficult to finish when a 1/2 inch slab was cast. The resin content was raised from 12 to 13 percent by weight of the powder but this did not significantly improve the mix with the 90 percent aggregate loading.

The time to cure was also observed when making the trial batches and it was found to be excessive at 65°F. Additional initiator was then added to the prepackaged system in order to produce a concrete that would set up in 2 1/2 hours at 65°F. Dural supplied a sufficient quantity of extra BCP-35 to increase the concentration by one-half percent by weight of the liquid for the entire shipment of polymer materials.

On Monday August 15, 1983 traffic was detoured from the two northbound lanes of the Clackamas River Bridge at 6:30 a.m. Shortly thereafter, the deck preparation began. Using a 65 horsepower Porta-shotblast machine, the top 3/16 inch of surface mortar was removed from an area measuring 300 feet long and 20 feet wide. It required approximately six hours to complete this task. Unlike the shotblaster used on a previous project, this unit was self contained on a four feet by eight feet operator riding vehicle. Approximately three passes in each direction over a one foot wide path were needed to provide an acceptable surface texture and the required depth of removal. When the shotblasting was completed the deck was broomed and blown with compressed air to remove any steel shot that was not picked up by the shotblast machine.

In addition to preparing the deck, the materials and equipment were mobilized on Monday. Two - nine cubic foot drum mixers and three concrete buggies were rented from a local supplier and stored in the state maintenance yard.

A preconstruction and safety meeting was also conducted with the maintenance supervisors to reacquaint them with the hazard of working with the flammable resin. Respirators with organic vapor filters, eye shields, rubber gloves and rubber footwear were issued to each worker who would be handling the polymer concrete. Job assignment for the various tasks were also made at this meeting. The manpower requirements are presented in Table 4.

Table 4

Manpower requirements

Operation	Number
Mixing	6
Buggy Operators	3
Tack coat applicators	2
Screed operator	1
Rakers	3
Foreman	1
	16

On Tuesday August 16, traffic was removed from the two northbound lanes at 6:45 a.m. The shotblaster was unloaded from its trailer and began to sweepblast the outside lane. The light shotblasting was done to remove any contamination that occurred overnight. An area measuring 10 feet

by 300 feet was cleaned by 8:15 a.m. and the shotblast equipment was removed from the site. Compressed air was then used to remove any steel shot and dust.

Beginning at 8:30 a.m. a group of maintenance workers began setting the screed rail while another group prepared the batching area. By 10:00 a.m. the mixers were in place and all of the materials were positioned for easy handling. At 10:30 a.m., the screed was unloaded from a bridge truck and set on the rails. The rails were two inch diameter pipes and they rested on adjustable supports which were embedded in four by four timbers.

The finishing machine used for this overlay was composed of a heavy steel frame which supported a pair of vibratory transverse strike-off beams. A one-half horsepower electric motor was used to propel the unit on the rails. A small electric generator was also mounted on the steel frame to supply power to both the vibrator and the electric drive motor.

At 10:45 a.m. an attempt was made to check the clearance between the screed and the deck at various locations but an electrical problem developed in the control panel. State electricians were summond to correct the problem and by 11:10 a.m. the screed became operational. Because of the delay in starting, the clearance between the screed and deck was only checked on the first 50 foot section. The screed was adjusted to produce a one-half inch clearance at the outside edges of the overlay and in between the wheel tracks. A one-inch thick section was generally obtained in the middle of the wheel tracks.

Beginning at 11:15 a.m. the first gallon of primer was applied to the deck at an average thickness of 16 mils. It was poured out of a container and spread over a 100 square foot area by broom. Just prior to being used, the primer was initiated with Superox 742, a benzoyl peroxide paste, at a rate of 2.5 percent by weight. While the primer was being applied, the first two batches of polymer concrete were mixed in the drum-type mixers just off the end of the bridge. Each mixer produced 3.4 cubic feet of concrete per batch. The weight of the ingredients for each batch is presented in Table 5. The polymer concrete was mixed for one minute before it was discharged into concrete buggies and transported to the work area. When the concrete arrived on the deck it was quickly spread in front of the finishing screed by rakes and shovels. Once the screed started forward, it continued uninterrupted at a slow speed for 180 feet. This required excellent coordination between the groups mixing the concrete, placing the concrete and applying the primer.

Table 5

Weight of polymer concrete components per batch

Powder	250 lbs
Aggregate	200 lbs
Liquid	30 lbs
BCP-35 Initiator	.43 lbs

After the first 180 feet by 10 feet wide section had been overlaid, the screed machine left the rail causing a major delay. It took approximately 15 minutes to reset the screed back on the pipe rail. During this period two previously mixed batches of polymer concrete had to be wasted on the side of the road. In addition, an attempt was made to remove the polymer concrete that had already been deposited on the deck but which was not consolidated. As soon as the screed was repositioned on the rails, the work resumed. Additional primer was reapplied to the area immediately in front of the screed just before the delay occurred. This error in judgement resulted in a poorly finished and poorly consolidated section of overlay because the older polymer concrete began to set before it was finished.

The remainder of the outside lane was overlayed without major problems and the work was completed at 1:30 p.m.

The condition of the overlay in the outside lane was generally good except for some occasional roughness which was caused by screed drag. The rough areas were found along both outside edges and in between the wheel tracks. The reason for these defects is the overlay was too thin for the size of aggregate used. The original plan called for a minimum thickness of 1/2 inch but due to the irregular profile of the deck there were areas where only a 3/8 inch overlay or less was obtained. The area in the rutted wheel tracks did not sustain screed drag because of the thicker section.

In order to acquire a faster cure, 0.43 lbs. of BCP-35 initiator was added to each batch of polymer concrete. This resulted in a cure which permitted foot traffic on the overlay after one hour and vehicular traffic after 2 1/2 hours. Approximately 2 hours after the installation was completed an attempt was made to cut the overlay at the existing joints with a hand held power saw. This method was not successful because the polymer concrete was too hard. When an inspection was made during the next morning some transverse cracks were found in the overlay near the unsawed joints. A heavy duty concrete pavement saw was later used to cut the overlay at all of the joints.

On Wednesday morning, traffic was once again detoured from both northbound lanes at 6:30 a.m. Soon after, the inside lane was lightly shotblasted. By 8:15 a.m. the cleaning was completed and the shotblast equipment was removed from the deck. Any steel shot that remained on the deck was removed with high pressure air.

At 8:30 a.m. the equipment and materials arrived at the work site. The batching area was quickly organized and the screed rails were positioned on the deck. This work was completed by 10:15 a.m.

Before starting the overlay on the inside lane, the clearance between the screed and the deck surface was checked over the entire 300 foot length. Because of the screed drag on Tuesday the overlay thickness was increased to 3/4 inch on the inside edge of the pour. The rail was also adjusted at several locations to accommodate "high spots" on the deck. No screed drag was encountered on Wednesday because of the slightly thicker section.

At 10:45 a.m. the overlay began and it was completed at 12:30 a.m. without major problems. Only 200 lineal feet of overlay was placed because the polymer materials were depleted due to the increase in overlay thickness. An inspection of the inside lane was made immediately after construction and it was found to have a smooth flat surface. After a 2 1/2 hour cure vehicular traffic was allowed on the polymer concrete overlay. The weather conditions during construction on both days was very good with air temperatures between 70°F and 74°F.

Shortly after the overlay had been installed, the shrinkage of the polymer concrete and the polymer mortar was measured in the laboratory with equipment supplied by FHWA. The materials were mixed at 70°F and placed in an 8 inch by 18 inch form. The thickness of the specimens was one inch. The polymer mortar was tested first and it had a strain of 0.00178 in/in after an hour and 0.00278 in/in after 14 hours. No additional movement was detected at 24 hours. The material reached its peak exotherm of 90°F at 1 hour and 5 minutes.

The polymer concrete was then tested and it also reached a peak exotherm of 90°F shortly after one hour. The strain recorded at one hour was 0.00095 in/in and 0.00266 in 14 hours. Again no further shrinkage was measured at 24 hours.

The weights of the ingredients used in each test are listed below.

	Polymer Mortar	Polymer Concrete
Powder	15 lbs	8.00 lbs
Liquid	1.5 lbs	0.96 lbs
Aggregate	0	6.40 lbs
BCP-35	9.72 gm.	6.22 gm.

The low bid prices for the polymer materials from Dural were as follows:

Powder	27400 lbs @	.52/lb	= 14280.00
Liquid	3350 lbs @	1.95/lb	= 6532.50
Primer	640 lbs @	3.00/lb	= 1920.00
			$22700.50

These prices included delivery to Milwaukie, Oregon. The cost of the dry prepackaged pea gravel was two cents per pound.

Evaluation

Although the overlay was placed without too many problems the polymer concrete system is not completely acceptable. Skid testing was conducted on the overlay one week after installation and the results were very poor. The average skid number in the inside lane was only 21.6 while the outside lane had an average skid number of 24.5. Both lanes were later subjected to a light scabbling and this treatment raised the skid numbers to 35 and 45 respectively.

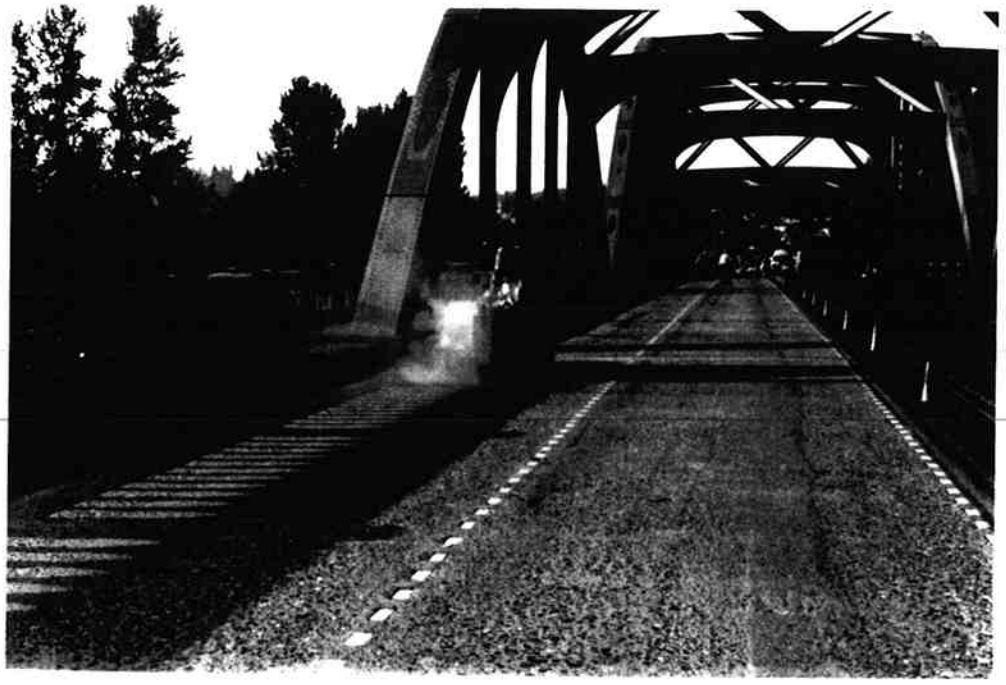
An in-depth inspection of the overlay was conducted one month after construction and just prior to the scabbling. The observations made during this inspection and the results of the testing were disappointing. Some tight map cracking was found throughout the inside lane while only minor transverse cracks were occasionally found in the outside lane. Some delaminations were also detected at the meet line between adjacent panels at a few locations and some medium sized delaminated areas were found in both lanes. When the polymer concrete was removed from three of the delaminated areas, the failure was found to have occurred in existing deck and not at the interface line. Excellent bond was generally found between the overlay and the substrate concrete. Electrical resistance measurements were made on the polymer concrete overlay and the results indicated it was not impermeable due to cracking. Readings were typically between 2,000 and 10,000 ohms.

There is still some doubt whether or not the methyl methacrylate polymer concrete overlay system will ever receive wide acceptance. In order for it to be installed properly, greater than normal care must be exercised. The odor associated with methyl methacrylate resin and the potential health hazard from its vapor requires the use of masks by those working with it. Improvements in the surface texture to increase the skid number could be realized by a light brooming before the initial set. This was an oversight by the principal investigator.

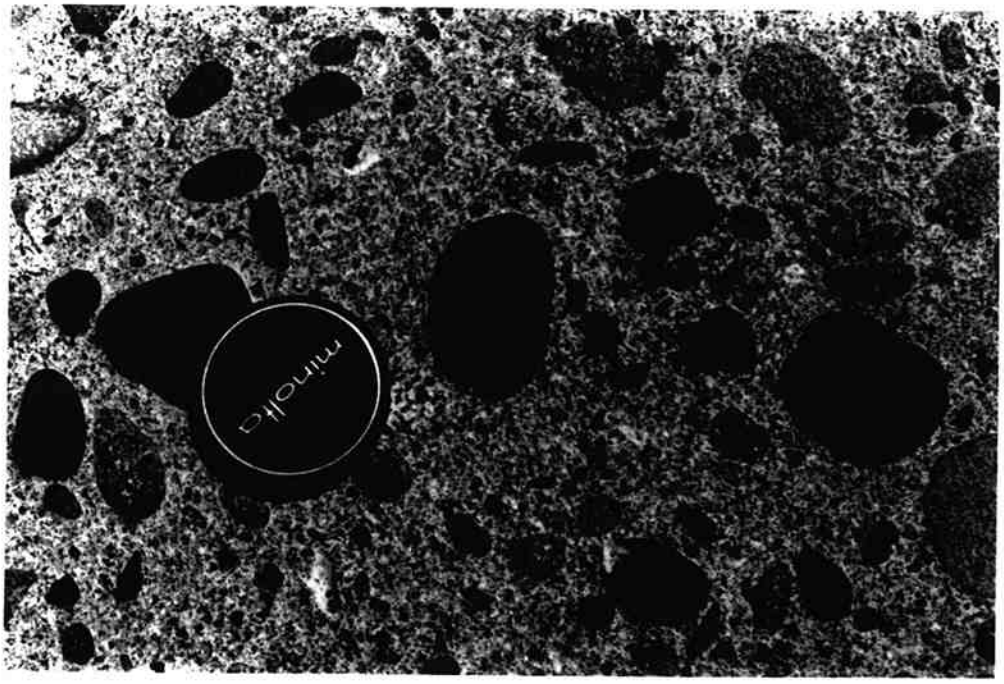
The cracking of the overlay in the outside lane may have been due to excessive vibration of the finishing screed which caused too much liquid to migrate to the surface. Cores removed from the deck indicated the concrete was well consolidated and that the cracks were not reflective. There is noticeable movement of the deck on the Clackamas River Bridge and it may be the methyl methacrylate resin is too brittle to withstand the constant bending.

A sequence of pictures showing the installation of the polymer concrete is presented in the appendix.

Clackamas River Bridge
Bridge No. 1617

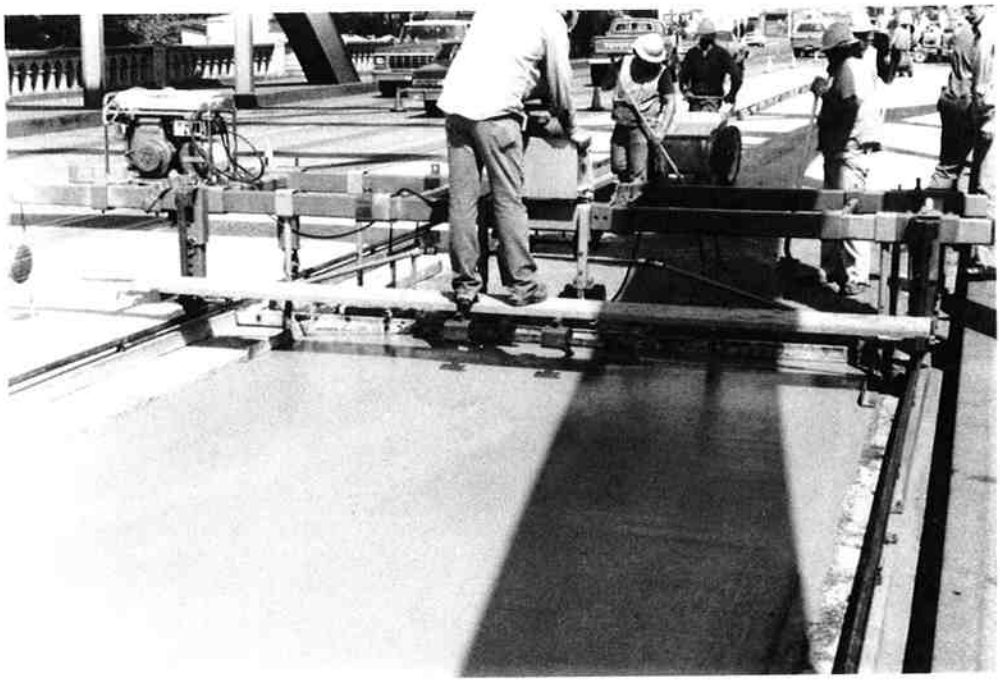


Porta-shotblaster cleaning deck

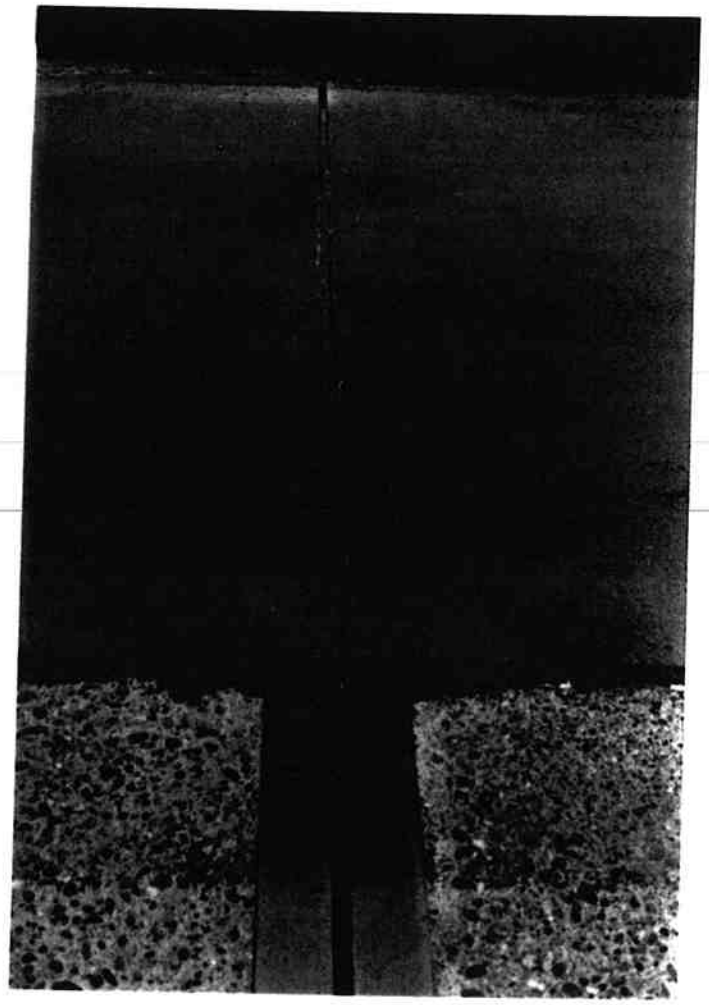


Close-up of deck surface after cleaning

Polymer concrete in front of screed



Polymer concrete after finishing



Saw cut in polymer concrete at expansion joint