CLACKAMAS RIVER BRIDGE
POLYMER CONCRETE OVERLAY

Task Order 11
DOT-FH-11-8876

Final Report

by

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Prepared for

FEDERAL HIGHWAY ADMINISTRATION
Washington, D.C. 20590

October 1986

INTRODUCTION

During the week of August 15, 1983, an experimental methyl methacrylate polymer concrete overlay was placed on a portion of Oregon City's fifty-two year old Clackamas River Bridge on Highway 99E. The purpose was to determine the skid number (1) of this thin overlay and observe the wearing characteristics of a Federal Highway Administration (FHWA) formulated polymer concrete.

PRE-CONSTRUCTION

Before construction began on the experimental overlay, a condition survey of the bridge deck was made. The tests performed during this survey included measurements of half-cell potentials, chloride ion concentrations, wheel rut depths, delaminations, and skid resistance (see Table A).

TABLE A

CLACKAMAS RIVER BRIDGE DECK SURVEY: PRE-OVERLAY

Date:	:	6-3-83
Lane:	:	all four, South and Northbound
Rut Depth	:	3/8" to 5/8"
Skid No. (sn40)	:	36.2 Average
Delamination	:	± 16 Sq.Ft.
Ravelling %	:	exposed and polished aggregate throughout
Half Cells (-)	:	0.03 to 0.23 volts
Chlorides	:	
0 - 0.5"	:	2.8 lbs/cy
0.5" - 1"	:	1.8 lbs/cy
1" - 1.5"	:	0.7 lbs/cy
1.5" - 2"	:	0.4 lbs/cy

In order to develop the optimum aggregate and resin loading and the required curing time, several small batches of concrete were produced in the laboratory prior to construction. Using a 3/8" to #8 aggregate gradation, the percent of aggregate to polymer powder was varied at 70, 80, and 90%.

(1) Skid Numbers are unitless measures of pavement skid resistance determined in accordance with ASTM Method E274, adjusted to a standard speed of 40 mph. The numbers at 40 mph should be above 37 to be satisfactory, as reported in NCHRP Report 37.

The polymer concrete containing 70 to 80% aggregate had good workability while the 90% 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% by weight of the powder but this did not significantly improve the mix with the 90% aggregate loading.

Because the required curing time was found to be excessively long, additional initiator (0.5% by weight of the liquid) was added to the prepackaged system in order to produce a concrete that would set up in 2.5 hours at 65 degrees F (see Appendix for polymer concrete mix design).

The shrinkage of the polymer mortar and concrete was measured with equipment supplied by the FHWA. The materials were mixed at 70 degrees F and placed in an 8" x 18" x 1" form. The polymer mortar was tested first and it had a strain of 0.00178 inches per inch after 1 hour and 0.00278 inches per inch after 14 hours. The material reached its peak exotherm of 90 degrees F in 65 minutes. The polymer concrete was then tested and it also reached a peak exotherm of 90 degrees F shortly after one hour. The strain recorded at one hour was 0.00095 inches per inch and 0.00266 inches per inch in 14 hours. No further shrinkage was measured in either sample at 24 hours.

CONSTRUCTION

Construction began on Monday, August 15, 1983, with the deck preparation. Using a 65 horsepower Porta-shot blast machine, the top 3/16" of surface mortar was removed from an area measuring 300 feet long and 20 feet wide. When completed, the deck was broomed and blown with compressed air to remove any steel shot that was not picked up by the shotblast machine.

Eye shields, rubber gloves, rubber footwear and respirators were issued to each of the sixteen state bridge maintenance workers who would be handling the polymer concrete. The respirators, while for safety, also protected the workers from the very strong odor of the methyl methacrylate.

Tuesday morning, after adjusting the screed, the first gallon of primer was applied to the outside lane at an average thickness of 16 mils, 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% by weight.

While the primer was being applied, the first two batches of polymer concrete were mixed in drum-type mixers for one minute, discharged into concrete buggies and transported to the work area. In order to acquire a faster cure, 0.43 pounds of BCP-35 Initiator had been added to each batch during mixing. When the concrete arrived on the primed 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.

After the first 180' x 10' 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 dumped. A half-way successful attempt was made to remove the polymer concrete that had been deposited on the deck but not consolidated. The delay resulted in a poorly finished and poorly consolidated section of the overlay, and skin patches were later required at the site where the screed left the rail. As soon as the screed was repositioned on the rails, work was resumed and the remainder of the outside lane was overlaid without major problems.

Approximately 2 hours after completing the installation, an attempt was made to cut the overlay at the existing joints with a hand held power saw. Due to the hardness of the polymer concrete, this method was unsuccessful, and a heavy-duty concrete pavement saw was later required to cut the joints.

The post construction condition of the outside lane overlay was fair, with some occasional roughness caused by screed drag. Rough areas were also found along both outside edges and in between the wheel tracks, due to the overlay being too thin for the size of aggregate used (2). The area in the rutted wheel tracks did not sustain screed drag because of the thicker section.

On Wednesday morning, 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" on the inside edge of the pour. The rail was also adjusted at several locations to accommodate "high spots" on the deck. These changes eliminated any screed drag on the inside lane.

The polymer materials were depleted due to the increase in overlay thickness. Consequently, only 200 lineal feet of overlay were placed on the inside lane. An inspection immediately following construction found the inside lane to have a smooth, flat surface. After a 2.5 hour cure, traffic was allowed on the deck.

The weather conditions during construction were very good with air temperatures between 70 and 74 degrees F.

(2) The original plan called for a minimum thickness of 1/2", but due to the irregular profile of the deck, there were areas where only a 3/8" overlay or less was obtained.

POST-CONSTRUCTION

August 24, 1983, one week after the overlay was constructed, skid tests were performed on the deck 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. A light brooming before the initial set would have improved the surface texture and increased the skid numbers. (On September 14, 1983, both lanes were subjected to a light scabbling which raised the skid numbers to 35 and 45 respectively.)

September 4, 1983, three weeks after construction, an in-depth inspection of the overlay was conducted. Tight map cracking was found throughout the inside lane at several locations. Minor transverse cracks were found in the outside lane at both ends of the pour near the neat concrete. Cores removed from the deck indicated the concrete was well consolidated and the cracks were not reflective.

Delaminations were detected at the meet line between adjacent panels at a few locations and 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 the existing deck and not at the interface line. Excellent bond was generally found between the overlay and the substrate concrete.

The outside lane had a slightly rough, open surface, more noticeable because of the accumulation of road debris and dirt. The skin patches placed in the area where the screed left the rail were in very good condition. Several small transverse ridges were found in the outside lane at locations where the screed rode up on large pieces of aggregate during the installation. These ridges caused a slight bump to traffic.

Electrical resistance measurements were made on the polymer concrete overlay and the results indicated it was permeable, probably due to cracking. The readings were typically between 2,000 and 10,000 ohms.

Finally, there were several black skid marks, some fifteen feet long, on the polymer concrete overlay, which might be indicative of poor skid resistance.

On September 14, one month after installation, the P.C. overlay on the Clackamas River Bridge was inspected, tested and scabbled. The inspection revealed a large percentage of map cracking in the inside lane, while there was only an occasional new crack in the outside lane. Delaminations were found in both lanes, especially at cracked sections. Resistivity readings were made which again indicated a permeable overlay, with readings between 3,000 and 12,000 ohms.

Eight months after construction, a visual inspection showed the overlay to be in good condition except for some minor cracking throughout and a minor abrasion in one area of the outside lane. The abrasion was in the area where the screed had left the rail during construction.

On September 4, 1984, the first yearly inspection was completed. The map cracking observed in the 1983 survey was not nearly as evident at this time. This might have been due to the surface scabbling masking the cracks. Since the 1983 survey, the overlay had developed tight, hairline, reflective cracks. These cracks did not appear to affect the performance of the overlay as a wearing surface.

The skid resistance had decreased since the scabbling from 35 to 33.4 on the inside lane, and 45 to 38.5 on the outside lane. These compared to a control of 36.4 on the neat concrete.

Lastly, when the chloride samples were taken, the odor of methyl methacrylate was noted. This indicated the polymerization reaction had not been completed. Consequently, continued polymerization may have occurred.

The final inspection was performed on August 6, 1985. The results are compiled along with the results of the previous inspections and are presented in Table B.

Resistivity readings and half-cell measurements were taken at the same locations as in the 1984 inspection. The resulting resistivity readings once again reflected a permeable overlay. The half cell potentials were very low, indicating a 90% probability that no corrosion was occurring.

TABLE B

CLACKAMAS RIVER BRIDGE DECK SURVEY - POST CONSTRUCTION

Date:	:	9/4/84		8/6/85	
Lane:	:	ins.-outs.		ins.-outs.	
Skid No. (sn40)	:	33.1	38.5	40.6	50.7
Delam's, sq.ft.	:	32	56	101	97.5
Spalling, %	:	0.3	1.5	0.3	1.5
Ravelling, %	:	0	5.5	0	5.5
Half Cells, -mv	:	0.082	0.102	0.035	0.030
Resistivity, k	:	24.5	3.6	4.7	5.2
Chlorides #/yd	:				
0 - 0.5"	:	.15	.15	N	N
0.5" - 1"	:	.42	.15	N	N
1" - 1.5"	:	.15	1.12	N	N
1.5" - 2"	:	.77	1.16	N	N

N: Not Tested

Chain dragging revealed 198.5 square feet of delaminations distributed throughout the overlay, with the majority concentrated around the meet lines between the two lanes.

Ruts depth measurements were recorded, with an average depth of 5/16" in the outside lane and 1/5" in the inside lane.

No increase in cracking or raveling was noted.

CONCLUSIONS AND RECOMMENDATIONS

While many of the problems encountered in this experimental project could be attributed to construction errors, the methyl methacrylate polymer concrete overlay still did not provide a satisfactory overlay. However, it did provide valuable experience and information, from which the following points are made:

1. The screed drag and many of the resultant problems in the outside lane were probably attributable to the size of the largest aggregate and the design thickness. As noted from Table B, the inside lane with its increased design thickness had fewer laydown problems and performed better. The aggregate used contained 61% of 3/8" to 1/4" material. This indicates that minimum design thickness be 2 or more times the size of the largest aggregate in the mix.

2. The cracking of the overlay in the outside lane may have been due to excessive vibration of the finishing screed causing too much liquid to migrate to the surface. Also, there is noticeable movement of the deck on this bridge; it may be the methyl methacrylate resin is too brittle to withstand the constant bending.

3. The skid resistance, while poor, could have been improved if the deck had been lightly broomed before the initial set.

4. The overlay was permeable from the beginning due to the immediate cracking.

5. In order for the overlay to be installed properly, greater than normal care had to be exercised.

6. The odor associated with methyl methacrylate resin and the potential health hazard from its vapor required the use of masks by those working with it.

7. Delaminations occurred throughout the overlay, indicating the loss of bond over time between the deck and the polymer concrete overlay.

8. The rutting and ravelling which occurred may have been due to the brittleness of the overlay.

Until these points have been addressed, we do not recommend the use of methyl methacrylate polymer concrete for use on bridge deck overlays.

APPENDIX

Polymer Concrete Powder Mix Design

Material	Weight Percent
Round silica sand	75.60
Calcium carbonate CR 12	20.00
Crylcon 4160	3.00
S-440	0.64
BCP-35	0.50
TiO_2	0.25
Carbon Black	0.01

Polymer Concrete Liquid

Methyl methacrylate	99.00
N, N-dimethyl-p-toluidine	1.00

Polymer Concrete Primer

Methyl methacrylate	82.00
S-440	1.00
A-174	1.00
Crylcon 4160	15.00

Round Silica Sand Gradation

Sieve Size	% Passing
#10	100
16	80 $\pm$ 6
30	35 $\pm$ 6
50	18 $\pm$ 6
100	10 $\pm$ 6
200	2 maximum

Polymer Concrete Aggregate Gradation

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