Type A Polymer Concrete Overlay Field Trials

Interim Report

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by

William J. Quinn
Principal Investigator

Oregon State Highway Division
Research Section
Salem, Oregon 97310

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On July 31 and August 1, 1982, the Oregon State Highway Division successfully placed a methyl methacrylate polymer concrete overlay on a portion of one span of a major interchange ramp in Portland, Oregon. Two proprietary polymer concretes were used in this experimental overlay project. They were Crylcon, formulated by DuPont, and Fabucrete, produced by Dural International. The main objectives of the project were (1) to evaluate the mixing and placement characteristics of the methyl methacrylate polymer concretes as overlay materials, (2) to examine the durability, skid resistance, impermeability and crack susceptability of the materials in bridge deck construction and (3) to evaluate the preparation of the deck surface using an airless shot-blast machine.

The bridge selected to receive the polymer concrete overlay was the "D" line Structure No. 8588D at milepost 6C301.64 on Interstate Highway 5. It is a two-lane, one-way traffic bridge which has an ADT of 27,200 vehicles. The bridge was constructed in 1963 and, due to the high traffic volume it carried, the deck was badly worn with much exposed and polished aggregate and 1/2 to 3/4 in. wheel ruts. Before this bridge was finally chosen for the experimental overlay, the deck was inspected for spalling and tested for delaminations, chloride ion content and active corrosion potential by means of the half-cell method. A skid resistance test was also performed. The inspection of the deck revealed no spalling or delamination but there were several areas where rebars were exposed. The chloride ion content was found to average 1.4 lb/cu yd concrete at the 0 to 1 in. depth and 0.6 lb/cu yd concrete at the 1 to 2 in. level. The maximum half-cell reading was 0.10 volts when the deck was tested with a copper-copper sulfate electrode. The average right lane skid number was 32.5 when tested at 40 mph on the concrete deck.

The original work plan called for a 1 in. thick overlay to be placed on a 100 ft section of deck but because of a slight shortage of polymer material, the overlay was reduced to an area of 80 ft long by 32 ft wide. The depth of the overlay varied across the deck. It was approximately 1-1/4 in. in the wheel tracks and 3/4 in. at the roadway centerline and gutter.

The polymer concrete overlay work was initially scheduled for Saturday and Sunday July 17 and 18 during nonpeak traffic hours. The project had to be postponed, however, because the powder component of the Fabucrete polymer concrete failed to arrive in Oregon on time. Consequently, the overlay was rescheduled for Saturday and Sunday, July 31 and August 1.

During the week preceding the overlay, a concrete finishing machine was constructed by the bridge maintenance crew for another project, but one which was ideal for the polymer concrete work. The unit consisted of a heavy metal tubular frame which supported a vibratory screed. The frame rode on four wheels. A pipe rail support system provided the necessary adjustments to allow the correct finished grade to be obtained. Trial overlays using wet sand indicated the equipment would work with polymer concrete.

All of the polymer materials were purchased and supplied by FHWA. This included the dried aggregate used as a filler in the polymer concrete. The packaging of the polymer materials and aggregates for the two polymer concretes varied considerably. The Crylcon powder was packaged in 33 lb polyethylene lined sacks while the Fabucrete came in unlined 50 lb paper sacks. The Crylcon liquid component came in 38 five-gal cans, while the Fabucrete liquid was shipped in three 55-gal drums. The aggregate used with the Crylcon mortar was 3/8 to 3/16 in. stone and it was shipped in 100 lb burlap sacks. The Fabucrete system required the 50-50 blending of two aggregate sizes, a 3/8 in. to No. 10 and a No. 4 to No. 30. Each of these aggregates was packaged in 50 lb paper sacks. The proportions of the various polymer concrete components are shown in Table 1.

On Friday, July 30, the day immediately preceding the overlay, a meeting was held in the state maintenance yard with the bridge maintenance men who were scheduled to place the overlay. Details of the mixing, placing and finishing techniques for polymer concrete were discussed in length. Jack Fontana, Brookhaven National Laboratory, who was providing technical assistance on the project, spoke to the group about safety. At the conclusion of the meeting a small batch of polymer concrete was prepared to demonstrate the material and to introduce the workers to the unique methyl methacrylate odor. The appearance of the Fabucrete polymer concrete was somewhat dry and there was a lack of fine material in the mix. A change was quickly made in the mix design to overcome the deficiencies. One other problem was noted during the mixing demonstration, and that was the polymer concrete failed to gain strength at the expected rate. The reason for this was the Fabucrete and Crylcon were warm weather formulations and the ambient temperature was between 63 and 66 F. Some deterioration of the initiator in the Fabucrete powder was also suspected. Additional initiator was required to hasten the polymerization of both polymer concretes.

After the meeting, all of the Fabucrete materials and other supplies were loaded onto trucks in preparation for Saturday's work. At 5:30 a.m. on Saturday, July 31, the first group of maintenance workers began setting traffic warning signs and safety cones along the work area. By 6:15 a.m. the traffic was diverted from the work lane and the airless shotblast equipment arrived at the site to remove the top 3/16 to 1/4 in. of surface mortar. This equipment was provided by Transcon Services Inc. of Spokane, Washington. It consisted of a power shotblaster, a 460 volt generator and a dust collector. The shotblaster was capable of cleaning a 20 in.-wide patch during each pass.

It took over one hour to unload the shotblast equipment and to get in position to begin work. The deck had a superelevation of 0.10 ft/ft on the span to be overlayed and this required all equipment to be blocked to prevent it from running downgrade.

Shotblasting began at 7:35 a.m. and was not completed until 11 a.m. After operating for a short time, the generator ran out of fuel. After a one-hour delay the shotblasting was resumed and the 16 by 80 ft area was finally prepared. Two passes of the shotblaster were necessary to remove the desired 3/16 to 1/4 in. of surface mortar. Additional passes were needed at each end of the overlay area to produce a minimum 3/8 in. deep cut. This deeper section was specified in the areas where the overlay was tapered.

No other work was permitted within 25 ft of the shotblaster machine while it was operating because of flying steel shot. When the shotblasting was occurring at the far end of the overlay area, workers began to set the finishing machine rails. One rail was placed on top of the curb and the other was placed just outside the roadway centerline. After the rails were in place, the finishing machine was set on them and the clearance between the screed and deck surface was checked. Adjustments in the rail elevation were made as needed to produce the desired overlay thickness.

At 12 noon, the methyl methacrylate primer was applied to the first 15 by 16 ft section of deck. One worker poured the primer onto the deck at a rate of 65 sq ft/gal while another worker spread it evenly with a broom.

At 12:07, the mixing of the first batch of Fabucrete polymer concrete began in one of the two 7-cu ft drum mixers rented for this project. After a 2-minute mixing period, the polymer concrete was discharged from the mixer into a concrete buggy. It was then deposited onto the deck and quickly spread with rakes and shovels. The two 7-cu ft drum mixers were used continuously to batch 106 cu ft of concrete. The first four and last four batches of polymer concrete were made without coarse aggregate because they were used in tapered sections. The ingredients and their proportions for this mortar mixture are designated Mix A in Table 1. The remaining Fabucrete polymer concrete is designated Mix B in Table 1.

Approximately 16 fluid ounces of Cadox 40E, a benzoyl peroxide paste, was added to the Fabucrete liquid before it was placed into the mixer. This additional initiator decreased the required cure time and shortened the allowable work time slightly. No intermediate cleaning of the mixer or tools was required during the overlay.

The time required to load, mix and discharge each 3.4 cu ft batch was approximately 4 minutes.

The mixing, placing and finishing of the Fabucrete polymer concrete went smoothly and the overlay was completed by 1:37 p.m. There were no great problems during the mixing phase and the only problem during placing was the slipperiness of the primer. The workers operating the two concrete buggies had difficulty when walking on the wet primer. There was no problem in keeping the correct amount of polymer material in front of the screed after it was deposited onto the deck. There were a few problems, however, in getting a uniform surface finish on the polymer concrete. Some dry areas appeared behind the screed and attempts to work up fines did not succeed. No satisfactory explanation has been determined for this defect. Also, a few ridges appeared in the overlay surface in areas where the screed was stopped while waiting for more polymer concrete to be delivered. These ridges produced a slightly bumpy ride but traffic is expected to smooth out the roughness.

Seventeen workers were needed to mix, place and finish the 1,280 sq ft polymer overlay in 1 1/2 hours. A breakdown of their activities follows:

Activity	No. of Workers
Loading Mixers	5
Operating Concrete Buggies	2
Operating Screed	2
Raking and Shoveling Concrete in Front of Screed	3
Concrete Finishers	2
Primer Application	2
Working Foreman	1

The equipment and supplies were removed from the site within 1 hour after the polymer concrete was in place and traffic was allowed on the overlay at 3 p.m. which allowed a 1 1/2 hour cure.

On Sunday, August 1, 1982, traffic was removed from the left lane by 6:15 a.m. and shotblasting began at 7 a.m. By 9:30 a.m. the shotblasting was completed and the deck was blown clean. Not all of the shot was recycled or sucked up by the vacuumn system so it had to be blown from the deck. On both days the shotblaster did an excellent job of providing a clean and well textured surface upon which to place the overlay. The exposed aggregate in the deck had a rough profile and all exposed rebars were extremely clean. The rate of shotblasting was approximately 650 sq ft/hr.

The rails and finishing machine were installed into position between 9:30 a.m. and 11 a.m. As before, the clearance between the screed and the deck surface was checked before mixing began.

Beginning at 11:15 a.m. the Crylcon primer was applied to the first 15 ft section of the left lane at a rate of 75 sq ft/gal. Approximately 10 minutes later mixing of the first batch of Crylcon polymer concrete started. The first four and last four batches were mortar and contained no aggregate. This mixture is designated Mix C in Table 1. As before, the mortar was used in the 10 ft tapered sections. The same 7-cu ft drum mixers were used to mix the Crylcon polymer concrete. BFF-50, a benzoyl peroxide powder, was added to the Crylcon liquid immediately before mixing to shorten the set up time of the concrete. Ambient air temperature was between 60 and 67 F during placement on Sunday. The mix design for the Crylcon polymer concrete containing aggregate is designated Mix D in Table 1.

The gradation of the aggregate and the higher resin content in the Crylcon mix produced a much more workable concrete. No open areas were found in the overlay surface but there were some surface defects where the finishing machine left the rail or where there was a prolonged delay in forward travel of the screed. These problems occurred on both days with the same results. There was a noticeable difference in the resin primers as the Crylcon liquid produced a more slippery surface. Although no accidents occurred, the slippery deck was considered hazardous to the workmen.

The overlay ended at 12:50 p.m. after a total placement time of 1 hour and 40 minutes. The same 17 work positions were needed to accomplish the overlay within this time. A 1 hour and 45 minute cure was permitted before traffic was allowed over the new overlay.

The general appearance of the methyl methacrylate polymer concrete is good except the open areas in the Fabucrete surface allowed abrasion to occur. The only problem during mixing was producing and transporting the concrete quickly enough to keep up with the screed. Transporting the polymer concrete in concrete buggies was hazardous because the primers were very slick and difficult to walk on. Some of the workers did not like the methyl methacrylate odor and they wore organic filter masks. Breathing through a mask did not hinder the worker's progress.

The aproximate cost to place the methyl methacrylate polymer concrete overlay was $85/sq yd. This figure reflects the time required to acquire the necessary equipment and supplies before the overlay began. Because the overlay area was small, the mobilization and labor costs were unusually high. Excluding mobilization, a breakdown of the actual cost follows:

	Per Sq Ft	
Materials	$5.83	
Labor	$1.56	
Equipment Rental	$ .31	
Deck Preparation	$1.00	
Total	$8.70	or $78.32/sq yd

If the polymer concrete overlay work were to be performed on a regular basis and on a larger area, the cost would be lower and could approach $60/sq yd. A realistic cost breakdown may look like the following:

	Per Sq Ft	
Materials	$4.50	
Labor	$ .50	
Equipment Rental	$ .60	
Deck Preparation	$ .80	
	$6.40	or $57.60/sq yd

Post Construction Evaluation

Visual examinations of the overlay were made three days and two weeks after construction. During these times both the Fabucrete and Crylcon polymer concrete materials appeared to be performing very well. No visible cracking was detected and the overlay appeared to be well bonded to the deck. Some very slight abrasion was noted in two small areas in the Fabucrete where the surface appeared to be deficient in binder.

Skid resistance measurements were made on each material three weeks after construction. Four tests were made in each lane at 40 mph. The bare portland cement concrete deck was also tested for comparison purposes. The average skid number on the Fabucrete polymer cncrete was 36.4 while the Crylcon polymer concrete had an average skid number of 40. The average skid number on the bare pavement in the Fabucrete lane was 34.5 and the average value in the Crylcon lane was 37.5. The friction testing was done with a K.J. Law Model 1270 pavement skid tester.

Additional friction measurements will be made in two months to determine the short term effects of traffic on the polymer concrete overlays. Seven weeks after the overlay was placed cores were removed from each lane. Examination found the densities of the two materials noticeably different. The Crylcon polymer concrete had good consolidation while the Fabucrete polymer concrete had many tiny air holes.

During the time the cores were being removed, a close visual examination was made of both polymer concretes and again no cracking was discovered. A chain drag test was also performed at this time and the results indicated no delaminations were present in either lane. Finally, electrical resistance measurements were made on a 6 ft grid on a portion of each material. The Crylcon polymer concrete had eight readings above 700,000 ohms and all ten readings were above 300,000 ohms.

The ten readings made on the Fabucrete polymer concrete, however, were below 8,000 ohms. These results indicate the Fabucrete overlay is permeable.

Conclusion

The successful installation of a thin methyl methacrylate polymer concrete overlay was accomplished by Oregon State bridge maintenance workers. The mixing, placing and finishing were performed without a great deal of difficulty. The acceptance of the polymer concrete process will be slow, however, because it is labor intensive. Five workers were needed to hand load the two 7-cu ft concrete mixers continuously in order to keep the required quantity of concrete in front of the finishing screed. On a larger overlay project, mechanized batching would be essential.

The workability of the Crylcon polymer concrete was superior to that of the Fabucrete mixture because of the aggregate gradation and the resin content. Trial batches of polymer concrete should be prepared before every project to ensure workability by adjusting resin content and aggregate loading. Since temperature is a key element in the curing process, trial batches are needed within the temperature range the overlay will be placed. Additional initiator in powder form should be available for use should there be a decrease in ambient temperature during placement or a deterioration of the initiator in the prepackaged polymer concrete.

The airless steel shotblaster was effective in removing the top 3/16 to 1/4 in. of surface mortar. It was especially useful where exposed rebars were encountered in the deck in that the bars were cleaned without damage. Although the shotblasting process is a little slow, it is recommended on projects where the overlay will be placed immediately after the deck preparation or where there is much exposed reinforcing steel.

TABLE 1
Polymer Concrete Mix Proportions

FABUCRETE	Component Weights Per Batch	
	Mix A	Mix B
Liquid Resin	45.5 lb	32.5 lb
Powder	350.0 lb	250.0 lb
#2 Stone*	100.0 lb	100.0 lb
#4 Stone**	---	100.0 lb
% Resin (by total weight)	9.2	6.7
Cadox 40E	16 fluid oz	16 fluid oz

CRYLCON	Mix C	Mix D
Liquid Resin (7012)	40.0 lb	40.0 lb
Powder	400.0 lb	200.0 lb
3/8 to #10 in. stone	---	200.0 lb
% Resin (by total weight)	9.1	9.1
BFF50	16 fluid oz	16 fluid oz

* No. 2 Morie Well Gravel. See Table 2 for gradation.
** No. 4 Morie Well Gravel. See Table 2 for gradation.

Table 2
Aggregate Gradations

Morie No. 2 Well Gravel

Sieve No.	Percent Passing
8	95.0
10	82.0
12	53.9
14	15.8
16	6.8
18	2.1
20	0.9

Morie No. 4 Well Gravel

Sieve No.	Percent Passing
4	97.9
6	63.6
8	7.5
10	2.1
12	0.5