Polymer Concrete Bridge Deck Overlays

Deschutes River Bridge (Biggs)
and Maupin Bridge (Maupin)

Final Report

by

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16. Abstract

This report documents the construction and performance of two thin polymer concrete (with polyester/styrene resins) bridge deck overlays. The overlays were constructed in Biggs and Maupin, Oregon in June 1993.

Several problems were encountered during construction that resulted in bare spots and/or a rough riding surface. The bare spots could be attributed to the polymer concrete curing before aggregate placement. Maintaining a uniform grade and providing a smooth riding surface was difficult because of bare spot repair, cold joints, and joint repair. More than 900 sq. ft. of delamination was noted at the Deschutes River Bridge within six months following construction; 4,500 sq. ft. was noted after 1 1/2 years. More than 2,200 sq. ft. of delamination was noted at the Maupin Bridge after six months; 6,600 sq. ft. was noted after 1 1/2 years. The polymer concrete has broken loose and is easily removed in blocks. Both overlays are scheduled for removal in the fall of 1995.

We recommend that controlled field tests of polymer concrete (with polyester/styrene resins) be required before these products are used extensively by ODOT. When the next polymer concrete overlay is constructed the following recommendations should be followed to aid proper placement:

a) Drains shall be temporarily covered to keep the slurry mix out.
b) All deck striping shall be removed prior to overlay construction.
c) The contractor shall be required to maintain a continuous delivery of materials to the bridge deck during overlay construction. The amount of material available for application should be evenly matched with the number of construction workers.
d) Joint repair shall include the removal of material 12 to 18 inches on each side of the joint. Heavy shot blasting or 1/4-inch diamond grinding shall be used for concrete removal around the joints. The material used to fill the joint shall be feathered in to provide a smooth riding surface.
e) Workers shall not be allowed to walk on the fresh overlay to broadcast the aggregate.
f) The aggregate shall be broadcast from a distance to provide uniform coverage and allow the wind to remove finer particles.
g) The overlay shall be feathered to zero inches at the drains to reduce the possibilities of standing water at the curb line.
h) Final raking shall be in the direction of traffic.
i) If edge tape (duct tape) is used, it shall be removed as soon as possible (if the mix sets up, edge tape removal may cause delamination).
j) Gauge rakes shall be checked and hooks replaced frequently to maintain the specified minimum thickness of overlay.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

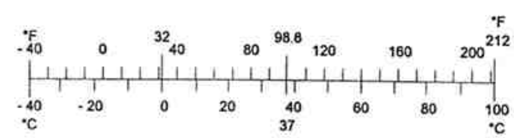
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement

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Polymer Concrete Bridge Deck Overlays

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1.0 INTRODUCTION

This report describes the construction procedures and reports the problems which occurred during construction of two polymer modified concrete bridge deck overlays. Overlay costs are also presented along with a description of performance after six months and 18 months. The material used for the overlays was Transpo T-38 methacrylate slurry supplied by Transpo Industries, Inc. The bridge deck overlays were funded by the Oregon Department of Transportation (ODOT).

The objectives of this study are to evaluate the construction and performance of two thin polymer concrete overlays with a polyester/styrene resin constructed in the summer, 1993. The information included in this report will be used to write procedures and specifications for future overlays.

1.1 BACKGROUND

A number of 20 to 50-year old bridges in ODOT's Region 4 and throughout the state are in relatively good condition except for the decks. The deck problems are most often located in the upper part of the deck slab and include incorrectly installed rebar, insufficient rebar cover, transverse cracking and worn, rutted surfaces. When the distress is limited to the upper portion of the deck, there are various types of thin (1/4" to 1/2") non-structural overlays, including polymer concrete, that will seal and protect the deck and restore the wearing surface.

Presently, the polymer concrete using polyester/styrene resins has only been used in small test sections on several bridges across the state. However, the California Department of Transportation (DOT), Nevada DOT, Washington DOT and the Federal Highway Administration have used polymer concrete (with polyester/styrene resins) since the mid 1980's with success. In order to further evaluate the material in Oregon, Region 4 personnel recommended the installation and evaluation of this overlay system on two bridges in District 9. The polymer concrete overlay was expected to be constructed in a relatively short amount of time at a reasonable cost.

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2.0 LOCATION AND SUPPORTING DATA

2.1 LOCATION

The two bridges included in this project are the Maupin Bridge (#966) on U.S. Route 197 at M.P. 45.87 in Maupin and the Deschutes River Bridge (#322) on Oregon Route 206 at M.P. 3.91, near Biggs. The vicinity map for the projects is shown in Figure 2.1. Note that both bridges cross the Deschutes River.

2.2 WEATHER CONDITIONS OF BIGGS AND MAUPIN

The weather conditions for the two bridge sites are listed in Table 2.1.

Table 2.1: Weather Information for Bridge Overlay Construction Locations

	Deschutes River Bridge (Biggs)[1]	Maupin Bridge (Maupin)[2]
Elevation (feet)	285	1041
Average Daily Temperature of Coldest Month(°F)	35	31
Mean Daily Temperature Swing in Coldest Month (°F)	12	14
Average Daily Temperature of Warmest Month(°F)	76	68
Mean Daily Temperature Swing in Warmest Month (°F)	31	28
Average Annual Precipitation (inches)	9	11

[1] No Station located at Biggs. Data listed is from the Arlington Station.
[2] No Station located at Maupin. Data listed is from the Moro Station.

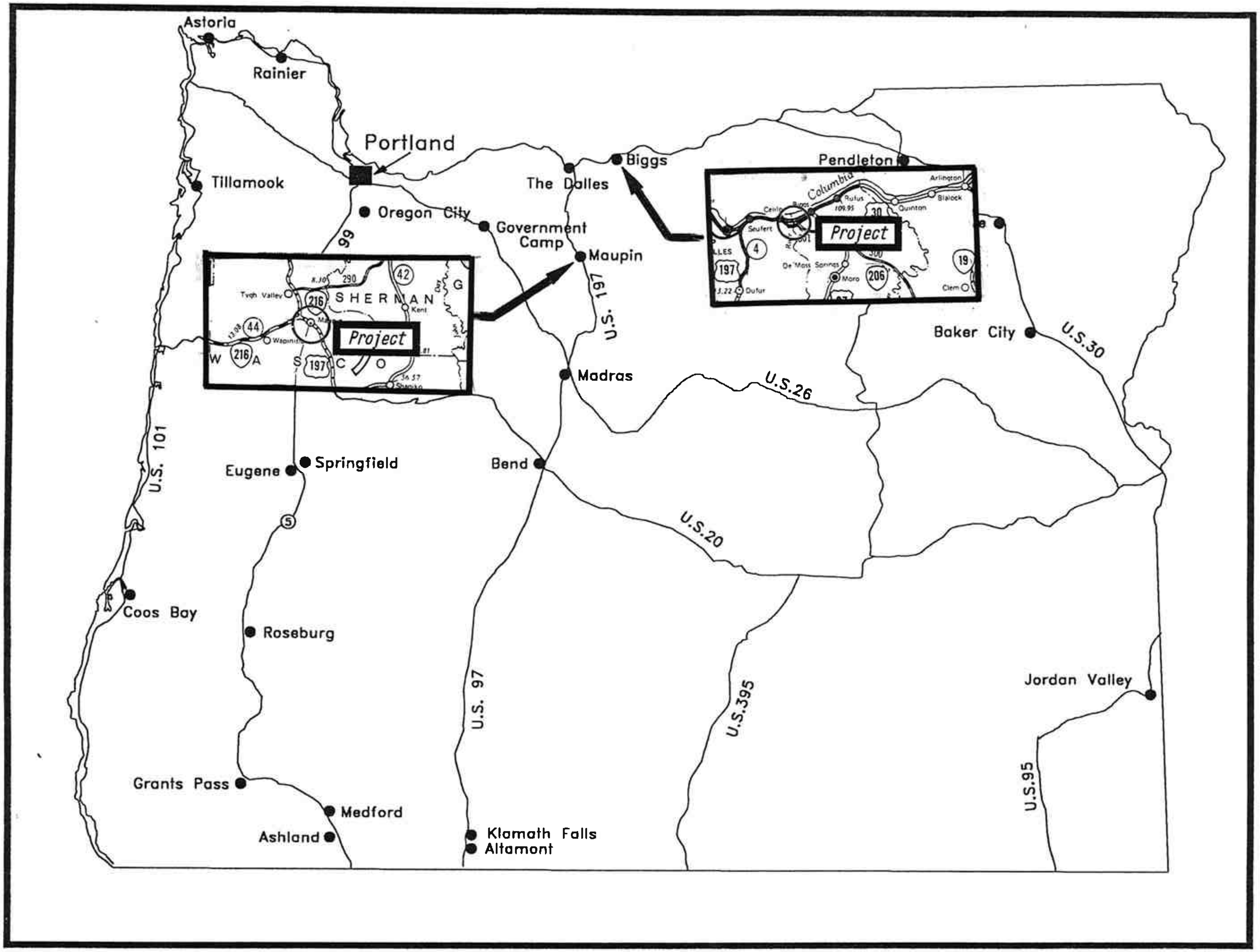

Figure 2.1. Vicinity Map.

2.3 BRIDGE PLAN AND PROFILE

The two bridges have fundamental geometrical design differences. The 38-year old Biggs structure has a level, tangent deck, with four bents. The older Maupin structure, built in 1929, has a narrow deck with both a horizonal curve and grade change of -2.6% to - 3.2%. The north end of the bridge is 28 feet higher than the south end of the structure. It did not appear that bridge geometry affected construction. Figures 2.2 and 2.3 present the bridge plans and profiles.

2.4 EXISTING CONDITIONS

Both bridge decks were inspected prior to the overlay construction to identify distress that could affect long-term, post-construction performance. Transverse cracking was noted on the Biggs bridge deck near the bents. Polished aggregates in the wheelpaths and random popouts were also observed. Transverse cracking was noted on the Maupin Bridge deck, along with polished aggregate, and popouts. In addition, the deck surface near the armored expansion joints was spalled. A crack map was made and pre-construction photos taken of both decks by the Region Bridge Inspector.

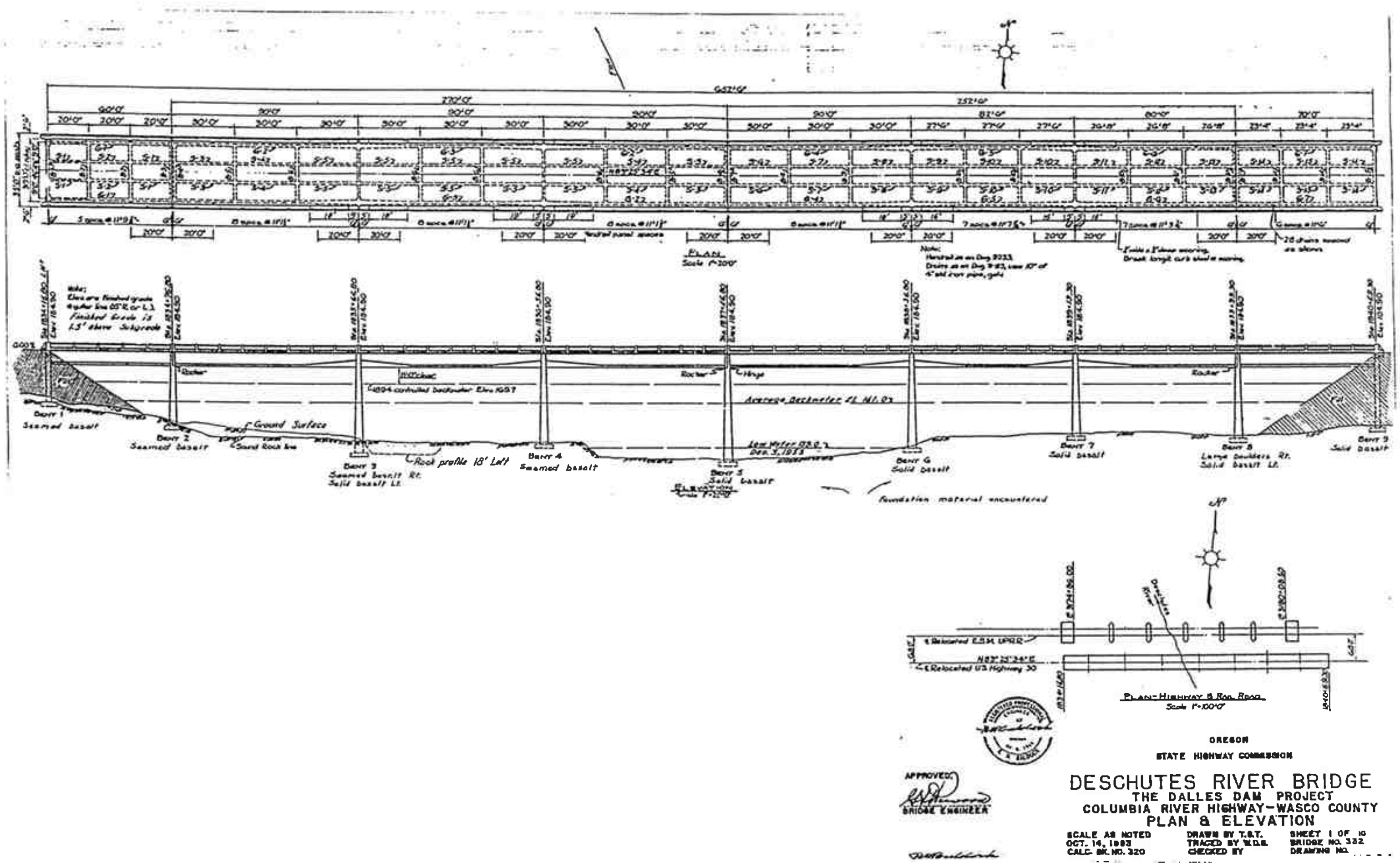

Figure 2.2. Deschutes River Bridge Plan and Elevation.

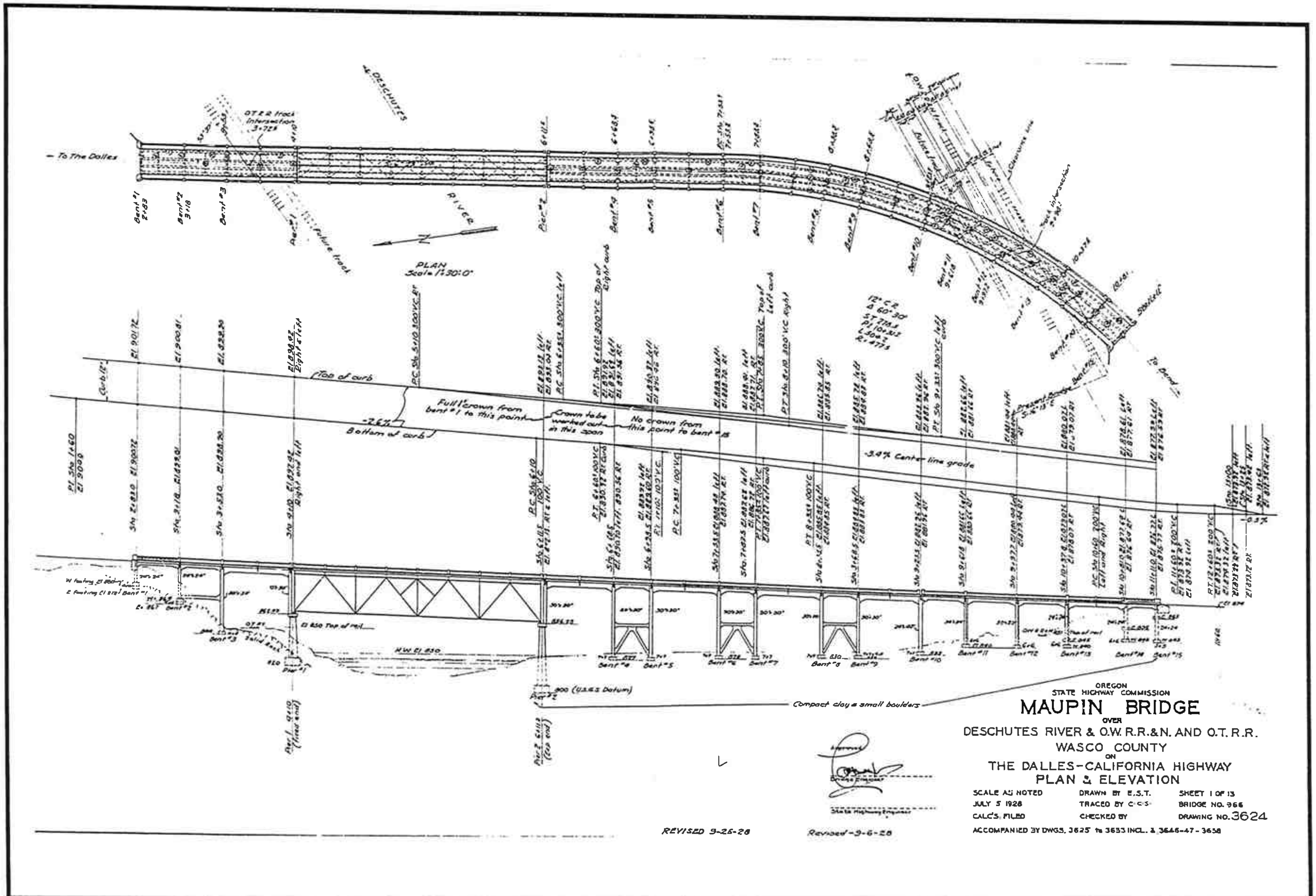

Figure 2.3. Maupin Bridge Plan and Elevation.

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3.0 COSTS

A general services contract was prepared for the bridge deck overlay work. A copy of the project prospectus is included in the Appendix. Six contractors bid on the project and the contract was awarded to David Mowat Company, from Kirkland, Washington. The contract costs included $17,000 for bridge deck preparation and $177,893 for the polymer concrete for a total cost of $194,893. Figure 3.1 presents the unit costs ($/sy) for all six bidders.

A. Pat Aldrich Construction
Bend, Oregon

B. Diamaco, Inc.
Kirkland, Washington

C. JAL Construction
Bend, OR

D. Lorentz Brunn
Portland, OR

E. David Mowat Company
Kirkland, WA

F. Pioneer Waterproofing
Portland, OR

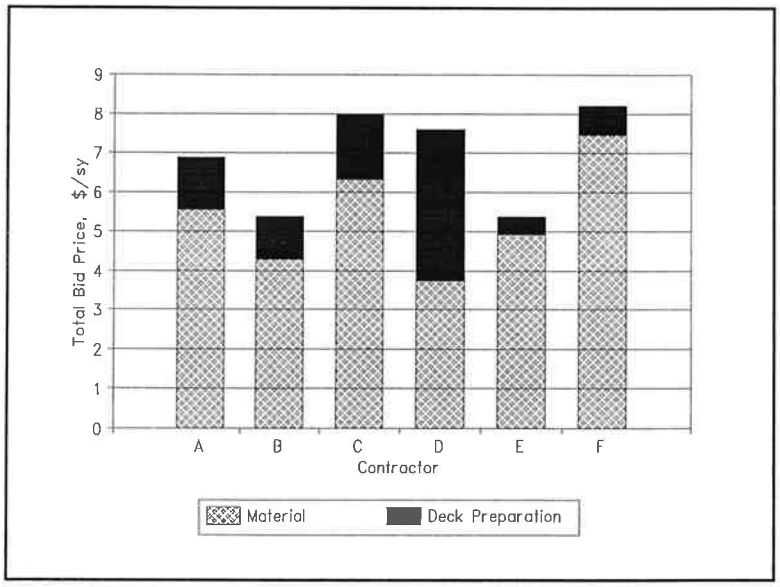

Figure 3.1. Material and Deck Preparation Costs.

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4.0 CONSTRUCTION

The bridge deck overlay near Biggs was started on June 2 and completed on June 9, 1993. From Biggs, the contractor moved to Maupin where an overlay was started on June 10 and completed on June 17. In addition, a test section was constructed at Maupin to evaluate various types of aggregate. The contractor returned to the Biggs bridge in late July to correct deficiencies. The following describes the polymer concrete overlay construction, problems, and test section construction.

4.1 OVERLAY CONSTRUCTION

Overlay construction included four steps: 1) deck preparation, 2) primer (seal coat) application, 3) polymer slurry application followed by broadcasted aggregate, 4) removal of excess aggregate by sweeping and blowing with compressed air, and 5) final seal coat application.

Deck preparation included two methods: air driven chiselling and shot blasting. Most of the surface was shot blasted, however, an air driven chisel was used near joints to remove broken concrete. The first pass of the shot blasting at Biggs is shown in Figure 4.1. Preparation near an expansion joint is shown in Figure 4.2. The contract called for the removal of 0.8 lbs/sq. ft. of concrete which equated to a 66 mils removal depth to clean the deck. This depth was obtained by setting speed and number of passes made by the shot blasting machine. The rate for the shot blaster was set by a test run on 150 feet of deck. The speed was noted and the amount of material removed was weighed to set the rate. Some sandblasting was also done near the curbs to remove material missed by the shot blaster. Old concrete near the armored joints (steel plates which protect the expansion joints) was chipped out to a depth greater than 1/4-inch and a width of 6 inches. All pavement marking (striping) was also removed from the bridge deck since adhesion tests showed that primer/polymer concrete mixes have a poor bond with painted stripes.

After each lane was shot blasted, a primer seal of methacrylate was applied with long handled paint rollers. The spread rate for the primer seal was set at 16 mils thickness or about one gallon per 100 square feet. Transpo's representative stated that once the methacrylate prime seal was applied, the lane could be opened to traffic with no detrimental effects. This procedure was followed throughout the construction, allowing a thirty-minute minimum curing time for the seal before the lane was opened for traffic. After the lane was re-opened for traffic, the next lane was shot blasted and seal coated.

The next step was to spread the polymer slurry and broadcast the Steilacoom #8 aggregates on top of the slurry. Prior to application of the polymer concrete adjacent to a finished lane, the edge was covered with duct tape to prevent an overlapping joint. Figure 4.3 shows the application of duct tape. The polymer slurry was applied at a uniform depth of 1/4-inch by using a gauge rake. The effective spread rate was about 560 ft/gal. Holes and minor depressions were leveled out, but basically, the existing grade was followed. The coordination of mixing slurry and broadcasting aggregate was important to keep the operation continuous to minimize cold joints. The mortar mixer used to mix the polymer concrete is shown in Figure 4.4. Since the aggregates were over broadcast to insure full coverage, there was an excess of loose aggregates which did not stick to the polymer concrete. This excess rock was swept into piles and removed from the deck. Compressed air was also used to blow away loose rock near the curbs and rock on the deck not removed by brooming. Figure 4.5 shows the excess rock being removed on the overlay at Maupin. Note the completed adjacent lane overlay.

The last step included a final application of methacrylate seal coat. This layer was spread with long handled paint rollers in the same manner as the primer. The spread rate of 32 mils thickness was regulated by using one gallon per 50 square feet. Application of the seal coat is shown in Figure 4.6. Sections were opened to traffic thirty minutes after the seal coat was applied.

The total overlay construction time varied from the Deschutes River Bridge (Biggs) to the Maupin Bridge (Maupin). Variables such as experience, number of workers, traffic control, and bridge geometry affected the rate of construction.

4.2 PROBLEMS

Several problems were encountered during overlay construction that created bare spots and/or a rough riding surface. The bare spots (areas where the aggregate did not stick) could be attributed to the polymer concrete curing before aggregate placement. Maintaining a uniform grade and providing a smooth riding surface were difficult because of bare spot repair, cold joints between batches, and deck joint preparation.

Problems with bare spots occurred at both overlay sites. At Biggs, the problem was due to the contractor's difficulty in placing the aggregate in a timely manner. Once the contractor had gained experience with the product, he was able to match the amount of material mixed to the available manpower to insure consistent delivery. This included mixing larger slurry batches of polymer concrete using a portable masonry mixer and having adequate manpower to broadcast the aggregates. Users should remember to "match the batch to the patch."

Weather played a part in creating bare spots on the test section at Maupin. Warm winds and high deck temperatures decreased the curing time of the polymer slurry and the aggregate did not stick on a large area. This is discussed in more detail in the next section. A different problem associated with the weather was also noted at Maupin. On one afternoon, a strong warm wind was blowing when the primer coat was applied to the northbound deck. This caused some of the sealer to evaporate or cure before it penetrated the deck. A few popouts were observed to be "dry" with no methacrylate in them after the seal was applied. The air temperature was estimated to be about 80° F, and the deck temperature about 120° F when this happened.

Localized repair of the bare spots included applying additional methacrylate and rock. However, application of more material resulted in ridges which created a rough riding surface.

Cold joints, which resulted in rough riding surfaces, were created on the Deschutes River Bridge when the contractor started out mixing slurry in 5-gallon buckets. Because of the delay between batch preparation and application, cold joints were created. To eliminate the problem, 50-gallon batches were mixed in a mortar mixer. Changes in the procedure to insure a steady delivery of slurry to the deck, eliminated about half of the cold joints. In some areas, the rough joints were smoothed out with rock during application of the seal coat.

Rough spots were also created at the expansion joints. In the areas near the joints, the concrete had been chipped out more than 1/2-inch deep. Since the polymer only filled to 1/4-inch, a low area, 6 inches wide was left on both sides of the joint. More aggregate was added to some joints which caused ridges. Since this occurred on both sides of the armored joint, a bump was felt by motorists driving over it. The worst joint was repaired by making a cut line with a carbide saw, and then chipping the polymer concrete off. On the second joint application, more care was taken to "fill and feather" the depression by adding more polymer and rock by hand. This method had limited success and was not repeated.

A better solution to preparation along the armored expansion joints may be to remove material 12 to 18 inches on each side of the joint. The wider area would allow for a better transition when filling with the polymer concrete. Also, instead of chipping, heavy shot blasting or diamond grinding may produce better results.

To maintain a smooth surface, other methods were incorporated such as keeping the workers from walking on the new slurry while raking and broadcasting. On other epoxy overlays, the workers had worn golf shoes while walking on the overlays. The Transpo T-38 material proved to be tackier and the practice was stopped. Also, the raker finished with longitudinal rather than transverse strokes, so that rake marks would coincide with the direction of traffic.

Both bridge decks required additional work. Following completion of the overlay in Biggs, 17 areas required additional work. One area, approximately 200 sq. ft., required removal and replacement. The other areas were minor ride problems like cold joints or small areas that could be treated with methacrylate. The additional work at Maupin included the localized repair of 10 areas. The majority of work (excluding the test section) was the repair of bare spots.

4.3 TEST SECTION LAYOUT

The supplier believed that aggregate was the cause of previous problems of reported aggregate loss on Transpo jobs. He suggested setting up a test section on the Maupin bridge deck. The section was to include six aggregate types including a control strip which used the Steilacoom rock. The six strips are located in the northbound lane at station 7+29.5. Each extends from the bridge deck center to the curb and is about 3 feet wide. The test section layout is shown in Figure 4.7.

During the construction of the aggregate test sections, the air and surface temperatures peaked for the job. The air temperature was estimated to be about 85° F with the deck temperature about 120° F. No reduction in the catalyst had been made, so that with elevated temperatures, the polymer concrete on the test section catalyzed before the aggregate spread was completed. The result of this was that the rock would not stick to most of the test strips. Consequently, the polymer concrete on the test strips was chiseled off the following day. A new prime coat was applied and re-spread with the polymer concrete. This time, the aggregates stuck well, giving the test section a uniform and completely covered surface.

One concern was raised when the polymer concrete was chiseled off the test section: the polymer concrete broke off in 0.5 to 2 sq. ft. chunks. The large size chunks could be an indication of potential overlay delamination.

When the test section was reconstructed the next day, two strips were added at the south end. Strip 4A is a replication of 4, and 5A is a replication of 5. Strip 4A was added for comparison to Strip 4 which was not removed after the original construction. Section 5A was added to utilize the remaining Oregon Emery. Figure 4.8 shows the completed test section.

Figure 4.1. Shot blasting at Biggs.

Figure 4.2. Deck preparation adjacent to expansion joint.

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Figure 4.3. Duct tape application at overlay joint.

Figure 4.4. Polymer concrete being mixed in a mortar mixer.

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Figure 4.5. Excess aggregate on overlay at Maupin. Adjacent lane shows completed overlay.

Figure 4.6. Seal coat application.

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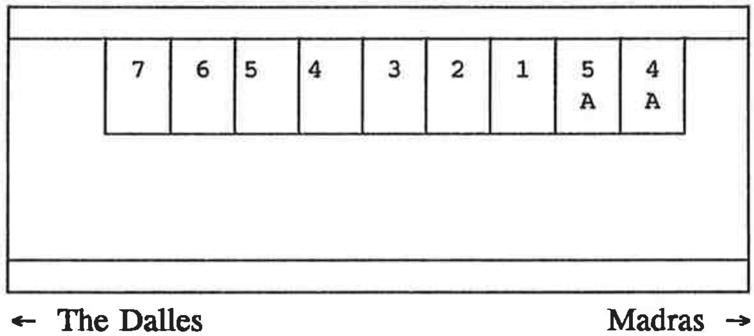

Figure 4.7. Test Section

1. Indag #8, homogeneous basalt; 3M Company, Corona, California
2. Indag #8, homogeneous basalt; 3M Company, Belle Mead, New Jersey
3. Duralum 8 grit, aluminum oxide; Washington Mills, Grafton, Massachusetts
4. 8-16 Emerundum, Turkish Emery; Washington Milles, Grafton, Massachusetts
5. #8 Oregon Emery, corundum and magnetite, Oregon Emery Company, Halsey, OR
6. 2:1 blend of 2 parts Steilacoom:1 part Oregon Emery
7. Steilacoom #8, heterogenous basalt; Steilacoom Pit, Steilacoom, Washington

5A. Repeat of 5
4A. Repeat of 4

Figure 4.8. Test section at Maupin.

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5.0 TESTING

Prior to construction, the bridge decks were inspected visually for moisture. In addition, ASTM test method D-4263 (Standard Test Method for Indicating Moisture Content in Concrete by the Plastic Sheet Method) was done on various occasions to detect moisture on the bridge deck. The test method includes taping a piece of plastic to the deck and waiting for a set period of time. The plastic patch is then inspected for condensation.

Acceptance testing for the materials was done visually by the project manager's inspector and the supplier's representative. One shipment of aggregate was rejected because of moisture. All others were approved and used.

Laboratory tests on the aggregate included gradation and specific gravity. Results of these tests are presented graphically in Figures 5.1, 5.2, and 5.3. The graphs show all the aggregates used in the test section and indicate a narrow range in the gradations. There is more variability in the specific gravity. The properties measured in the laboratory will be considered when evaluating the long-term performances. The control rock (Steilacoom #8, heterogeneous basalt) was used on all of the surface except the test section.

Friction testing by ODOT Pavements Unit staff shortly after the overlays were constructed indicated that the bridge deck friction was good. Friction testing during the summer 1994, also indicated good skid resistance for both overlays.

Other testing for acceptance on these kinds of projects is under development. Michael Sprinkel, in a recent TRB paper, recommends testing the resin, aggregates, and concrete using standard ASTM and AASHTO test methods *(1)*.

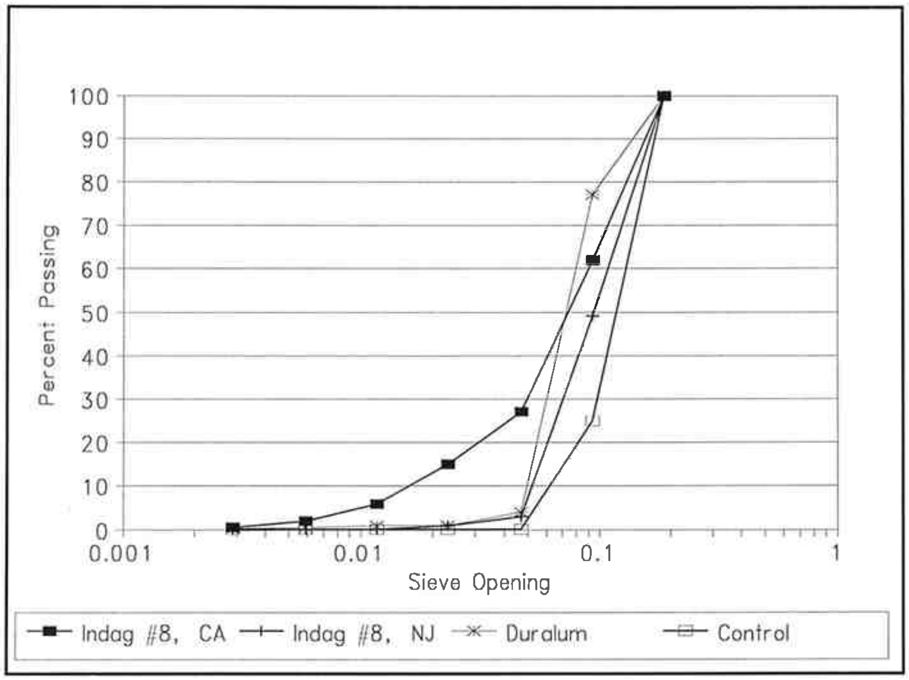

Figure 5.1. Gradations of Aggregate Used for Overlay.

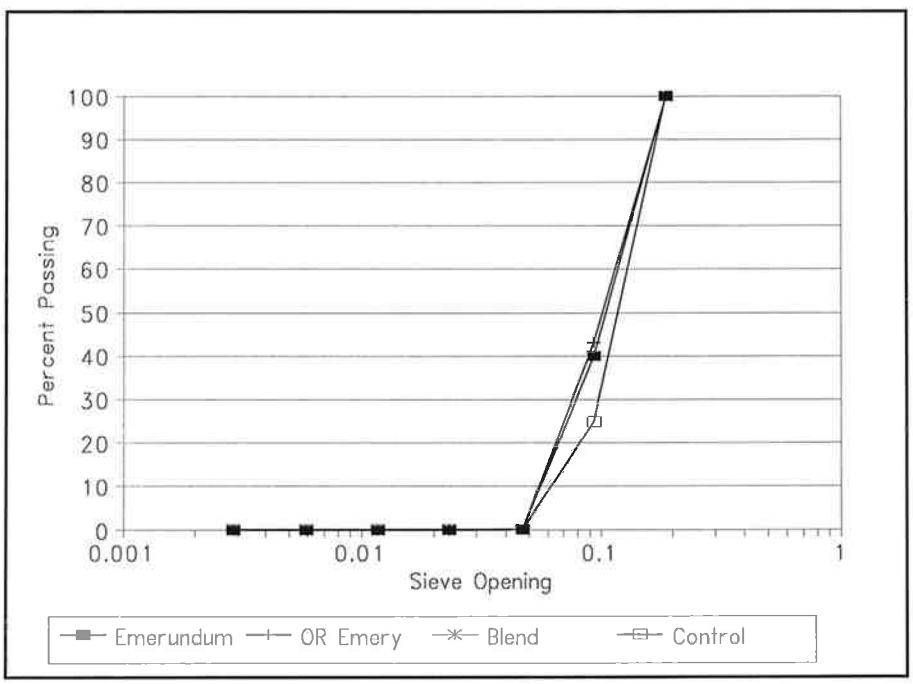

Figure 5.2. Gradations of Aggregate Used for Overlay.

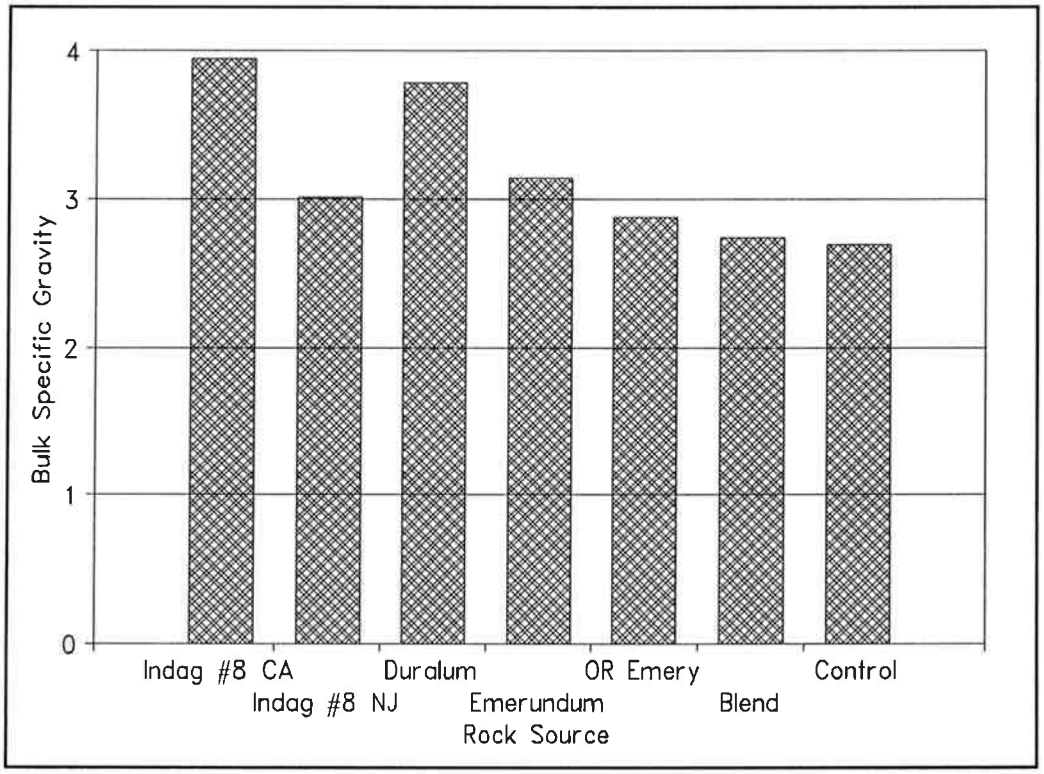

Figure 5.3. Apparent Specific Gravities of Aggregates Used for Overlay.

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6.0 BRIDGE #322 (BIGGS) INSPECTIONS & TESTING

6.1 SIX-MONTH INSPECTION

On January 20, 1994, Mike Pulzone, Region 4 Bridge Inspector, and Eric Brooks made a semi-annual inspection of the overlay on Bridge #322. Rake marks and discolored areas were observed during the inspection. No visible cracking related to delamination was found. The westbound lane had an overall appearance of a "multiple" patch job. Visible joints, reworked areas, rake marks, and bare spots of polymer concrete without surface aggregate created the patched look.

6.2 TESTING

Delamination and bond strengths were determined by ASTM test method D4580 (Standard Practice to Measure Delaminations in Concrete Bridge Decks by Sounding) and ACI test method 503R (bond strength tests). The testing was done by the Region 4 Bridge Inspector with the help of The Dalles bridge crew and a member of the Research Unit. The work was completed on January 20, 1994.

The entire deck surface was checked for delamination by the "sounding method" (ASTM D4580). Both hammer and heavy chain were used. The bad areas were plotted on a scale drawing of the bridge deck, Figure 6.1, for further evaluation. Small delaminated areas located along the curb and center lines were found across the entire deck. The largest delaminated area was found on the east end of the westbound lane. This distress section covers a total area of about 900 square feet.

To test the bond strength of the overlay to the existing concrete, cores were drilled in six locations on the deck. A bond strength test was performed on these cores in-place with a portable pull-testing device. The tensile strength required to disbond the cores was recorded and plotted on the scale drawing. Table 6.1 includes a listing of the recorded bond strengths and test locations.

According to literature published by the product manufacturer, Transpo, Inc., the polymer concrete should have a bond strength high enough to fail in the concrete substrate at 250-350 psi. Four of the tests indicated adequate bond strength of 250 psi or more. Test #4b indicated a weak substrate layer and Test #5b failed the epoxy holding the pull-puck to the surface. The force required to break the epoxy was 254 psi indicating that the primer strength must have been greater than the 250 psi minimum.

Table 6.1: Bond Strength Test Results, Westbound Lane (Biggs)

Test #	Breaking Force (psi)	Breaking Layer	Sta.	Distance From WB Curb (ft)	Overlay Condition
1b	271	primer	0+29	6	good
2b	288	primer	0+64	14	good
3b	339	primer	1+64	6	good
4b	110	substrate concrete	2+94	14	good
5b	254	glue	4+09	6	good
6b	288	primer	5+55	14	good

6.3 18-MONTH INSPECTION

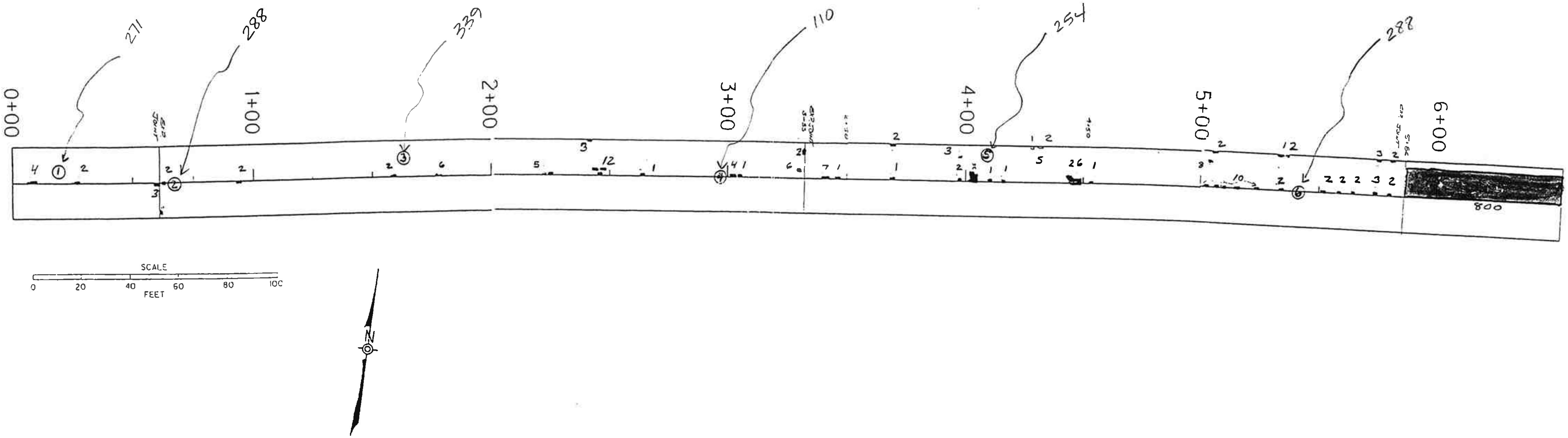
An inspection of the deck was made on 12/14/94 by the Region Bridge Inspector. The delaminated area had increased from more than 900 sq. ft. to 4,600 sq. ft. The overlay is scheduled for removal in the fall of 1995.

6.4 DISCUSSION OF POSSIBLE CAUSES OF DELAMINATION

The delamination discovered during chain drag tests was found along the curb and down the centerline. Deck preparation could be a cause of the delamination near the curb. Deck preparation along the curb was done by sand blasting since the shot blaster was not able to clean the surface adjacent to the curb because of the machine design. Because sand blasting is a manual operation, spots could have been missed or only done lightly which may have decreased the bond strength of the polymer concrete leading to delamination. The concrete substrate could also have been contaminated from material blowing off the sidewalk prior to primer application.

Duct tape placed over the finished lane edge to prevent an overlap coat of slurry mix could have caused the centerline delamination. Removing the tape weakened the joint and left a crack for water to seep beneath the mat.

The 800 square feet where delamination was noted in the westbound lane at the east end of the bridge, was applied late in the day (using headlights from the pickups for light). Because of a shortage of material, the prime coat was placed too thin. This section was also opened to traffic sooner than other sections.



Legend

⑥ Pull-Test Location
4 Square Feet of Delaminated Area
↙ Bond Strength

Polymer Modified Concrete Bridge Deck Overlay
Bridge #322 (Deschutes River) Delamination Map

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FIGURE 6.1

7.0 BRIDGE #966 (MAUPIN) INSPECTIONS, TESTING AND PATCH CONSTRUCTION

7.1 SIX-MONTH INSPECTION

On January 18, 1994, Mike Pulzone, Region 4 Bridge Inspector, made a semi-annual inspection of the overlay on Bridge #966. The inspector found that distress was visible in some areas including complete loss of the overlay in a few spots.

Although the areas missing polymer concrete were small, they provided access for water to enter under the overlay. Also noted on the deck were rake marks from construction. The marks were observed to be about one-half of the overlay depth. The marks represent weak areas in the surfacing where breaks could occur leading to delamination.

7.2 TESTING AND PATCH CONSTRUCTION

Testing included delamination (ASTM D4580) and bond strength tests (ACI 503R). The testing was done by the Region 4 Bridge Inspector with the help of The Dalles bridge crew and Eric Brooks from the Research Unit. Testing began on January 18, 1994 and was completed on January 20, 1994. Test method ACI 503R was modified by using a water cooled diamond drill bit versus the specified carbide tip dry hole saw.

The entire deck surface was checked for delamination by the "sounding method." Both hammer and heavy chain were used. The bad areas were plotted on a scale drawing of the bridge deck for further evaluation (see Figure 7.1). A discussion of the debonding pattern is included in the following section.

To investigate the repair of a delaminated area, a test patch using the polymer concrete was constructed. The area, near the center of the deck, was a 4 ft. by 20 ft. strip extending north from the expansion joint at Sta. 4+10. The deteriorated polymer concrete was cut on a straight edge with a carbide bladed circular saw to the depth of the original concrete. The overlay material was removed with a hammer and chisel. The material broke away in two-foot square sheets with a minimum of force being applied. No prime coat was visible on the deck; some was visible on the removed sheets. The exposed deck was wet and had to be dried with a torch before the new patch was applied. Figures 7.2 and 7.3 show the delaminated area prior to patching.

performed on these cores in-place with a portable pull-testing device. The tensile strength required to break the cores was recorded and plotted on the scale drawing (see Figure 7.1). The bond strength tests indicated a weak bond at the deck surface. The primer coat either failed to stick to the deck or did not stick to the overlay. None of the cores broke in the polymer concrete. In 66% of the tests, the primer was the breaking layer (see Table 7.1). In one case, the core broke at the pull testing device/core interface and in another case, the core broke within the concrete bridge deck (below the overlay).

According to literature published by the product manufacturer, Transpo, Inc., the polymer concrete should have a bond strength high enough to fail the substrate concrete: 250-350 psi. The average bond strength calculated for cores that failed at the primer contact was 150 psi. The low bond strength results in delamination.

Table 7.1 - Bond Strength Test Results, North Bound Lane (Maupin)

Test #	Bond Strength, psi	Breaking Layer	Sta.	Distance N.B. From Curb (ft.)	Overlay Condition
1	170	primer	2+87	3	slight delamination
2	85	primer	3+21	6.5	good
3	136	primer	3+75	10.5	good
4	144	primer	3+77	2	good
7*	122	primer	4+41	4	slight delamination
8	186	primer	4+98	6	good
9	186	primer	7+36	5	good
10	186	testing glue	8+20	3	good
11	170	substrate concrete	8+64	2	delamination
12	161	substrate concrete	9+53	10	delamination
13	170	primer	9+83	1	delamination
14	542	substrate concrete	10+55	16	slight delamination

* Cores 5 and 6 were not tested.

7.3 18-MONTH INSPECTION

The bridge deck was inspected by the Region Bridge Inspector on 12/14/94. The delamination had increased from over 2,000 sq. ft. to 6,600 sq. ft. The overlay is scheduled for removal the fall of 1995.

7.4 DISCUSSION OF POSSIBLE CAUSES OF DELAMINATION

The lower bond strength does not completely explain the areas of delamination. Several observations made during construction and review of the video tapes taken during construction indicate procedures and materials may have contributed to the delamination. Three main areas of delamination were noted: southern end of the north bound lane, curb line, and center line.

Based on the time of the overlay construction, the bridge may be divided into four sections as shown in Figure 7.1. The slurry mix was placed on Sections I, II, and III in the earlier part of the day while the bridge deck was cool. The slurry mix was placed on Section IV in the warmer sunny afternoon with air temperatures estimated at about 85°F. Deck temperatures were estimated about 120+°F. Note that Section IV has the greatest amount of delamination indicating a possible correlation to the high temperature.

Although the entire deck had traffic running on the prime coat at some time during construction, the southern 200 feet of the northbound lane, Section IV, was exposed to the most traffic. The slurry mix was applied to Section II the morning of June 16, 1993. In order to work on Section III at the same time, the one-way traffic was switched near the middle of the bridge from the northbound lane to the southbound lane (see Figure 7.1). Thus Section IV had daytime traffic driving on the primer. The higher traffic use could have contaminated the prime coat in Section IV. Contaminants on the road (this is cattle country) could have been tracked on to the prime coat.

The beginning of construction of Section IV proceeded without incident. By 2:30 p.m. when the test section near Station 7+36 was placed, the deck temperature had increased to over 100°F. The slurry mix catalyzed so rapidly that the workers could not spread the aggregate before it hardened. It was at this time that the amount of catalyst was reduced to increase gel time. This section had to be redone the following day. The high temperatures and improper mixing components could also have contributed to the delamination in Section IV.

Review of the video tapes show the workers walking in the polymer concrete slurry, and then stepping over into the adjacent lane in Section IV. Section IV had been primed but not finished at the time. The "tracked" slurry may have contaminated the surface. Thus another source of contaminated material was introduced.

Another procedural problem was the parking of the mix truck on the prime coat. Care was taken to prevent contamination due to spills: a sheet of plywood was placed under the mortar mixer. However, review of the video tapes revealed that this effort was ineffective as some white powder was observed on the primered deck. This also would furnish a source of contamination which would weaken the polymer concrete to bridge deck bond leading to delamination.

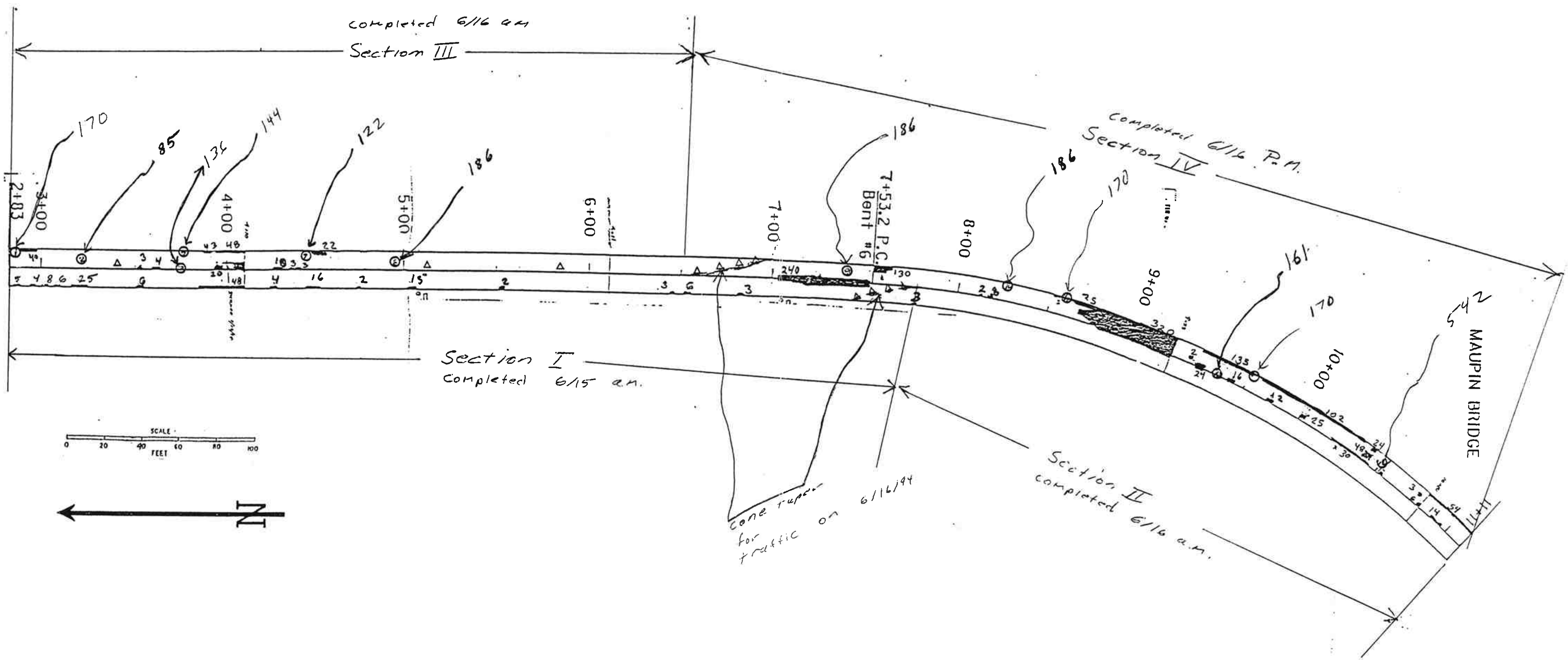
Several small delaminated areas were found which extended out about 1 foot from the curb line. The problem could have been related to traffic control on this narrow bridge. Larger vehicles' wheels scraped off the concrete of the curb. The grit generated by the wheels fell to the curb line and could have contaminated the primer and the polymer concrete, leading to delamination.

Deck preparation could also be another possible cause of the delamination near the curb. Deck preparation along the curb was done by sand blasting since the shot blaster was not able to clean the surface adjacent to the curb because of the machine design. Because sand blasting is a manual operation, spots could have been missed or only done lightly which may have decreased the bond strength of the polymer concrete leading to delamination.

Several small delaminations were found near the center of the two lanes. Duct tape was placed over the finished southbound lane edge to prevent an overlap coat of slurry mix. Removing the tape weakened the joint and left a crack for water to seep beneath the mat. Also, vehicles drove on the edge of the new mat before it hardened. This was observed in a few cases, when large R.V.'s and semi-trucks passed through the work zone. Both factors, a weakened overlay joint and traffic on the edge of the overlay, could have contributed to the centerline delamination.

In summary, the most significant delamination occurred in Section IV. The delamination could be attributed to contamination of the primered deck caused by traffic and/or spills of the powdered product prior to mixing. Warm weather, which lead to the adjustment of the catalyst for Section IV, may have also contributed to the delamination.

Smaller areas of delamination could also have been caused by contamination of the primed deck. In addition, sand blasting done along the curb line may not have provided an adequate surface for the primer to stick. Delamination along the centerline of the bridge could be attributed to weakened polymer concrete due to duct tape removal. The duct tape removal could also have created cracks which would allow water access. Deep rake marks in the final coat, caused by rapid catalyzing of the polymers, built in "failure" points which could allow water to penetrate below the mat.



Legend

- Pull test locations
- Cone-taper
- Square Feet of Delaminated Area
- Bond Strength

Polymer Modified Concrete Bridge Deck Overlay

Bridge #966 (Maupin) Delamination Map

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FIGURE 7.1

Figure 7.2: Delaminated Bridge Deck Prior to Overlay.

Figure 7.3: Sheets of Polymer Concrete.

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8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 CONSTRUCTION CONCLUSIONS

Construction of the overlays was less than ideal. Several aspects of the construction, however, provided information that should be considered during construction of future polymer concrete overlays.

The rate of production and the quality of the work improved dramatically when the contractor switched from hand mixing in a bucket to machine mixing in a mortar mixer. Bare spots or bumps at cold joints could be reduced by maintaining a continuous operation. The amount of mix produced also needs to be matched with the manpower available.

On separate occasions, rain and warm weather created delays during construction. One day, construction was delayed due to light rain. The materials cannot be applied on a damp surface. Light mist was dealt with by blow drying the deck, but a substantial rain storm stopped the project on another day. Warm weather may decrease the time for the polymer concrete to cure causing problems with aggregate sticking. Changes in air temperature and thus deck temperatures must be monitored. In some cases, the amount of catalyst may need to be adjusted to meet changing temperatures.

Extra work was required to maintain the grade at joints in order to provide a comfortable riding bridge deck. Feathering and extra layers should be used at joints where a significant amount of concrete is removed. Pre-leveling is also an option.

The gauge rakes used to spread the polymer concrete will wear down. The Transpo representative estimated that with his 2-hook rake, the hooks should be replaced every 2000 sq ft. If the hooks are not replaced, the overlay thickness will drop below the 1/4" thickness specified.

8.2 PERFORMANCE CONCLUSIONS

On Bridge #302 at Biggs, higher bond strengths corresponded with a small amount of overlay delamination. The areas where delamination was found could have been caused by inadequate deck preparation near the curb, contamination from material blowing off the sidewalk prior to primer application, and the removal of duct tape which weakened the polymer concrete and led to cracks along the centerline.

On Bridge #966 at Maupin, the most significant delamination occurred in Section IV. The delamination could be attributed to contamination of the primered deck caused by traffic and/or spills of the powdered product prior to mixing. Warm weather, which led to the adjustment of the catalyst for Section IV, may have also contributed to the delamination.

Smaller areas of delamination could also have been caused by contamination of the primed deck. In addition, sand blasting done along the curb line may not have provided an adequate surface for the primer to stick. Delamination along the centerline of the bridge could be attributed to weakened polymer concrete due to duct tape removal. The duct tape removal could also have created cracks which would allow water access. Traffic driving the edge before the cure was complete could also weaken the lap joint. Deep rake marks in the final lift, caused by rapid catalyzing of the polymers, built in "failure" points which could allow water to penetrate below the mat.

Because the polymer concrete has broken loose and is easily removed in blocks, the overlays are scheduled for removal in the fall of 1995.

8.3 RECOMMENDATIONS FOR IMPLEMENTATION

We recommend that controlled field tests of polymer concrete (with polyester/styrene resins) be performed before these products are used extensively by ODOT. When the next polymer concrete overlay is constructed the following recommendations should be followed to aid proper placement:

1) All deck striping shall be removed prior to overlay construction.

2) The contractor shall be required to maintain a continuous delivery of materials to the bridge deck during overlay construction. The amount of material available for application should be evenly matched with the number of construction workers.

3) Joint repair shall include the removal of material 12 to 18 inches on each side of the joint. Heavy shot blasting or diamond grinding shall be used for concrete removal around the joints. The material used to fill the joint shall be feathered in to provide a smooth riding surface.

4) Workers shall not be allowed to walk on the fresh overlay to broadcast the aggregate.

5) The aggregate shall be broadcast from about five feet to provide uniform coverage and allow the wind to remove finer particles. Blown dust on the slurry primed surfaces will cause contamination.

6) The overlay shall be feathered to zero inches at the drains to reduce the possibilities of standing water at the curb line.

7) Final raking shall be in the direction of traffic.

8) If edge tape (duct tape) is used, it shall be removed as soon as possible. If the mix sets up, edge tape removal may cause delamination.

9) Gauge rakes shall be checked and hooks replaced frequently to maintain the specified minimum thickness of overlay.

10) The air and deck temperatures shall be monitored and the catalyst amount changed according to manufacturer's instructions.

11) Construction shall be planned to keep traffic off of the primed surface.

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9.0 REFERENCES

1. M.M. Sprinkel, "Polymer Concrete Bridge Overlays," *Transportation Research Record*, No. 1392, 1993.

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Appendix: Project Prospectus

REGION 4 THIN DECK OVERLAY PROJECTS

SCOPE: This project consists of applying a thin (1/4" to 1/2") polymer concrete overlay to two concrete bridge decks. The purpose is to seal and improve friction on the cracked and worn but structurally sound decks. The Research Unit of ODOT will evaluate the construction and performance of the overlays. The material to be used is Transpo T-38 thin polymer overlay system, manufactured by Transpo Industries, Inc.

Bridge 1: #966 O-xing Oregon Trunk R.R. and the Deschutes River (at Maupin), Highway 197, M.P. 45.87. The deck area is approximately 16,560 sq. ft.

Bridge 2: #332 Deschutes River (near Biggs Jct.), Highway 206, The Old Columbia River Highway, M.P. 3.91. The deck area is approximately 19,575 sq. ft.

GENERAL INSTRUCTIONS:

Deck Preparation: The surface of the deck shall be prepared by shot blasting. The contractor shall remove 0.8 lb./sq. ft. or blast to clean aggregate as directed by the Project Manager. Extra blasting or chipping with hand-held chipping guns will be required at bridge deck ends and along expansion joints. These areas will be a minimum of 6 inches wide and will extend the width of the deck. The amount of material removed in these areas will be sufficient to ensure a minimum overlay depth of 1/2".

Installation: Prior to installation, the deck surface shall be free of dust, oil, visible contaminants and excessive moisture. The moisture content shall be determined by the Project Manager using ASTM D-4263. The authorized representative of Transpo Industries, Inc. shall be on site during all overlay construction. All materials including aggregate shall be certified by Transpo Industries, Inc. The contractor shall follow all relevant specifications recommended by Transpo Industries, Inc. concerning mixing, installing and cure. These relate to, but are not limited to, ambient air and deck surface moisture and wind velocity. The contractor shall block out all expansion joints to finish grade to provide an even grade across the expansion joint. The contractor shall be responsible to meet this finish grade specifications state in Section 00540.53 of the "Standard Specifications for Highway Construction" 1991, ODOT All drains shall be plugged to prevent any material from draining onto the ground or into the river. The contractor shall be responsible for meeting state and local regulations for the use and disposal of the overlay materials. The contractor shall also be responsible for the proper cleanup of equipment and disposal of cleaning materials, packaging and left over polymer concrete materials.

Temporary Protection and Direction of Traffic: Traffic Control will be the responsibility of the contractor. The contractor shall use equipment and methods as specified in "Oregon State Highway Division, SIGNING AND FLAGGING STANDARDS FOR SHORT-TERM WORK ZONES, 1990." This manual will be provided to bidders upon request. No separate payment will be made for traffic control. The costs for traffic control shall be included in the contractors bid price for polymer concrete.

DETAILED REQUIREMENTS:

Bid Schedule	Unit	Total
Deck Preparation	Lump Sum	All
Polymer Concrete	Lump Sum	All

No separate payment will be made for material on hand. The completion date for all work on this project is June 12, 1993. A Pre-work conference will be held prior to the start of any work. The authorized representative of Transpo Industries, Inc. shall attend this meeting along with the Contractor, Project Manager and the O.D.O.T. District 9 Manager.

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